

## APPENDIX A

### Calculations of the Pump Pressure

1. Cylinder with effective area of 4.43 in<sup>2</sup>

Pressure on the samples: 2500 psi (17236.9 kN/m<sup>2</sup>)

Area (3 samples 27 x 120 mm): 3.19 in x 4.72 in = 15.066 in<sup>2</sup> (9720 mm<sup>2</sup>)

Force on the press: 2500 lb/in<sup>2</sup> x 15.066 in<sup>2</sup> = 37665 lb (167533.9 N)

Cylinder effective area: 4.43 in<sup>2</sup>

Pump pressure: Force on press/ Cylinder area = 37665 lb / 4.43 in<sup>2</sup> = 8502.3 lb/in<sup>2</sup> (58621 kN/m<sup>2</sup>)

2. Cylinder with effective area of 5.15 in<sup>2</sup>

Pressure on the samples: 2500 psi (17236.9 kN/m<sup>2</sup>)

Area (3 samples 27 x 120 mm): 3.19 in x 4.72 in = 15.066 in<sup>2</sup> (9720 mm<sup>2</sup>)

Force on the press: 2500 lb/in<sup>2</sup> x 15.066 in<sup>2</sup> = 37665 lb (167533.9 N)

Cylinder effective area: 5.15 in<sup>2</sup>

Pump pressure: Force on press/ Cylinder area = 37665 lb / 5.15 in<sup>2</sup> = 7313.6 lb/in<sup>2</sup> (50425.4 kN/m<sup>2</sup>)

## APPENDIX B

### Statistical Analysis

**1. Four – factor factorial experiment.** Effect of four factors on ultimate tensile stress.

<u>Factors:</u>	<u>Levels:</u>
Species	1 – Southern pine 2 – Yellow-poplar
Strain	1 – 0 % 2 – 25 % 3 – 50 %
Treatment	1 – control 2 – TRT1 3 – TRT2 4 – TRT3
Type	1- mature 2 – juvenile

The experiment was performed in SAS (version 6.12 for Windows). ANOVA was performed using *proc glm* procedure.

**SAS output:**

```

4-FACTOR FACTORIAL
Effect of 4 factors on Ultimate Stress
ANOVA W/POST-HOC ANALYSIS
General Linear Models Procedure
Class Level Information

Class      Levels  Values
SPECIES      2      1 2
STRAIN       3      1 2 3
TRT          4      1 2 3 4
TYPE         2      1 2

```

Number of observations in data set = 420

4-FACTOR FACTORIAL  
Effect of 4 factors on Ultimate Stress  
ANOVA W/POST-HOC ANALYSIS

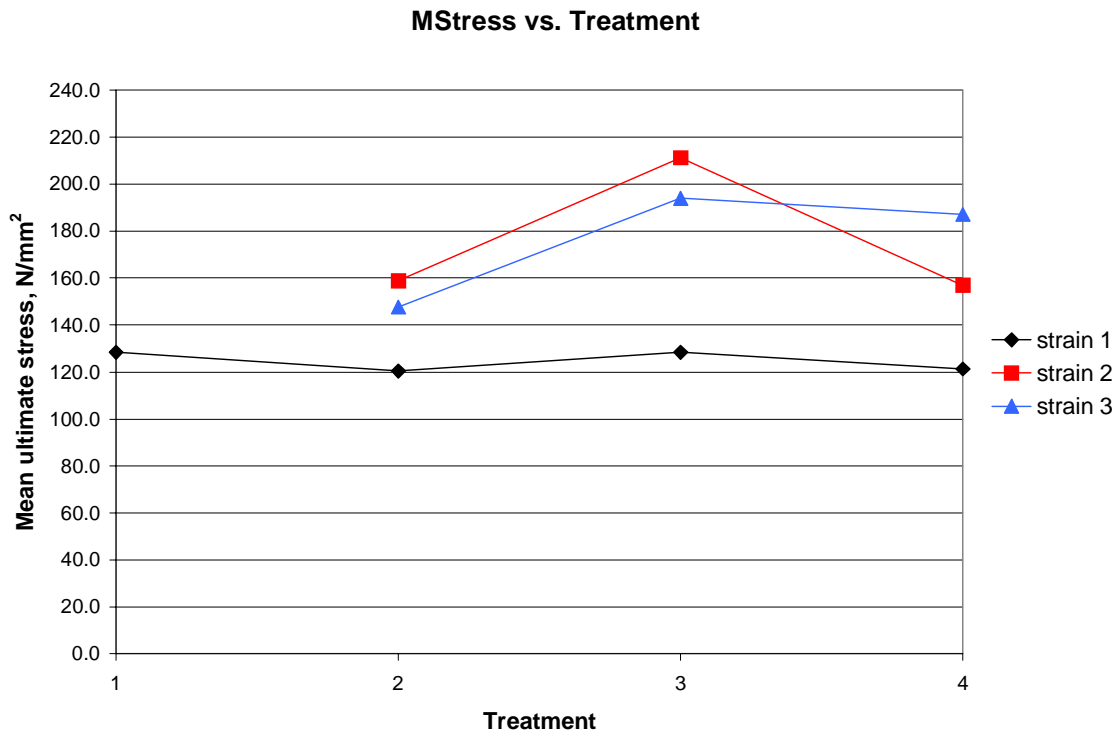
General Linear Models Procedure

Dependent Variable: STRESS

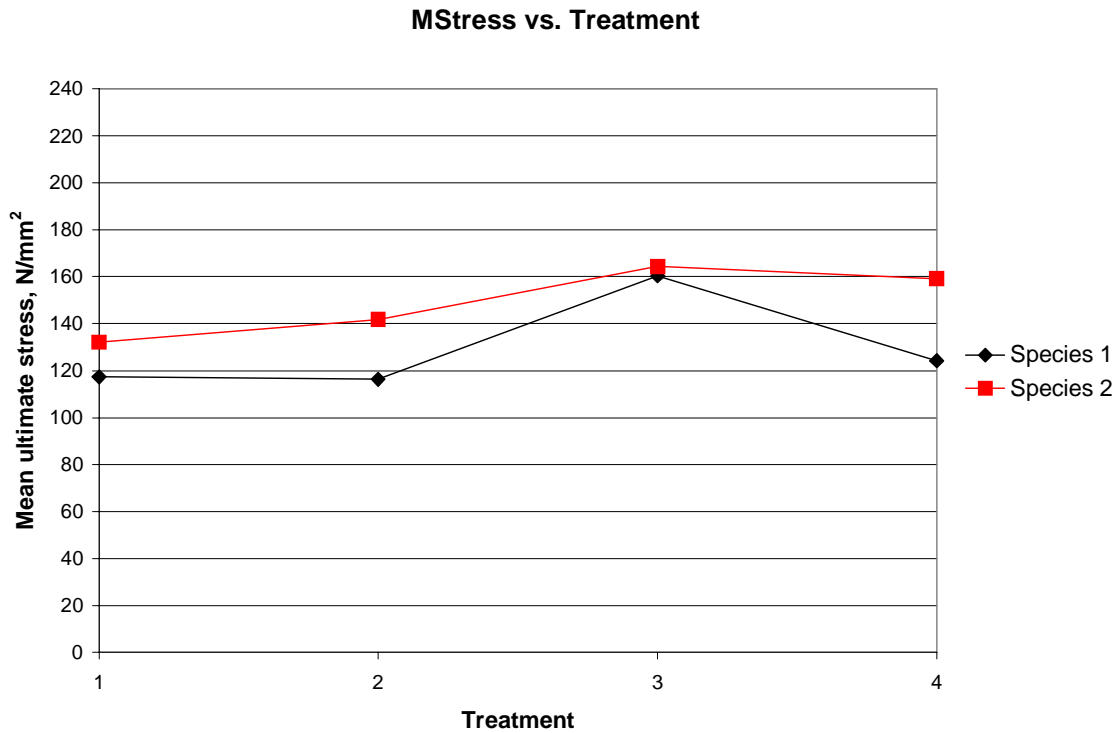
Source	DF	Sum of Squares	F Value	Pr > F
Model	16	418773.596413	26.90	0.0001
Error	403	392110.544063		
Corrected Total	419	810884.140476		
	R-Square	C.V.		STRESS Mean
	0.516441	21.26458		146.688095

Source	DF	Type I SS	F Value	Pr > F
SPECIES	1	33089.562698	34.01	0.0001
STRAIN	2	274851.978333	141.24	0.0001
TRT	3	47971.851389	16.43	0.0001
TYPE	1	22.860357	0.02	0.8783
SPECIES*TRT	3	12071.665165	4.14	0.0066
STRAIN*TRT	4	47048.245752	12.09	0.0001
SPECIES*STRAIN	1	101.096608	0.10	0.7474
SPECIES*TYPE	0	0.000000	.	.
STRAIN*TYPE	1	3616.336111	3.72	0.0546

Source	DF	Type III SS	F Value	Pr > F
SPECIES	1	18018.247668	18.52	0.0001
STRAIN	2	180366.396684	92.69	0.0001
TRT	3	66821.331200	22.89	0.0001
TYPE	1	461.946778	0.47	0.4912
SPECIES*TRT	3	19004.579548	6.51	0.0003
STRAIN*TRT	4	47048.245752	12.09	0.0001
SPECIES*STRAIN	1	1175.482207	1.21	0.2724
SPECIES*TYPE	0	0.000000	.	.
STRAIN*TYPE	1	3616.336111	3.72	0.0546



**Figure B1.** Interaction Plot: Mean Ultimate Stress vs. Treatment at three levels of strain.



**Figure B2.** Interaction Plot: Mean Ultimate Stress vs. Treatment at two levels of species.

**2. Four – factor factorial experiment.** Effect of four factors on tensile modulus.

**SAS output:**

4-FACTOR FACTORIAL  
Effect of 4 factors on Tensile Modulus  
ANOVA W/POST-HOC ANALYSIS

General Linear Models Procedure  
Class Level Information

Class	Levels	Values
SPECIES	2	1 2
STRAIN	3	1 2 3
TRT	4	1 2 3 4
TYPE	2	1 2

Number of observations in data set = 420

4-FACTOR FACTORIAL  
 Effect of 4 factors on Tensile Modulus  
 ANOVA W/POST-HOC ANALYSIS

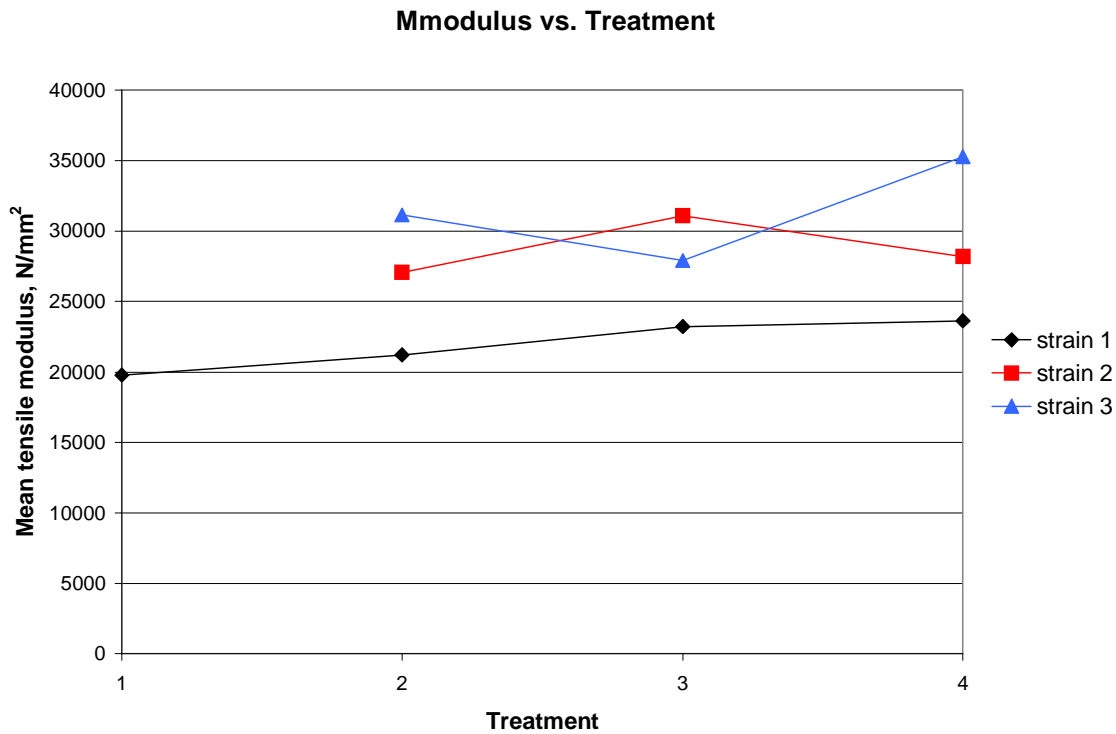
General Linear Models Procedure

Dependent Variable: MODULUS

Source	DF	Sum of Squares	F Value	Pr > F
Model	16	14463620421.6	36.93	0.0001
Error	403	9863368411.8		
Corrected Total	419	24326988833.3		
	R-Square	C.V.	MODULUS Mean	
	0.594550	19.21121	25751.6667	

Source	DF	Type I SS	F Value	Pr > F
SPECIES	1	2153125722.22	87.97	0.0001
STRAIN	2	8029976383.33	164.05	0.0001
TRT	3	997721013.89	13.59	0.0001
TYPE	1	2145091876.59	87.64	0.0001
SPECIES*TRT	3	154032876.07	2.10	0.0999
STRAIN*TRT	4	895306736.38	9.15	0.0001
SPECIES*STRAIN	1	79264653.08	3.24	0.0727
SPECIES*TYPE	0	0.00	.	.
STRAIN*TYPE	1	9101160.00	0.37	0.5423

Source	DF	Type III SS	F Value	Pr > F
SPECIES	1	451670783.13	18.45	0.0001
STRAIN	2	4396972882.69	89.83	0.0001
TRT	3	527233458.73	7.18	0.0001
TYPE	1	1804723560.00	73.74	0.0001
SPECIES*TRT	3	57154185.46	0.78	0.5065
STRAIN*TRT	4	895306736.38	9.15	0.0001
SPECIES*STRAIN	1	87398493.98	3.57	0.0595
SPECIES*TYPE	0	0.00	.	.
STRAIN*TYPE	1	9101160.00	0.37	0.5423



**Figure B3.** Interaction Plot: Mean Tensile Modulus vs. Treatment at three levels of strain.

**3. Four – factor factorial experiment.** Effect of four factors on specific ultimate tensile stress.

**SAS output:**

```

4-FACTOR FACTORIAL
Effect of 4 factors on specific ultimate stress
ANOVA W/POST-HOC ANALYSIS

```

General Linear Models Procedure

Class Level Information

Class	Levels	Values
SPECIES	2	1 2
STRAIN	3	1 2 3
TRT	4	1 2 3 4
TYPE	2	1 2

Number of observations in data set = 420

4-FACTOR FACTORIAL  
 Effect of 4 factors on specific ultimate stress  
 ANOVA W/POST-HOC ANALYSIS

General Linear Models Procedure

Dependent Variable: SSTRESS

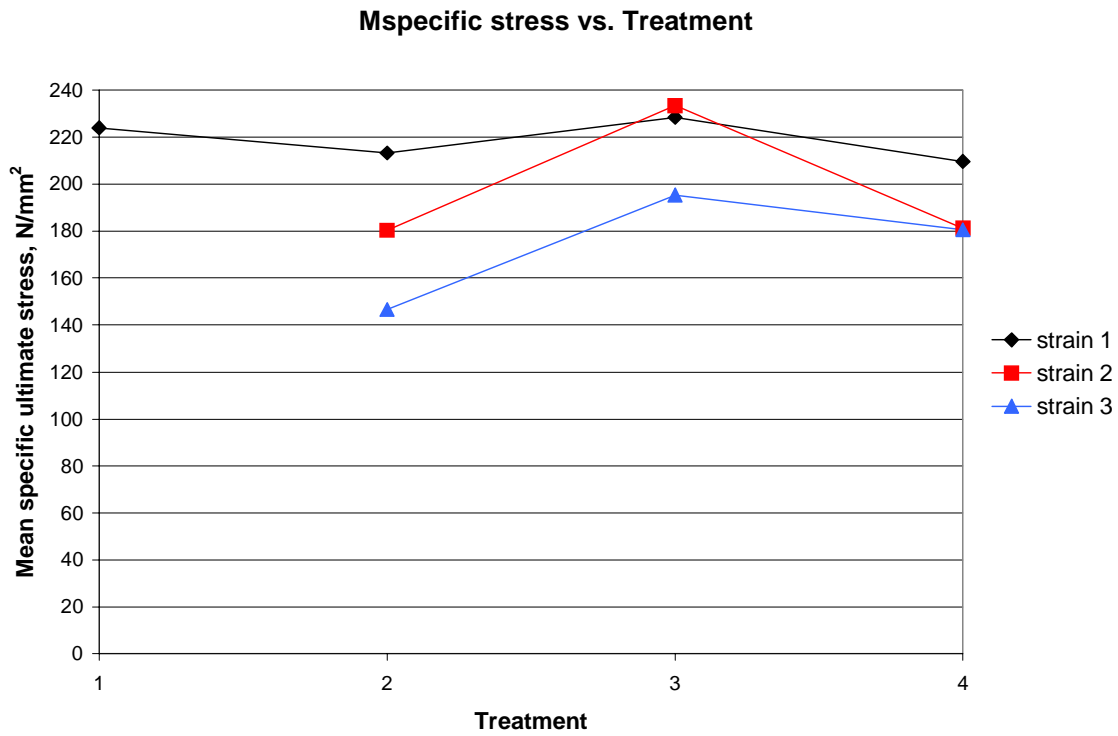
Source	DF	Sum of Squares	F Value	Pr > F
Model	16	450473.602902	17.80	0.0001
Error	403	637274.911383		
Corrected Total	419	1087748.514286		

R-Square	C.V.	SSTRESS Mean
0.414134	19.65551	202.314286

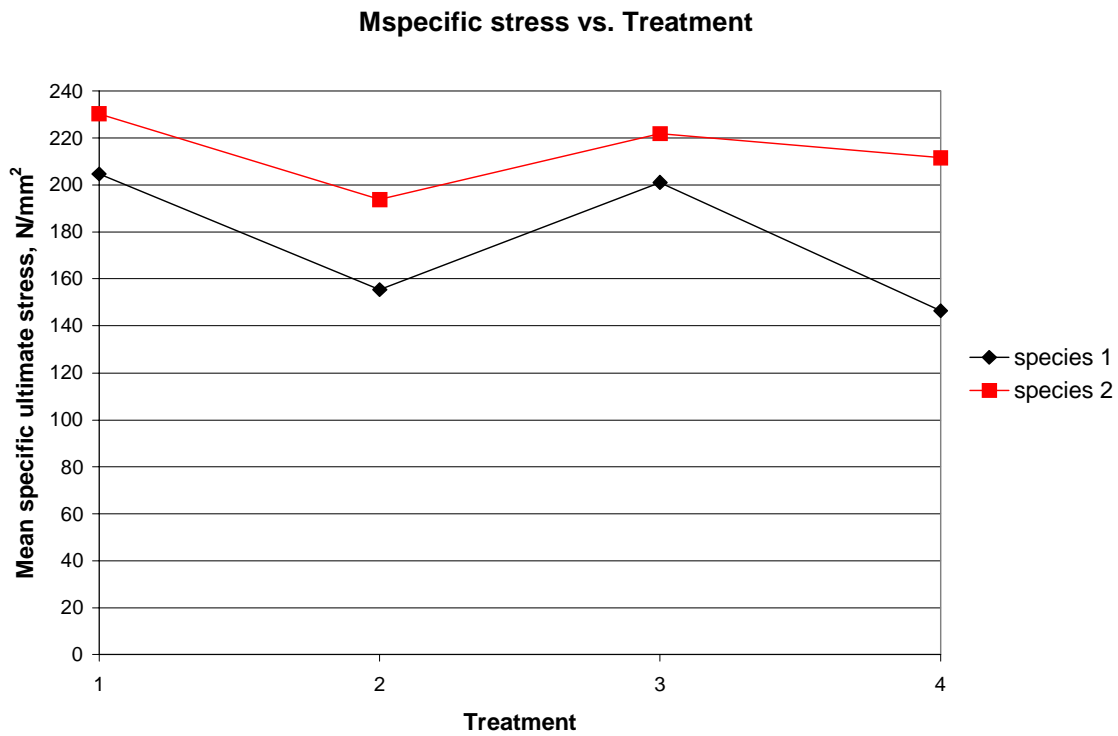
Source	DF	Type I SS	F Value	Pr > F
SPECIES	1	120775.314286	76.38	0.0001
STRAIN	2	157695.202222	49.86	0.0001
TRT	3	67309.444444	14.19	0.0001
TYPE	1	39470.057302	24.96	0.0001
SPECIES*TRT	3	23616.715173	4.98	0.0021
STRAIN*TRT	4	38954.893246	6.16	0.0001
SPECIES*STRAIN	1	2293.175229	1.45	0.2292
SPECIES*TYPE	0	0.000000	.	.
STRAIN*TYPE	1	358.801000	0.23	0.6341

Source	DF	Type III SS	F Value	Pr > F
SPECIES	1	32168.4806002	20.34	0.0001
STRAIN	2	81298.3027483	25.71	0.0001
TRT	3	87319.7684214	18.41	0.0001
TYPE	1	35129.3290000	22.22	0.0001
SPECIES*TRT	3	33623.9358388	7.09	0.0001
STRAIN*TRT	4	38954.8932462	6.16	0.0001
SPECIES*STRAIN	1	1265.5488733	0.80	0.3715
SPECIES*TYPE	0	0.0000000	.	.
STRAIN*TYPE	1	358.8010000	0.23	0.6341





**Figure B4.** Interaction Plot: Mean Specific Ultimate stress vs. Treatment at three strain levels.



**Figure B5.** Interaction Plot: Mean Specific Ultimate Stress vs. Treatment at two levels of species.

**4. Four – factor factorial experiment.** Effect of four factors on specific tensile modulus.

**SAS output:**

```
4-FACTOR FACTORIAL
Effect of 4 factors on specific tensile modulus
ANOVA W/POST-HOC ANALYSIS
```

```
General Linear Models Procedure
Class Level Information
```

Class	Levels	Values
SPECIES	2	1 2
STRAIN	3	1 2 3
TRT	4	1 2 3 4
TYPE	2	1 2

```
Number of observations in data set = 420
```

4-FACTOR FACTORIAL  
 Effect of 4 factors on specific tensile modulus  
 ANOVA W/POST-HOC ANALYSIS

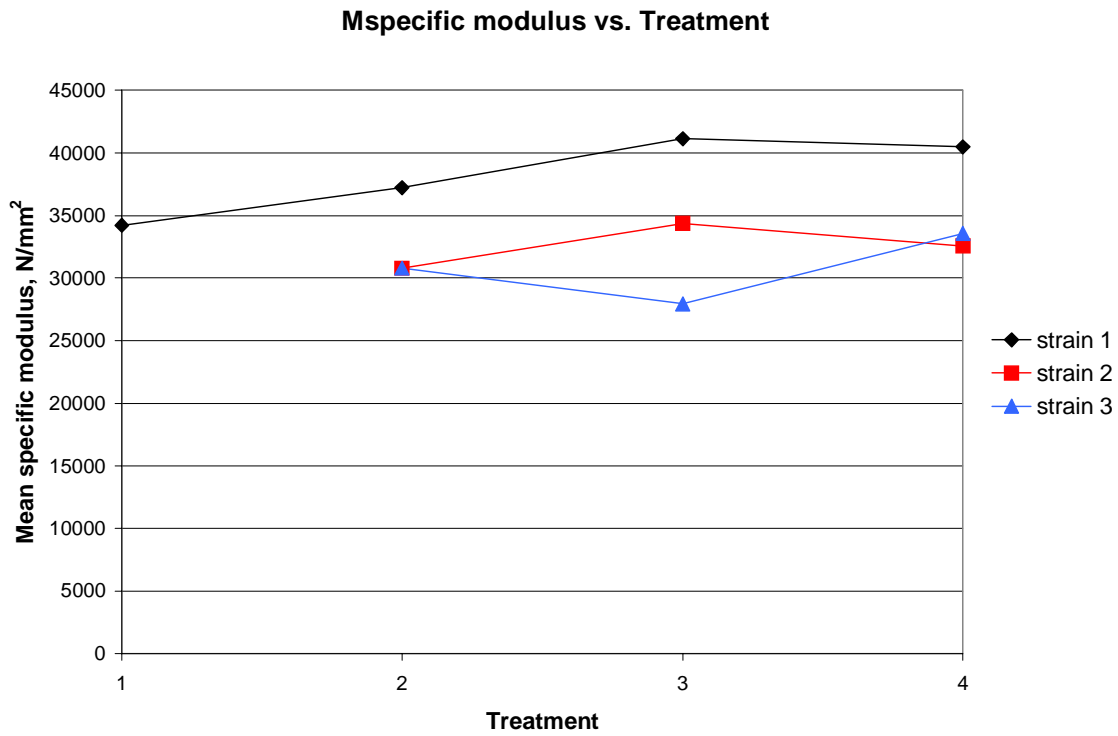
General Linear Models Procedure

Dependent Variable: SMODULUS

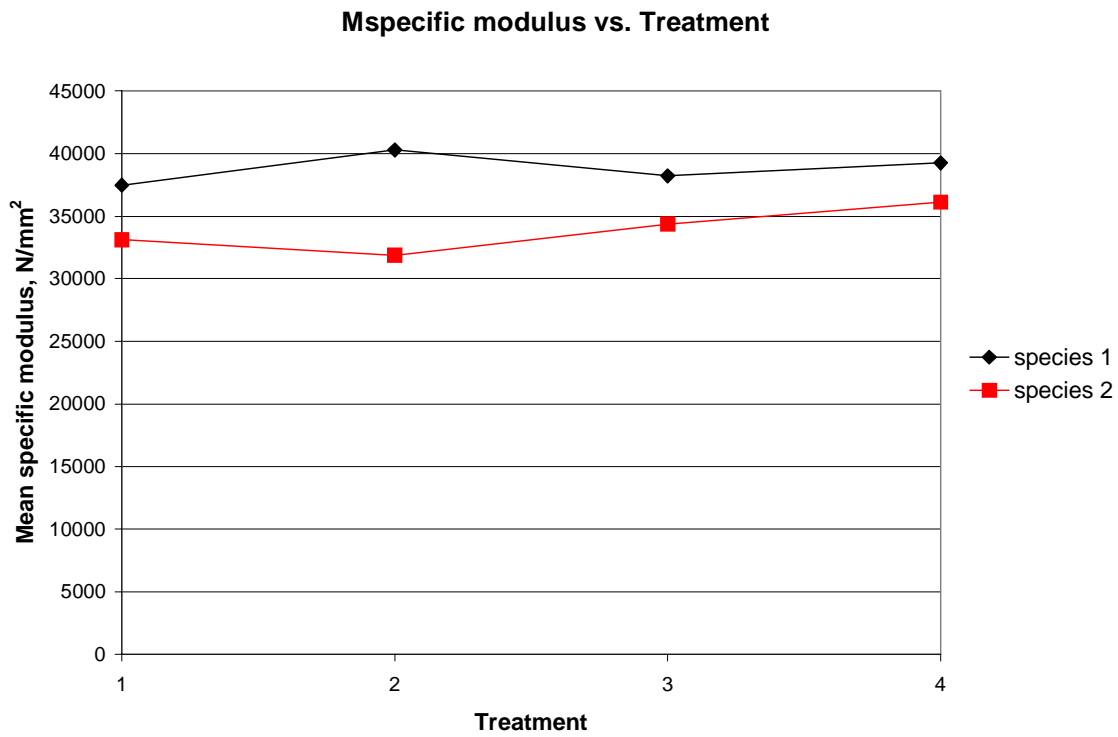
Source	DF	Sum of Squares	F Value	Pr > F
Model	16	11858464980.7	18.81	0.0001
Error	403	15880860638.3		
Corrected Total	419	27739325619.0		
	R-Square	C.V.	SMODULUS Mean	
	0.427497	17.81468	35237.6190	

Source	DF	Type I SS	F Value	Pr > F
SPECIES	1	1979765365.08	50.24	0.0001
STRAIN	2	5506866615.08	69.87	0.0001
TRT	3	1808677680.56	15.30	0.0001
TYPE	1	1164941667.77	29.56	0.0001
SPECIES*TRT	3	376805577.51	3.19	0.0237
STRAIN*TRT	4	828682213.51	5.26	0.0004
SPECIES*STRAIN	1	155528310.09	3.95	0.0476
SPECIES*TYPE	0	0.00	.	.
STRAIN*TYPE	1	37197551.11	0.94	0.3318

Source	DF	Type III SS	F Value	Pr > F
SPECIES	1	588802153.06	14.94	0.0001
STRAIN	2	3989943222.81	50.63	0.0001
TRT	3	1243186262.18	10.52	0.0001
TYPE	1	1013512004.44	25.72	0.0001
SPECIES*TRT	3	411840144.06	3.48	0.0160
STRAIN*TRT	4	828682213.51	5.26	0.0004
SPECIES*STRAIN	1	77034056.67	1.95	0.1628
SPECIES*TYPE	0	0.00	.	.
STRAIN*TYPE	1	37197551.11	0.94	0.3318



**Figure B6.** Interaction Plot: Mean Specific Modulus vs. Treatment at three levels of strain.



**Figure B7.** Interaction Plot: Mean Specific Modulus vs. Treatment at two levels of species.

**5. Four – factor factorial experiment.** Effect of four factors on change in specific gravity.

**SAS output:**

4-FACTOR FACTORIAL  
Effect of 4 factors on change in specific gravity  
ANOVA W/POST-HOC ANALYSIS

General Linear Models Procedure  
Class Level Information

Class	Levels	Values
SPECIES	2	1 2
STRAIN	3	1 2 3
TRT	4	1 2 3 4
TYPE	2	1 2

Number of observations in data set = 420

4-FACTOR FACTORIAL  
 Effect of 4 factors on change in specific gravity  
 ANOVA W/POST-HOC ANALYSIS

General Linear Models Procedure

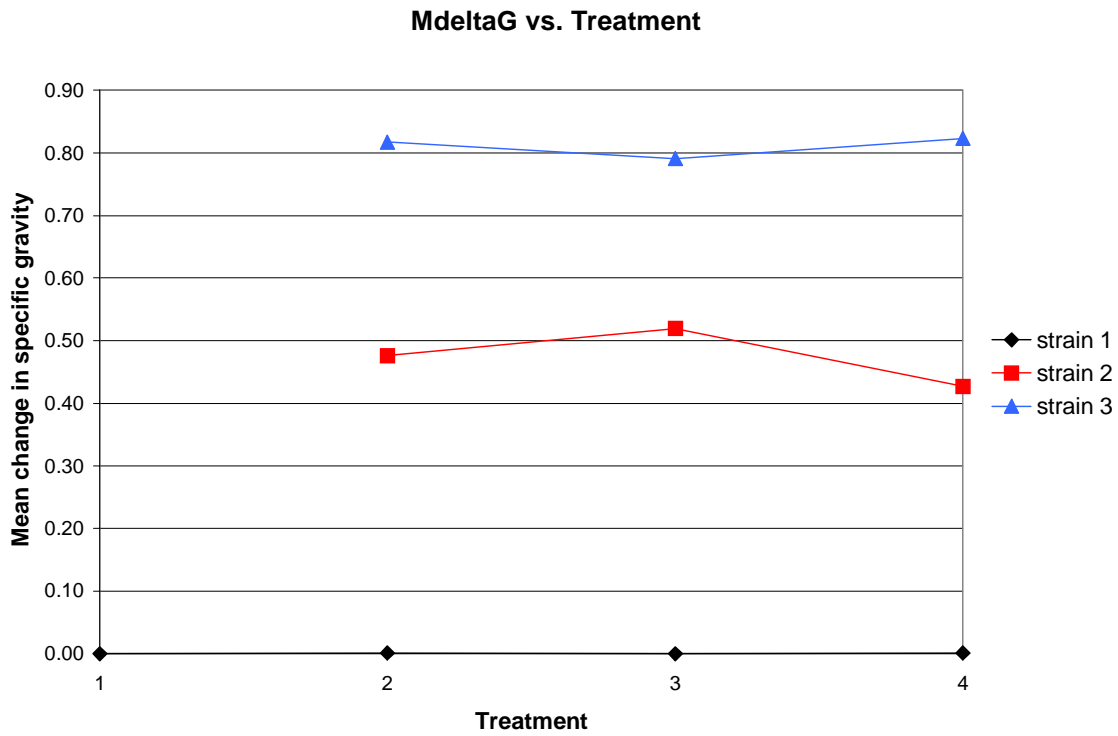
Dependent Variable: DELTAG

Source	DF	Sum of Squares	F Value	Pr > F
Model	16	59.19660891	758.70	0.0001
Error	403	1.96522443		
Corrected Total	419	61.16183333		

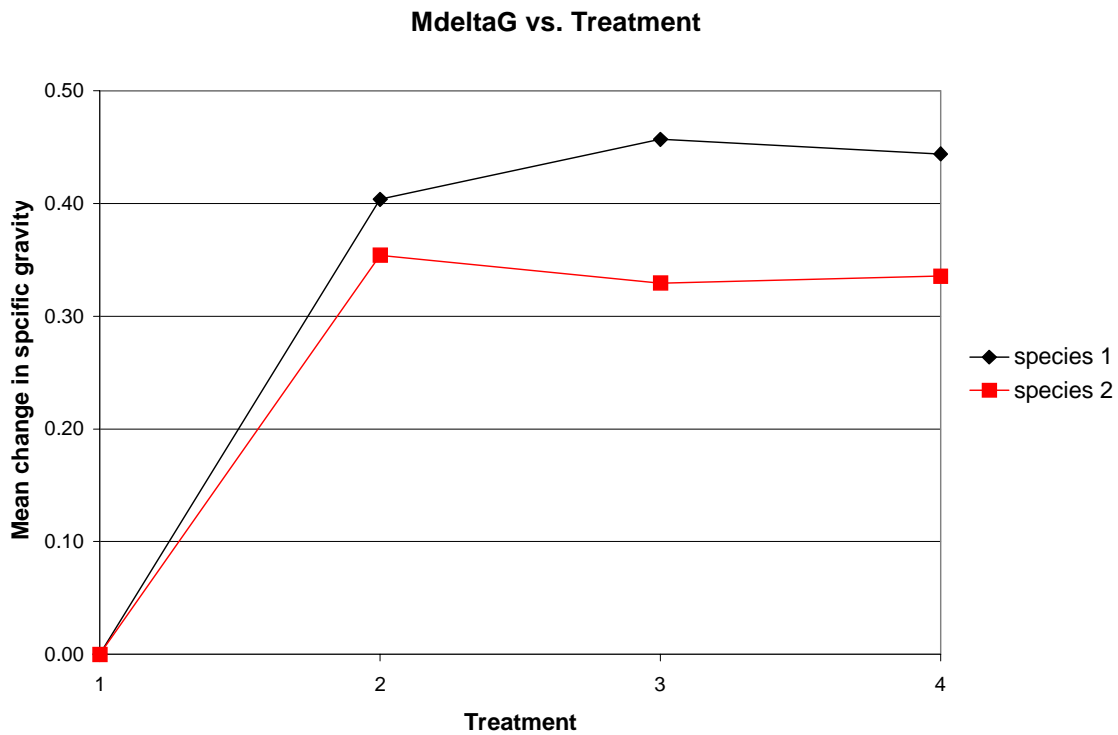
R-Square	C.V.	DELTAG Mean
0.967868	22.40594	0.31166667

Source	DF	Type I SS	F Value	Pr > F
SPECIES	1	0.52256794	107.16	0.0001
STRAIN	2	57.57952784	5903.79	0.0001
TRT	3	0.00173778	0.12	0.9490
TYPE	1	0.24320644	49.87	0.0001
SPECIES*TRT	3	0.09470155	6.47	0.0003
STRAIN*TRT	4	0.11116344	5.70	0.0002
SPECIES*STRAIN	1	0.14537271	29.81	0.0001
SPECIES*TYPE	0	0.00000000	.	.
STRAIN*TYPE	1	0.49833121	102.19	0.0001

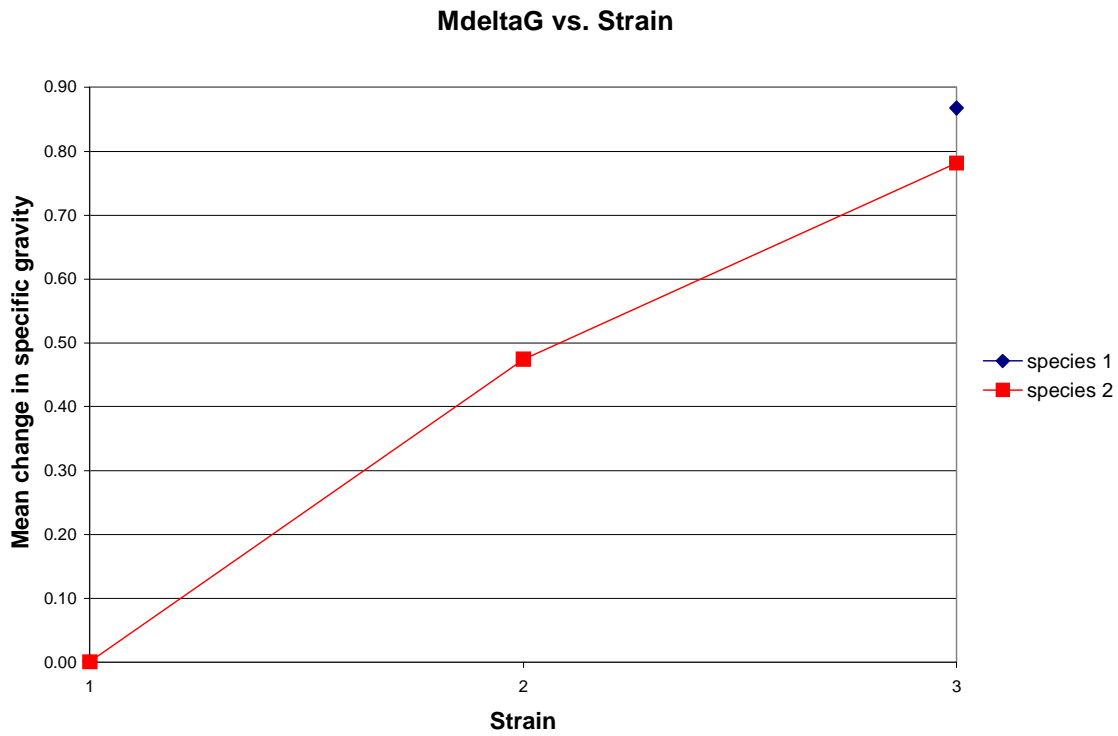
Source	DF	Type III SS	F Value	Pr > F
SPECIES	1	0.42016025	86.16	0.0001
STRAIN	2	35.96984028	3688.09	0.0001
TRT	3	0.04579324	3.13	0.0256
TYPE	1	0.49565601	101.64	0.0001
SPECIES*TRT	3	0.09623992	6.58	0.0002
STRAIN*TRT	4	0.11116344	5.70	0.0002
SPECIES*STRAIN	1	0.41163061	84.41	0.0001
SPECIES*TYPE	0	0.00000000	.	.
STRAIN*TYPE	1	0.49833121	102.19	0.0001



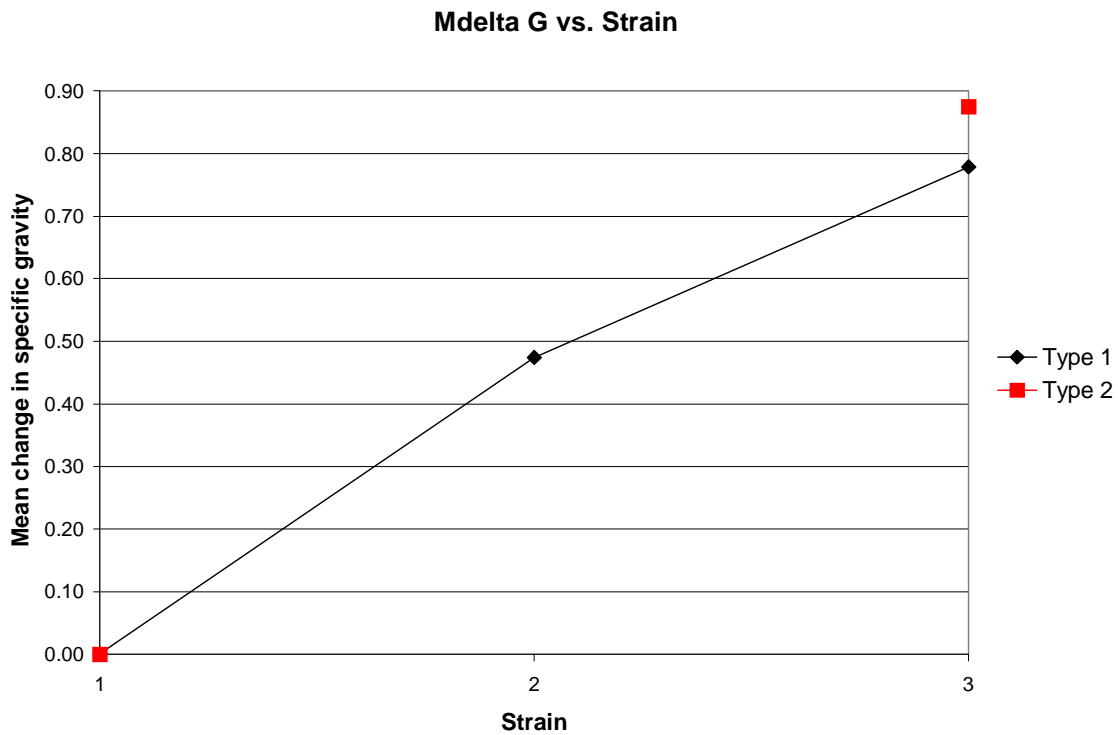
**Figure B8.** Interaction Plot: Mean Change in Specific Gravity vs. Treatment at three strain levels.



**Figure B9.** Interaction Plot: Mean Change in Specific Gravity vs. Treatment at two species levels.



**Figure B10.** Interaction Plot: Mean Change in Specific Gravity vs. Strain at two levels of species.



**Figure B11.** Interaction Plot: Mean Change in Specific Gravity vs. Strain at two levels of types of wood.



**6. Analysis of covariance** (ultimate stress- y, original specific gravity-x, as a covariate)  
The analysis was performed in SAS.

4-FACTOR FACTORIAL with ANALYSIS OF COVARIANCE  
EFFECT OF 4 FACTORS ON ULTIMATE STRESS

General Linear Models Procedure  
Class Level Information

Class	Levels	Values
SPECIES	2	1 2
STRAIN	3	1 2 3
TRT	4	1 2 3 4
TYPE	2	1 2

Number of observations in data set = 420

4-FACTOR FACTORIAL with ANALYSIS OF COVARIANCE  
EFFECT OF 4 FACTORS ON ULTIMATE STRESS

General Linear Models Procedure

Dependent Variable: STRESS

Source	DF	Sum of Squares	F Value	Pr > F
Model	8	355947.661647	40.20	0.0001
Error	411	454936.478829		
Corrected Total	419	810884.140476		
	R-Square	C.V.	STRESS Mean	
	0.438962	22.68086	146.688095	

Source	DF	Type I SS	F Value	Pr > F
SPECIES	1	33089.562698	29.89	0.0001
STRAIN	2	274851.978333	124.15	0.0001
TRT	3	47971.851389	14.45	0.0001
TYPE	1	22.860357	0.02	0.8858
SG	1	11.408870	0.01	0.9192

Source	DF	Type III SS	F Value	Pr > F
SPECIES	1	26540.145574	23.98	0.0001
STRAIN	2	252135.204813	113.89	0.0001
TRT	3	47983.256591	14.45	0.0001
TYPE	1	0.839817	0.00	0.9780
SG	1	11.408870	0.01	0.9192

Parameter	Estimate	T for H0: Parameter=0	Pr >  T	Std Error of Estimate
INTERCEPT	187.0104530 B	7.45	0.0001	25.09859122
SPECIES 1	-21.5019024 B	-4.90	0.0001	4.39116450
2	0.0000000 B	.	.	.
STRAIN 1	-54.6432040 B	-14.26	0.0001	3.83300466
2	-7.5105183 B	-1.21	0.2254	6.18659781
3	0.0000000 B	.	.	.
TRT 1	4.2932992 B	0.77	0.4405	5.56103292

**Analysis of covariance** (tensile modulus- y, original specific gravity-x, as a covariate)

4-FACTOR FACTORIAL with ANALYSIS OF COVARIANCE  
EFFECT OF 4 FACTORS ON TENSILE MODULUS

General Linear Models Procedure  
Class Level Information

Class	Levels	Values
SPECIES	2	1 2
STRAIN	3	1 2 3
TRT	4	1 2 3 4
TYPE	2	1 2

Number of observations in data set = 420

4-FACTOR FACTORIAL with ANALYSIS OF COVARIANCE  
EFFECT OF 4 FACTORS ON TENSILE MODULUS

General Linear Models Procedure

Dependent Variable: MODULUS

Source	DF	Sum of Squares	F Value	Pr > F
Model	8	13434101692.5	63.36	0.0001
Error	411	10892887140.8		
Corrected Total	419	24326988833.3		
	R-Square	C.V.	MODULUS Mean	
	0.552230	19.99149	25751.6667	

Source	DF	Type I SS	F Value	Pr > F
SPECIES	1	2153125722.22	81.24	0.0001
STRAIN	2	8029976383.33	151.49	0.0001
TRT	3	997721013.89	12.55	0.0001
TYPE	1	2145091876.59	80.94	0.0001
SG	1	108186696.45	4.08	0.0440

Source	DF	Type III SS	F Value	Pr > F
SPECIES	1	575177548.33	21.70	0.0001
STRAIN	2	6302535980.61	118.90	0.0001
TRT	3	887036409.10	11.16	0.0001
TYPE	1	618253985.58	23.33	0.0001
SG	1	108186696.45	4.08	0.0440

Parameter	Estimate	T for H0: Parameter=0	Pr >  T	Std Error of Estimate
INTERCEPT	20770.78743 B	5.35	0.0001	3883.698134
SPECIES 1	3165.38252 B	4.66	0.0001	679.478670
2	0.00000 B	.	.	.
STRAIN 1	-9022.83668 B	-15.21	0.0001	593.110303
2	-3660.57293 B	-3.82	0.0002	957.299880
3	0.00000 B	.	.	.
TRT 1	-4632.05416 B	-5.38	0.0001	860.501411