

1. Moisture in stored lumber is a concern for lumber manufacturers. One manufacturer wanted to conduct a study of the effect of five different storage conditions on lumber moisture content. At a management meeting to discuss the experiment, Wilbur (who had slept through his college statistics classes) suggested that they randomly choose 5 boards from production to assign to each storage condition. Orville (who had excelled in his college statistics courses), suggested that since there was a great deal of variation from tree to tree, that the experiment be conducted by taking a random sample of five logs of the same grade, and then randomly choosing five boards of the same type cut from each log. He suggested that each of the five boards from the same log be assigned to a different condition, the assignment to be done at random. His suggestion was adopted.¹

- (a) (10 points) Explain why Orville's design is an RCBD. Be sure to state what the blocks, treatments and experimental units are.

ANS: *It is a CBD because each treatment (storage condition) is forced to appear in each block (tree or log). It is a RCBD because the treatments are assigned to experimental units (boards) at random.*

- (b) (10 points) Why is this a better design than Wilbur's?

ANS: *Because it eliminates tree to tree (or log to log) variation.*

2. (20 points) Write out an additive model for Orville's experiment. Explain what each parameter means.

ANS: *The model is the additive RCBD model*

$$Y_{ij} = \mu + \tau_i + \gamma_j + \epsilon_{ij}, i = 1, \dots, 5, j = 1, \dots, 5,$$

where Y_{ij} is the moisture content for the board from log i under storage condition j , μ is the overall population mean, τ_i is the effect due to tree (log) storage type i , γ_j is the effect due to storage type j , and ϵ_{ij} is random error.

3. (10 points) The following is the ANOVA table for the model fitted to Orville's experimental data:

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Stat	Prob > F
Condition	4	2.404	0.601	13.74	< 0.0001
Board	4	7.396	1.849	42.26	< 0.0001
Error	16	0.700	0.044		
C Total	24	10.500			

In terms of mean moisture percentage, are there significant differences among storage conditions? Justify your answer.

ANS: *There appear to be significant differences among storage conditions (p-value: < 0.0001).*

4. (20 points) The following is SAS output for the Tukey multiple comparisons of the storage conditions. What does it tell you? Be specific.

Tukey's Studentized Range (HSD) Test for moisture

Comparisons significant at the 0.05 level are indicated by ***.

	Difference	Simultaneous
condition	Between	Level .95 Confidence
Comparison	Means	Limits

¹ The company's chairman was so impressed with Orville's statistical expertise, that he made him company president, and later his successor as chairman, thus proving the benefits of not sleeping in statistics classes.

4	- 2	0.6200	0.2147	1.0253	***
4	- 5	0.6200	0.2147	1.0253	***
4	- 3	0.7400	0.3347	1.1453	***
4	- 1	0.9200	0.5147	1.3253	***
2	- 5	0.0000	-0.4053	0.4053	
2	- 3	0.1200	-0.2853	0.5253	
2	- 1	0.3000	-0.1053	0.7053	
5	- 3	0.1200	-0.2853	0.5253	
5	- 1	0.3000	-0.1053	0.7053	
3	- 1	0.1800	-0.2253	0.5853	

ANS: It tells that at the overall 0.05 level, the mean moisture content for wood stored under condition 4 is greater than for any of the other conditions. We cannot discern any significant difference in mean moisture content among the other storage conditions.

5. Suppose Wilbur's design had been carried out: That is, the design was a CRD.

- (a) **(20 points)** Reanalyze the data in problem 2 as if it had been obtained from a CRD, by constructing the ANOVA table that results from ignoring the blocking. Here is one number for your table: the p-value of the F test is 0.2443.

ANS:

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Stat	Prob > F
Condition	4	2.404	0.6010	1.48	0.2443
Error	20	8.096	0.4048		
C Total	24	10.500			

- (b) **(10 points)** Do the results in (a) demonstrate that the blocking has been useful for these data? Explain.

ANS: Blocking has been very useful in reducing variation and revealing differences in mean moisture percentages among different storage conditions. Without blocking, we cannot statistically distinguish any differences. With blocking, we see that wood stored under condition 4 has significantly higher mean moisture content than wood stored under the other conditions.