

The Randomized Complete Block Design (RCBD)

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- The objective of this tutorial is to give a brief introduction to the design of a randomized complete block design (RCBD) and the basics of how to analyze the RCBD using SAS.

The RCBD is the standard design for agricultural experiments where similar experimental units are grouped into blocks or replicates.

It is used to control variation in an experiment by accounting for spatial effects in field or greenhouse.

e.g. variation in fertility or drainage differences in a field

The field or space is divided into uniform units to account for any variation so that observed differences are largely due to true differences between treatments.

Treatments are then assigned at random to the subjects in the blocks-once in each block

The defining feature of the Randomized Complete Block Design is that each block sees each treatment *exactly* once

Advantages of the RCBD

Generally more precise than the completely randomized design (CRD).

No restriction on the number of treatments or replicates.

Some treatments may be replicated more times than others.

Missing plots are easily estimated.

Disadvantages of the RCBD

Error degrees of freedom is smaller than that for the CRD (problem with a small number of treatments).

Large variation between experimental units within a block may result in a large error term
If there are missing data, a RCBD experiment may be less efficient than a CRD

NOTE: The most important item to consider when choosing a design is the uniformity of the experimental units.

The Layout of the Experiment

- Choose the number of blocks (minimum 2)
 - e.g. 4
- Choose treatments (assign numbers or letters for each)
 - e.g. 6 trt – A,B, C, D, E, F

1

2

3

4



Blocks

The number of blocks is the number of replications

Treatments are assigned at random within blocks of adjacent subjects, each treatment once per block.

Any treatment can be adjacent to any other treatment, but not to the same treatment within the block

A



B



C



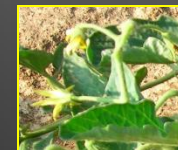
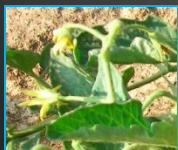
D



E



F



Treatments

Excel randomization

To generate random numbers

Use =RAND () ctrl enter

Randomize blocks

[**DATA**, **SORT** by column w/ =rand()]

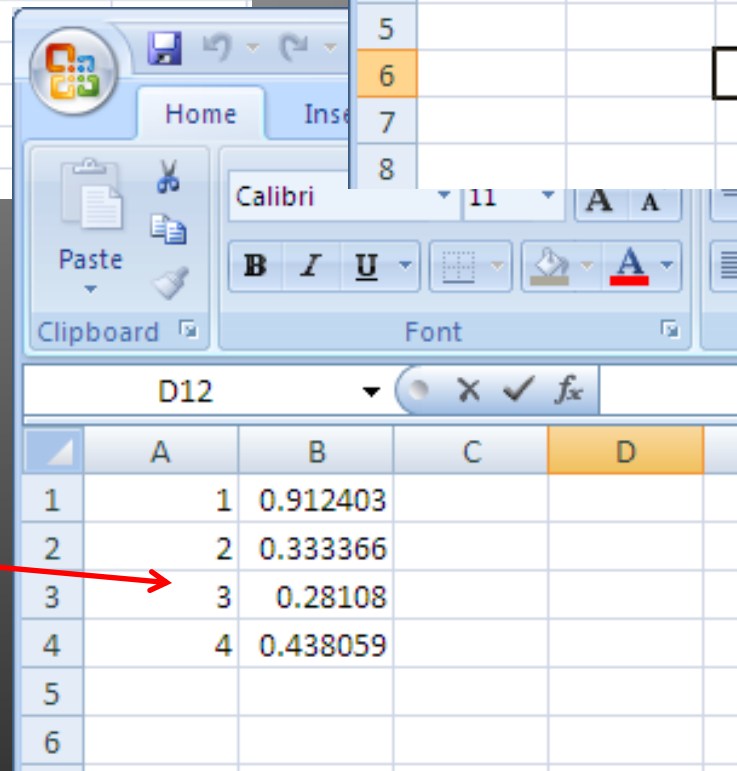
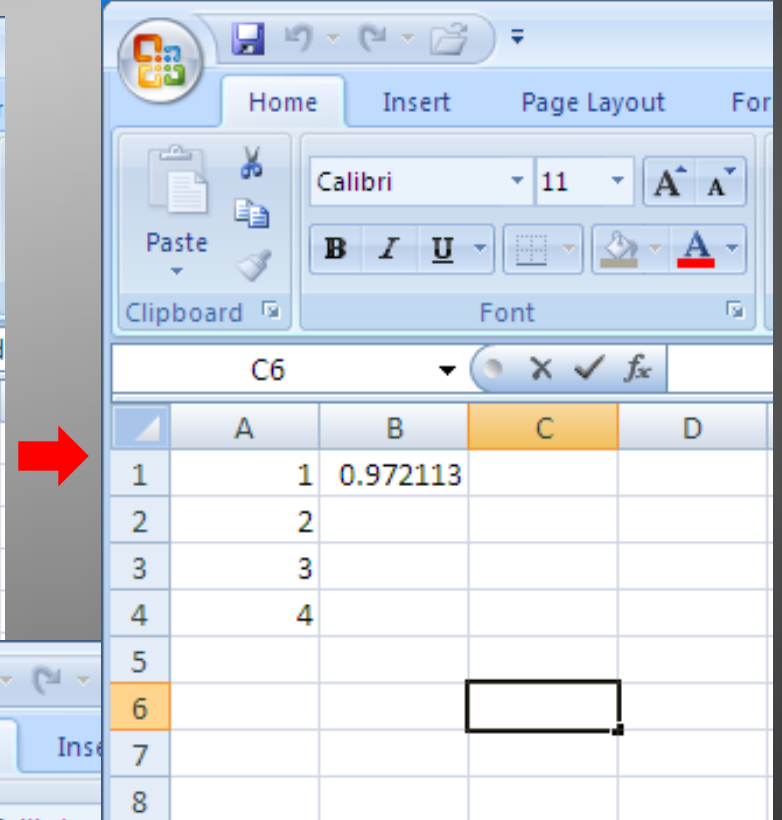
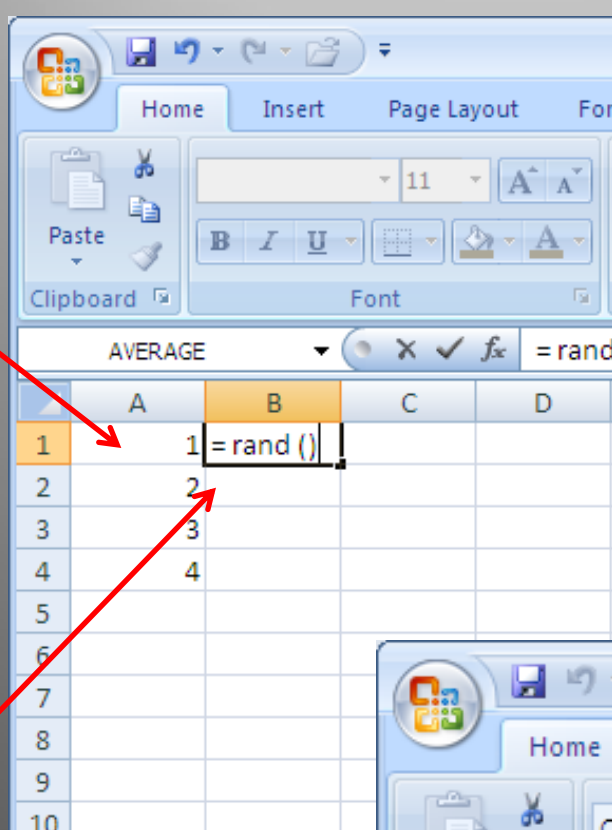
- Randomize treatments in each block independently

The first step is to randomize the treatments and blocks. This can be done in excel using the RAND function

1. Column A – list of blocks

2. Column B
Enter =rand()
to generate a
random
number

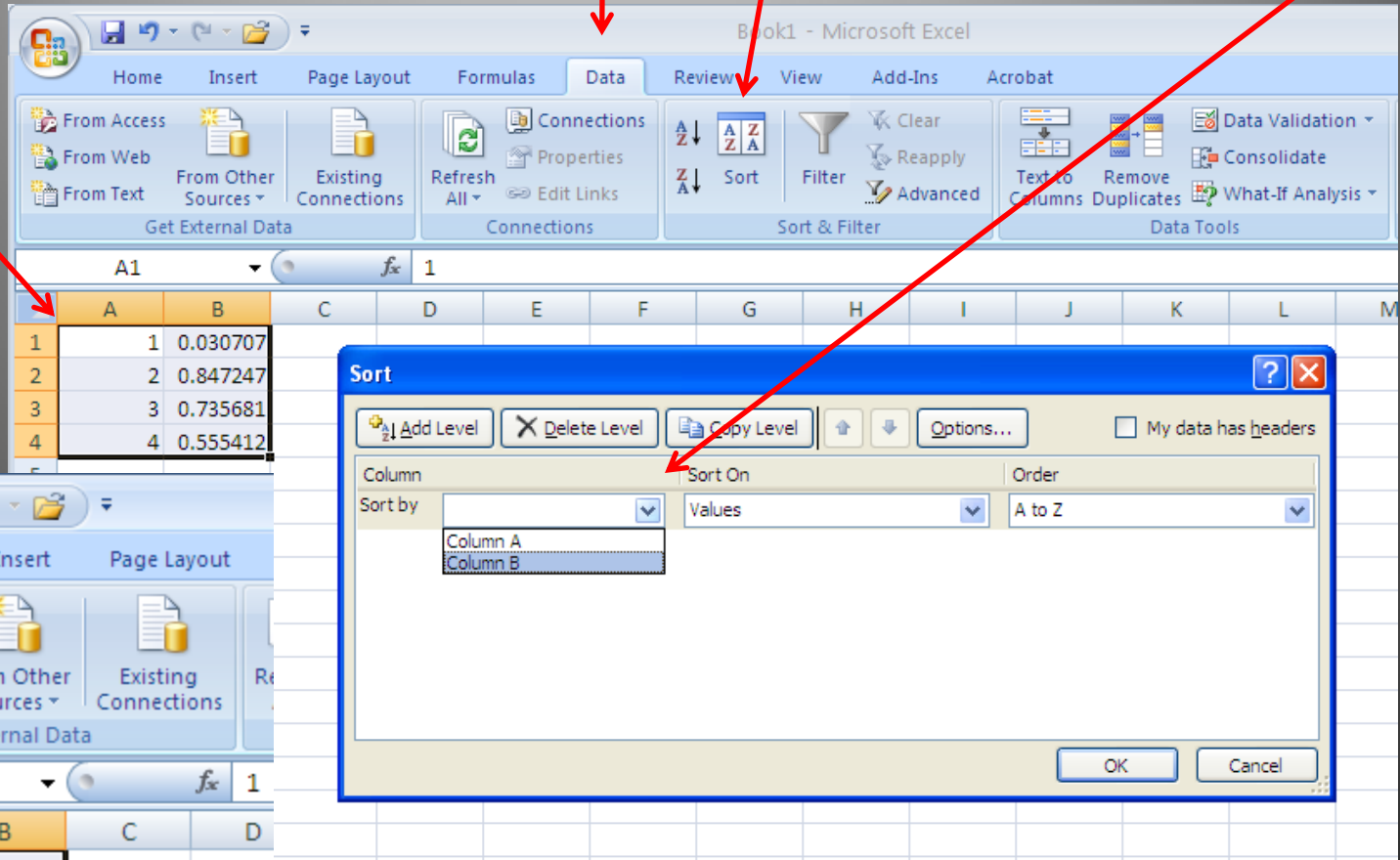
3. Copy and paste command
in remaining cells



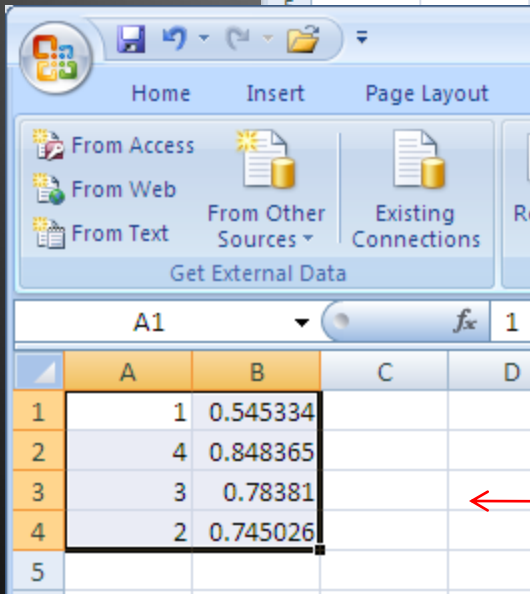
5. Select data then select sort

6. Then sort by column with random numbers

4. Select cells



Output in excel showing randomized blocks in first column. This is repeated for each block to randomize the treatments



```
proc factex;  
  factors block / nlev=4;  
  output out=blocks  
    block nvals=(1 2 3 4);  
run;  
  factors trt / nlev=6;  
  output out=rcbd  
    designrep=blocks  
    randomize (101)  
    trt cvals=('A' 'B' 'C'  
              'D' 'E' 'F');  
run;  
  
proc print data=rcbd;  
run;
```

**Randomization
for both blocks and
treatments can be
done using a SAS code**

Obs	block	trt
1	2	B
2	2	C
3	2	A
4	2	D
5	2	E
6	2	F
7	1	B
8	1	C
9	1	E
10	1	A
11	1	F
12	1	D
13	3	D
14	3	A
15	3	C
16	3	F
17	3	B
18	3	E
19	4	A
20	4	F
21	4	B
22	4	C
23	4	D
24	4	E



**SAS output
showing
randomized
blocks and
treatments**



Experimental design showing randomized blocks and treatments

Analysis using SAS

Have data in a format that can be directly imported into SAS or you can copy and paste your data into SAS

If importing data:

Have 1st line for variable names and data must start on line 2

Make sure you have variable names consistent with SAS, use only letters, numbers and _, and avoid spaces.

Excel for class [C]

Home Insert Page Layout Formulas Data Review

Clipboard Font Alignment

F13

	A	B	C	D	E	F	G
1	Blk	Trt	WC				
2		1	1	46.0			
3		1	2	47.7			
4		1	3	40.8			
5		1	4	71.3			
6		1	5	68.0			
7		1	6	62.7			
8		2	1	40.1			
9		2	2	50.9			
10		2	3	36.7			
11		2	4	72.0			
12		2	5	71.5			
13		2	6	67.1			
14		3	1	46.0			
15		3	2	49.3			
16		3	3	32.7			
17		3	4	68.5			
18		3	5	71.6			
19		3	6	66.0			
20		4	1	46.7			
21		4	2	49.4			
22		4	3	34.7			
23		4	4	71.5			
24		4	5	70.8			
25		4	6	64.0			

Ready

start SAS - [Log - (Untitled)] sas code

Model for RCBD

$$Y_{ij} = \mu + T_i + B_j + \text{random error}$$

- Y_{ij} - any observation for which
 - i is the treatment factor
 - j is the blocking factor
- μ - the mean
- T_i - the effect for being in treatment i
- B_j is the effect for being in block j

ANOVA table

Source	Degrees of Freedom	Sums of squares (SS)	Mean squares	F
Blocks	b-1	Block SS	BMS=BSS/b-1	BMS/ RMS
Treatment	t-1	Treatment SS	TMS=TSS/t-1	TMS/ RMS
Residual	(t-1)(b-1)	Residual SS	RMS=RSS/ (t-1)(b-1)	
Total	tb-1	SS Total		

t=number of treatments, b=number of blocks

GM = grand mean, BM = block mean and TM= treatment mean

$$BSS = \text{Sum } (BM-GM)^2$$

$$TSS = \text{Sum } (TM-GM)^2$$

$$RSS = \text{Sum } (V-BM-TM+GM)^2$$

SAS Editor

Data step: Creates a SAS system data file

Proc steps: Perform operations using the files created.

Always end with ‘;’

Programs for RCBD analysis
Proc GLM
Proc Mixed

The screenshot displays the SAS Editor window with the following content:

```
option ls=120;  
data water content;  
input block trt WC;  
datalines;  
1 1 46.0  
1 2 47.7  
1 3 40.8  
1 4 71.3  
1 5 68.0  
1 6 62.7  
2 1 40.1  
2 2 50.9  
2 3 36.7  
2 4 72.0  
2 5 71.5  
2 6 67.1  
3 1 46.0  
3 2 49.3  
3 3 32.7  
3 4 68.5  
3 5 71.6  
3 6 66.0  
4 1 46.7  
4 2 49.4  
4 3 34.7  
4 4 71.5  
4 5 70.8  
4 6 64.0  
;  
proc glm;  
class block trt;  
model WC=block trt;
```

The interface includes a menu bar (File, Edit, View, Tools, Run, Solutions, Window, Help), a toolbar, a Results pane on the left showing a tree view with 'Results' and 'GLM: The SAS System', and a taskbar at the bottom with the Start button and several open applications.

SAS Editor

The program steps are determined by the experimental design, how you collected your samples and how you want your data presented.

The screenshot displays the SAS Editor window with the following components:

- Menu Bar:** File, Edit, View, Tools, Run, Solutions, Window, Help.
- Toolbar:** Standard file and editing icons.
- Results Panel (Left):** Shows a tree view with 'Results' and 'GLM: The SAS System'.
- Main Editor (Right):** Contains the SAS program code and its output.

```
2 3 36.7
2 4 72.0
2 5 71.5
2 6 67.1
3 1 46.0
3 2 49.3
3 3 32.7
3 4 68.5
3 5 71.6
3 6 66.0
4 1 46.7
4 2 49.4
4 3 34.7
4 4 71.5
4 5 70.8
4 6 64.0
;
proc glm;
class block trt;
model WC=block trt;
means trt/lsd;
run;
quit;
```
- Taskbar (Bottom):** Shows the Windows Start button, taskbar with icons for Results, Explorer, Output - (Untitled), Log - (Untitled), and Editor - Untitled1 *.
- System Tray (Bottom Right):** Shows the current directory 'C:\Documents and Settings\ji.16' and active applications like SAS, SAS Code for So..., TRAVELDRIVE (F:), and Micro.

SAS code for Analysis of RCBD

Sample SAS GLM statements:

```
PROC GLM;
```

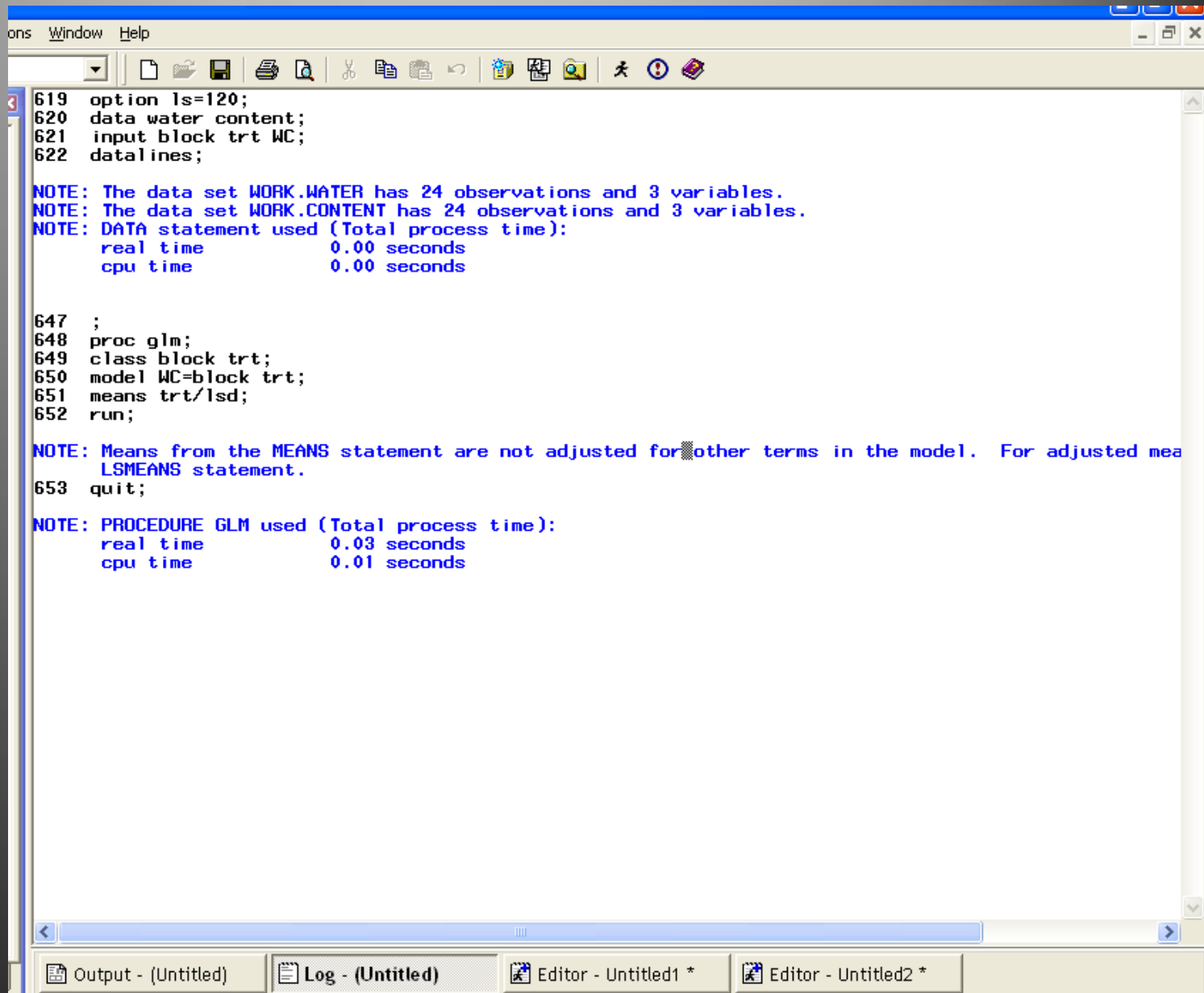
```
    CLASS BLOCKS TREATS;
```

```
    MODEL WC = BLOCKS TREATS;
```

```
RUN;
```

SAS Log

Check for errors in your program. These are usually highlighted in red.



The screenshot shows a SAS Log window with the following content:

```
619 option ls=120;
620 data water content;
621 input block trt WC;
622 datalines;

NOTE: The data set WORK.WATER has 24 observations and 3 variables.
NOTE: The data set WORK.CONTENT has 24 observations and 3 variables.
NOTE: DATA statement used (Total process time):
      real time           0.00 seconds
      cpu time            0.00 seconds

647 ;
648 proc glm;
649 class block trt;
650 model WC=block trt;
651 means trt/lsd;
652 run;

NOTE: Means from the MEANS statement are not adjusted for other terms in the model. For adjusted means use the LSMEANS statement.
653 quit;

NOTE: PROCEDURE GLM used (Total process time):
      real time           0.03 seconds
      cpu time            0.01 seconds
```

The window title is "ons Window Help". The taskbar at the bottom shows four open windows: "Output - (Untitled)", "Log - (Untitled)", "Editor - Untitled1 *", and "Editor - Untitled2 *".

SAS Output

Check your Class Level information

e.g. Check for correct number of blocks and treatments

The screenshot shows the SAS software interface. The main window displays the output of the GLM procedure. The output text is as follows:

```
The GLM Procedure
Class Level Information

Class          Levels    Values
block          4        1 2 3 4
trt            6        1 2 3 4 5 6

Number of Observations Read      24
Number of Observations Used      24
```

The window title is "Window Help". The taskbar at the bottom shows four open windows: "Output - (Untitled)", "Log - (Untitled)", "Editor - Untitled1 *", and "Editor - Untitled2 *".

SAS Output

Provides degrees of freedom, sums of squares, F values and probabilities

Variable: WC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	4292.213333	536.526667	84.08	<.0001
Error	15	95.720000	6.381333		
Corrected Total	23	4387.933333			

	R-Square	Coeff Var	Root MSE	WC Mean
	0.978186	4.504244	2.526130	56.08333

Source	DF	Type I SS	Mean Square	F Value	Pr > F
block	3	1.560000	0.520000	0.08	0.9691
trt	5	4290.653333	858.130667	134.48	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
block	3	1.560000	0.520000	0.08	0.9691
trt	5	4290.653333	858.130667	134.48	<.0001

Taskbar: SAS - [Output - ...], SAS Code for So..., TRAVELDRIVE (F:), Microsoft Excel -..., Microsoft Power..., 9:36 AM

SAS Output

If the probabilities indicate significant differences, a comparison between means can be done using the Least Significant Difference (LSD)

Written in your SAS code as:
means trt/lsd

Table: WC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	4292.213333	536.526667	84.08	<.0001
Error	15	95.720000	6.381333		
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trt	5	4290.653333	858.130667	134.48	<.0001

The screenshot shows the SAS software interface with the following details:

- Windows title bar: "SAS - [Output - ...]"
- Menu bar: "File Edit View Options Help"
- Toolbar: Standard file operations (New, Open, Save, Print, Copy, Paste, Undo, Redo, Find, Help, etc.)
- Output window: Displays the ANOVA and LSD results for variable 'WC'.
- Taskbar: Shows other open applications like "SAS Code for So...", "TRAVELDRIVE (F:)", "Microsoft Excel -...", and "Microsoft Power...".
- System tray: Shows the time as "9:36 AM".

SAS Output

Treatments with different letters have significant differences between them



indow Help

The GLM Procedure

t Tests (LSD) for WC

This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	15
Error Mean Square	6.381333
Critical Value of t	2.13145
Least Significant Difference	3.8073

Means with the same letter are not significantly different.

t Grouping	Mean	N	trt
A	70.825	4	4
A	70.475	4	5
B	64.950	4	6
C	49.325	4	2
D	44.700	4	1
E	36.225	4	3

Output - (Untitled) Log - (Untitled) Editor - Untitled1 * Editor - Untitled2 *

SAS - [Output - ...] SAS Code for So... TRAVELDRIVE (F:) Microsoft Excel -... Microsoft Power...

External Link

SAS [Online]. SAS Institute. Available at: www.sas.com/ (verified 5 Jan 2011).

Additional Resource

Clewer, A. G., and D. H. Scarisbrick. 2001. Practical statistics and experimental design for plant and crop science. John Wiley & Sons Ltd., New York.