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

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

Image credit: Francis Lab, The Ohio State University

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

Excel randomization

To generate random numbers

Use =RAND () ctrl enter

Randomize blocks

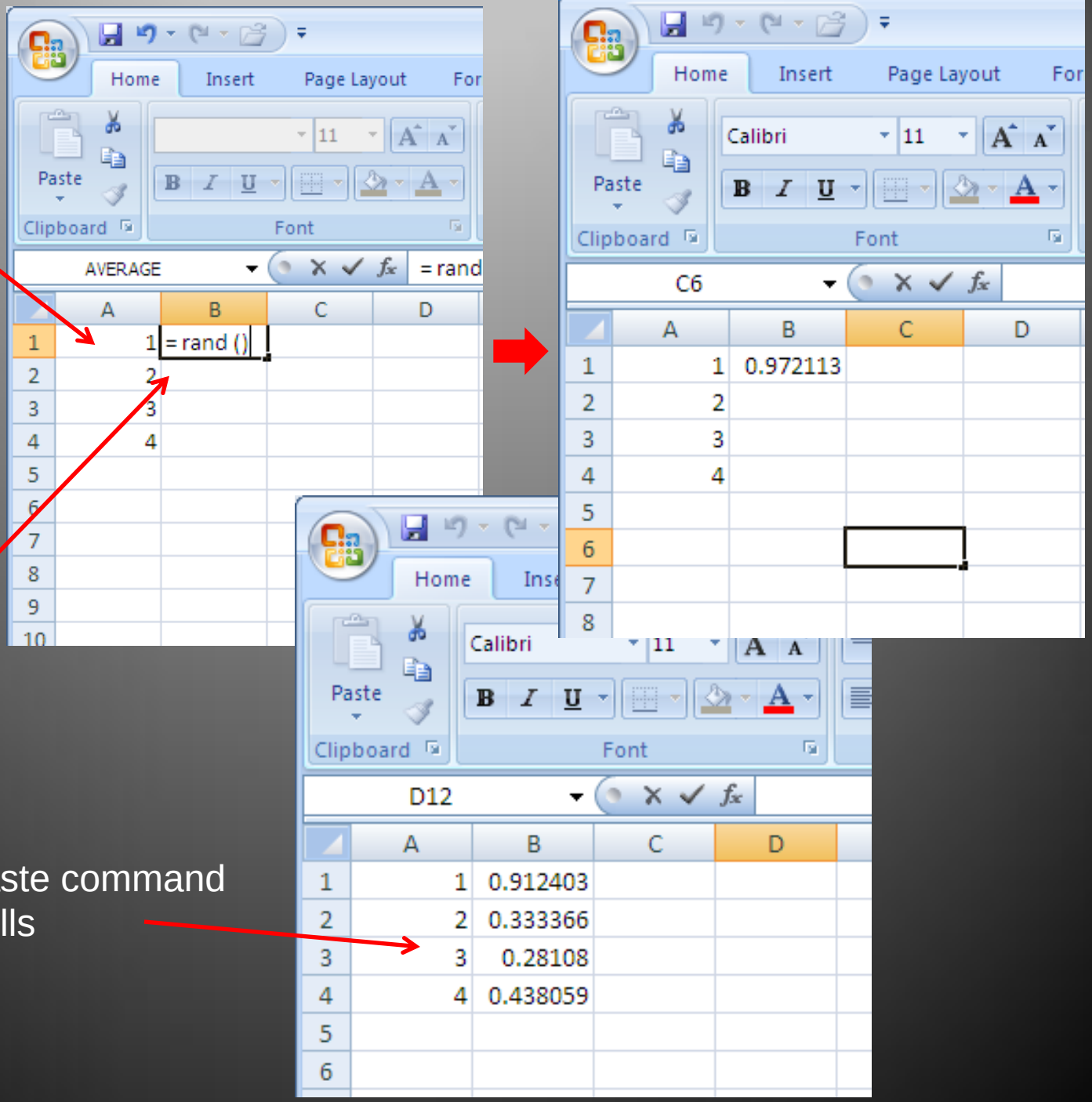
[DATA, SORT by column w/ =rand()]

- Randomize treatments in each block independently

1. Column A – list of blocks

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

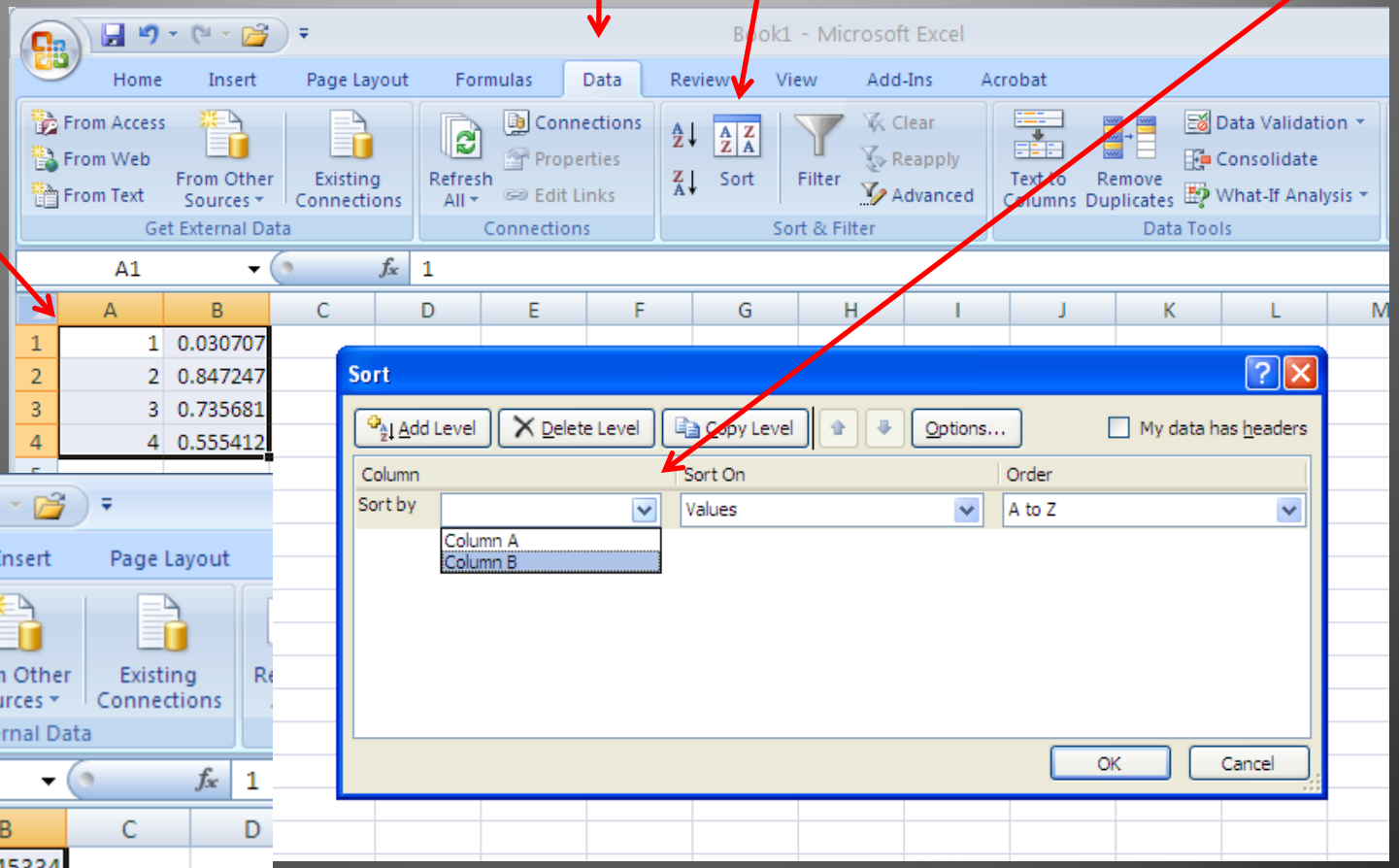
3. Copy and paste command in remaining cells

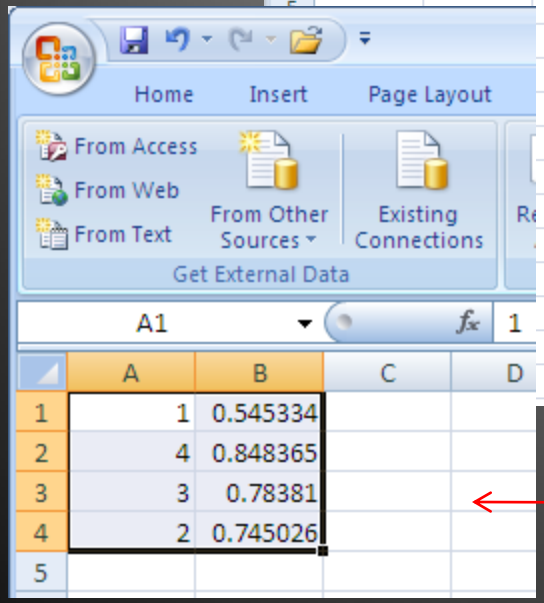


5. Select data then select sort

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

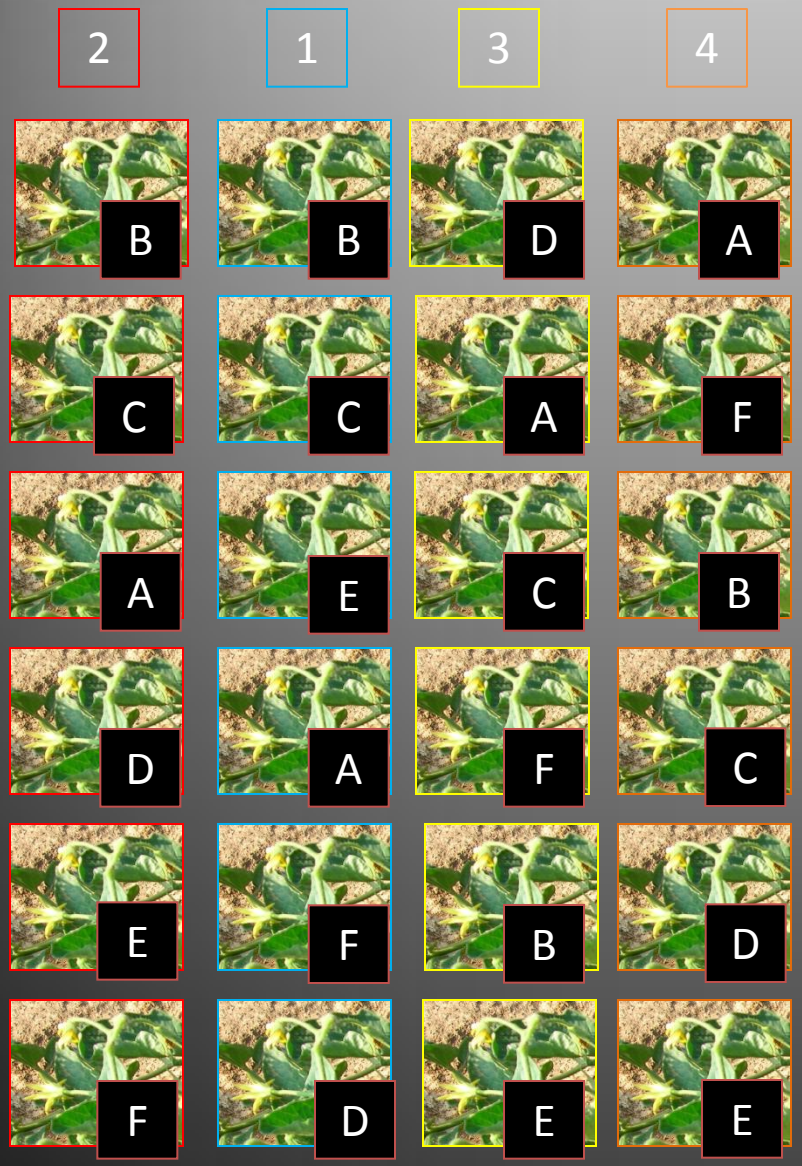
```
proc factex;
    factors block / nlev=4;
    output out=blocks
        block nvals=(1 2 3 4);
  run;
    factors trt / nlev=6;
    output out=rcbd
        designrep=blocks
        randomize (101)
        trt cvals=('A' 'B' 'C'
                'D' 'E' 'F');
  run;

  proc print data=rcbd;
  run;
```

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

The SAS System 14:30 Monday, August 4, 2008 3

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

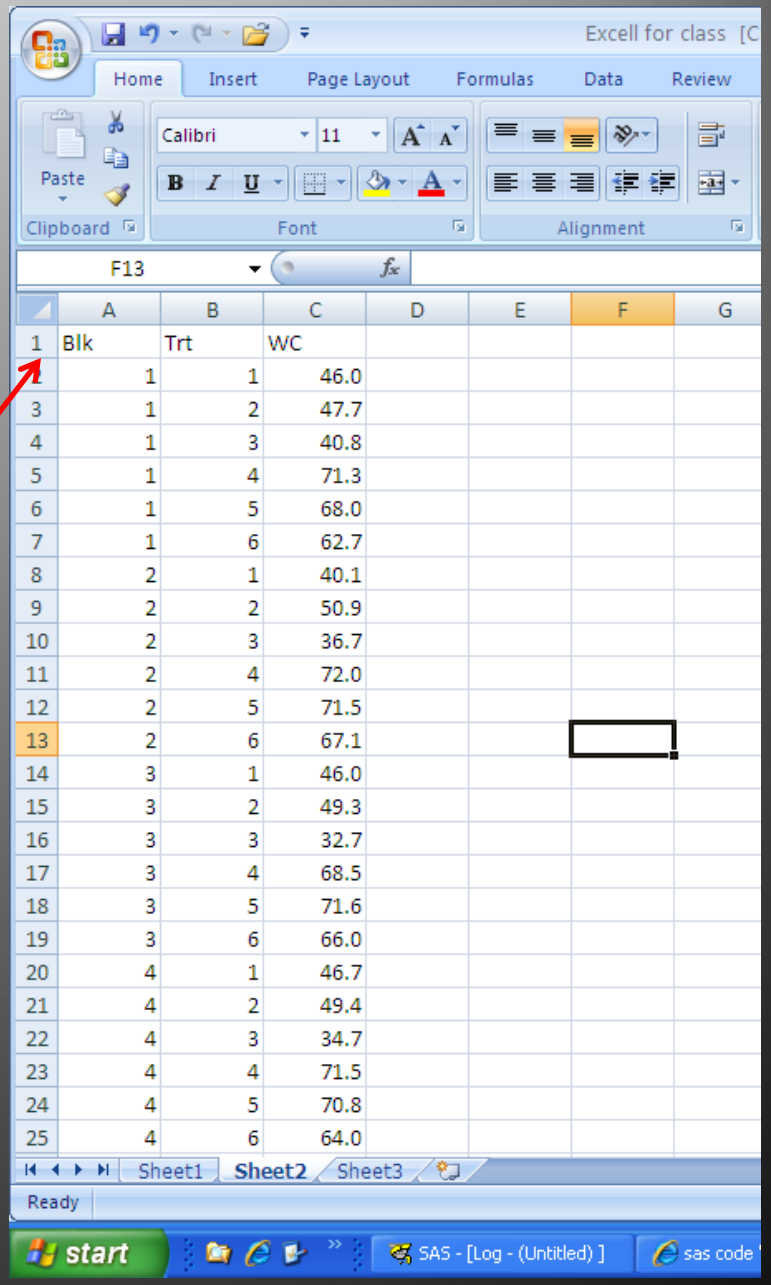
Image credit: Francis Lab, The Ohio State University

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.



	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				

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 = Sum $(BM-GM)^2$ TSS = Sum $(TM-GM)^2$ RSS = Sum $(V-BM-TM+GM)^2$

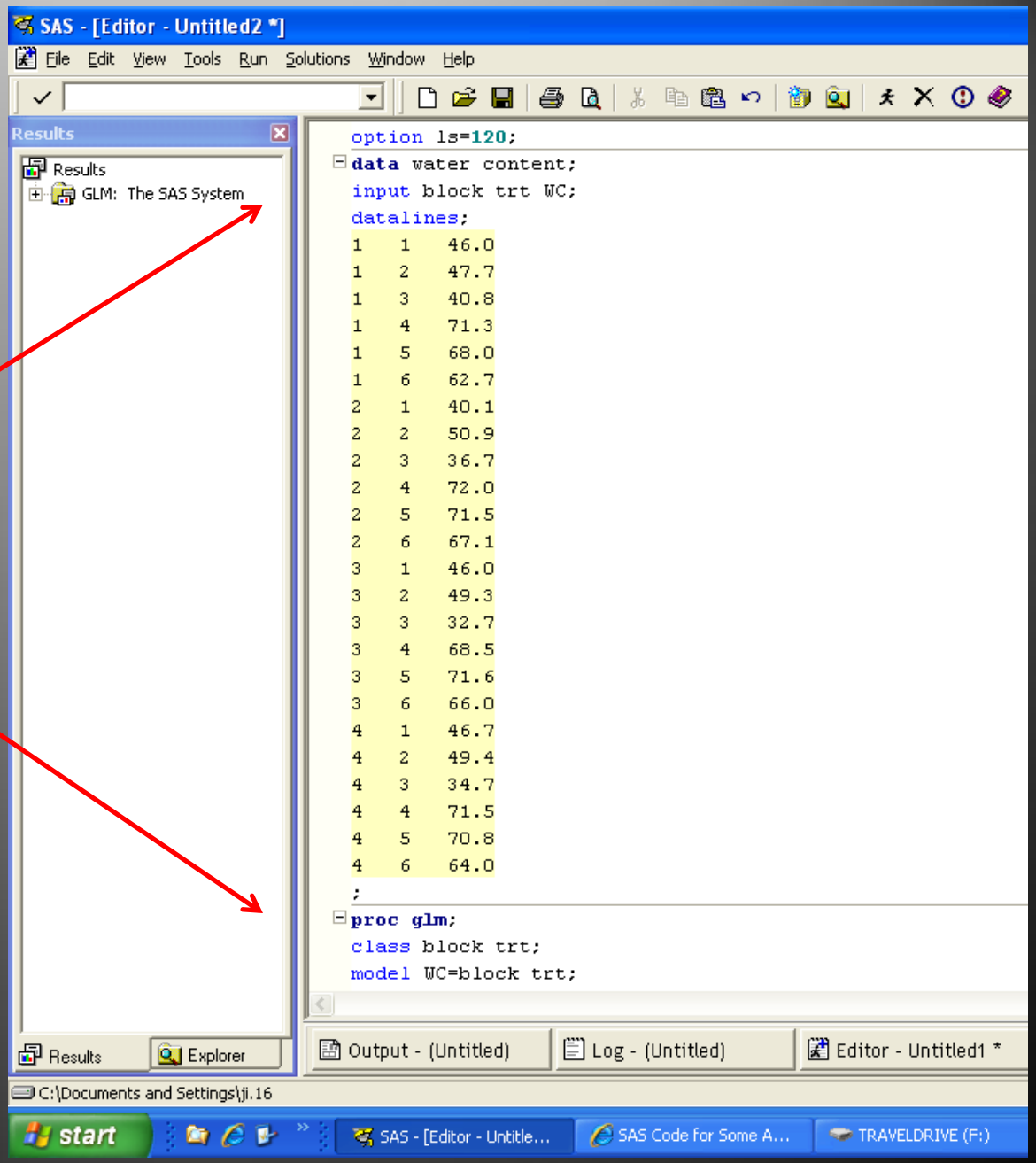
SAS Editor

Data step: Creates a SAS system data file

Proc steps: Perform operations using the files created.

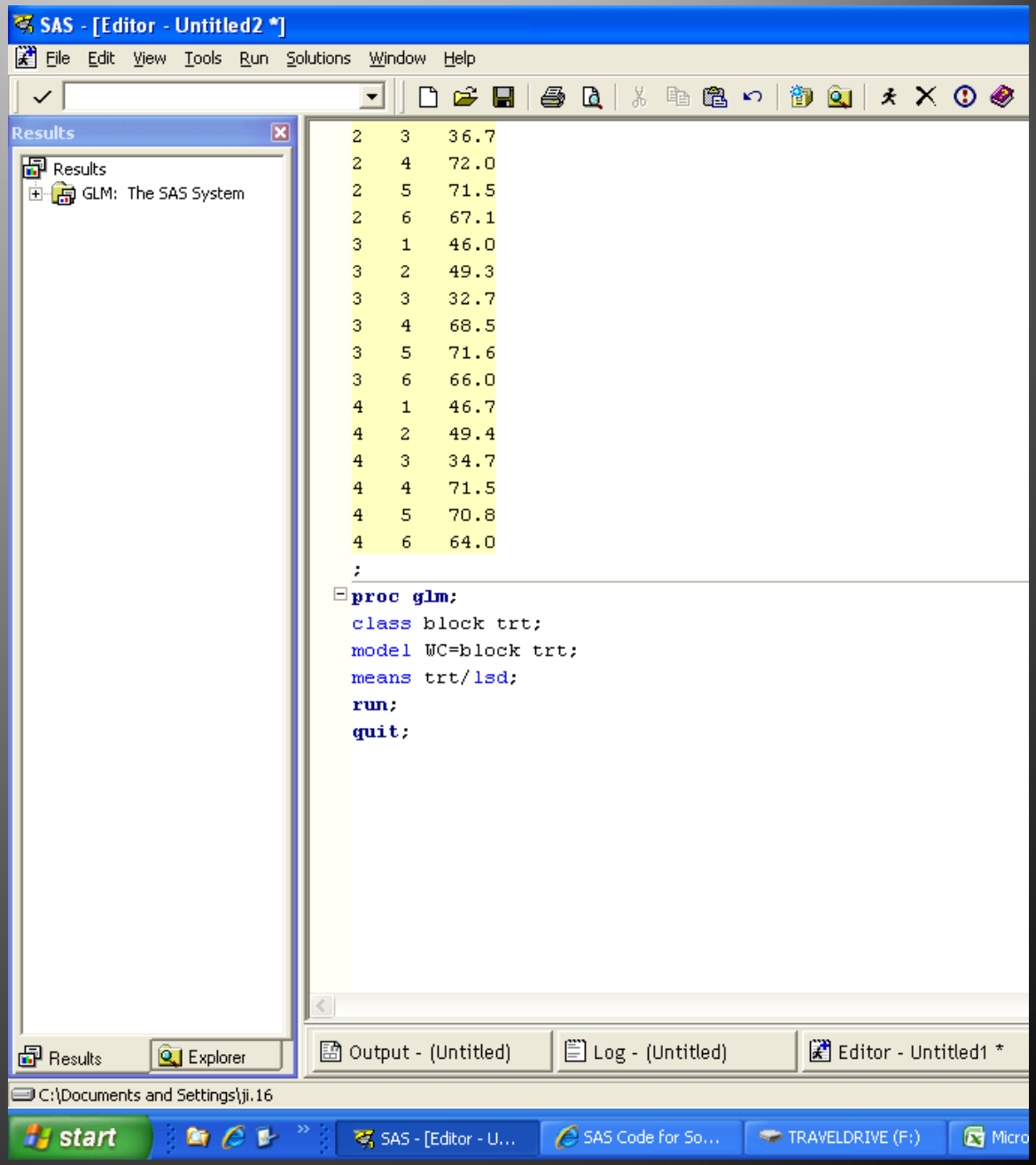
Always end with ';'

Programs for RCBD analysis
Proc GLM
Proc Mixed



SAS Editor

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



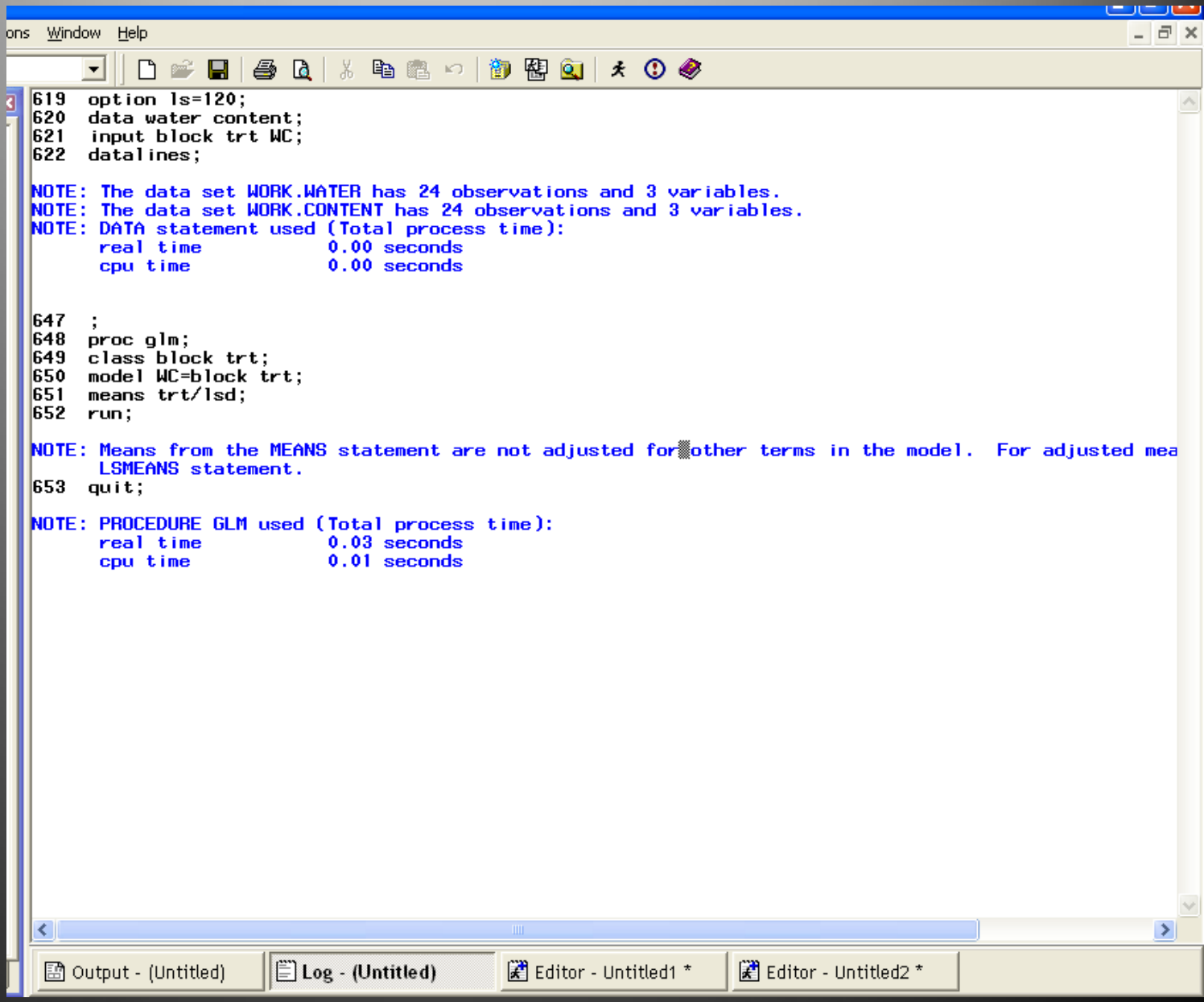
SAS code for Analysis of RCBD

Sample SAS GLM statements:

```
PROC GLM;
    CLASS BLOCKS TREATS;
    MODEL WC = BLOCKS TREATS;
RUN;
```

SAS Log

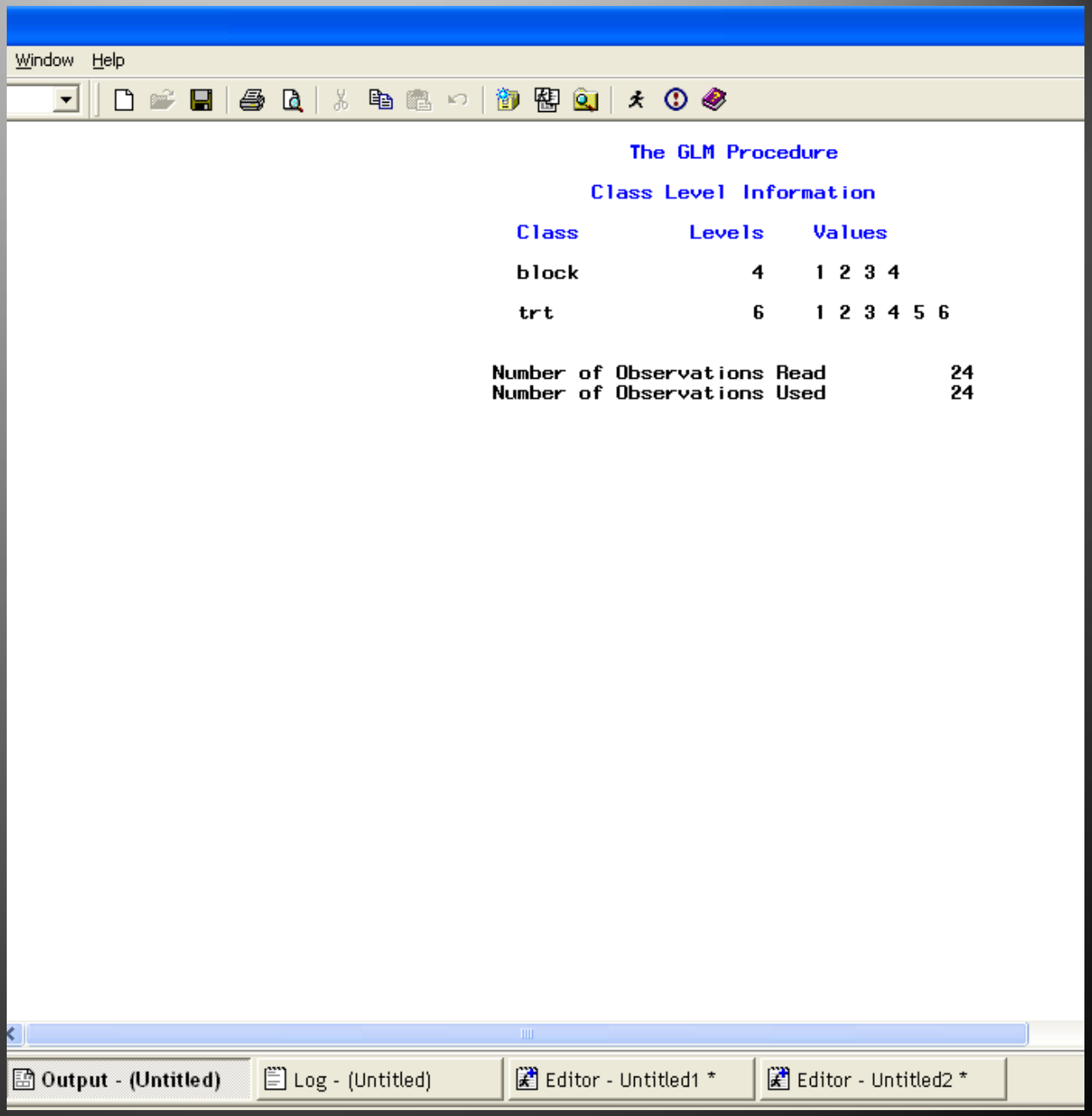
Check for errors in your program. These are usually highlighted in red.



SAS Output

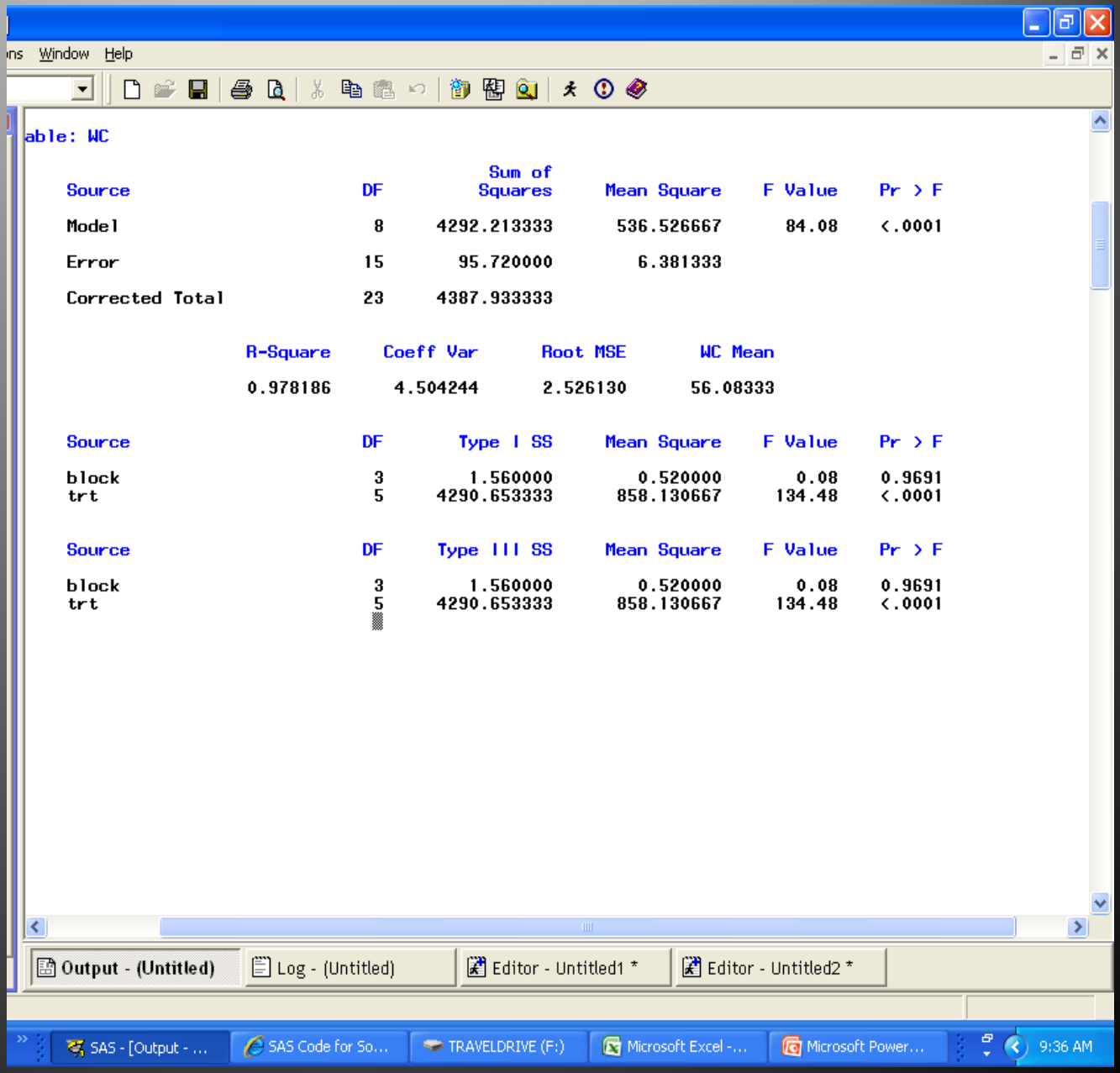
Check your Class Level information

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



SAS Output

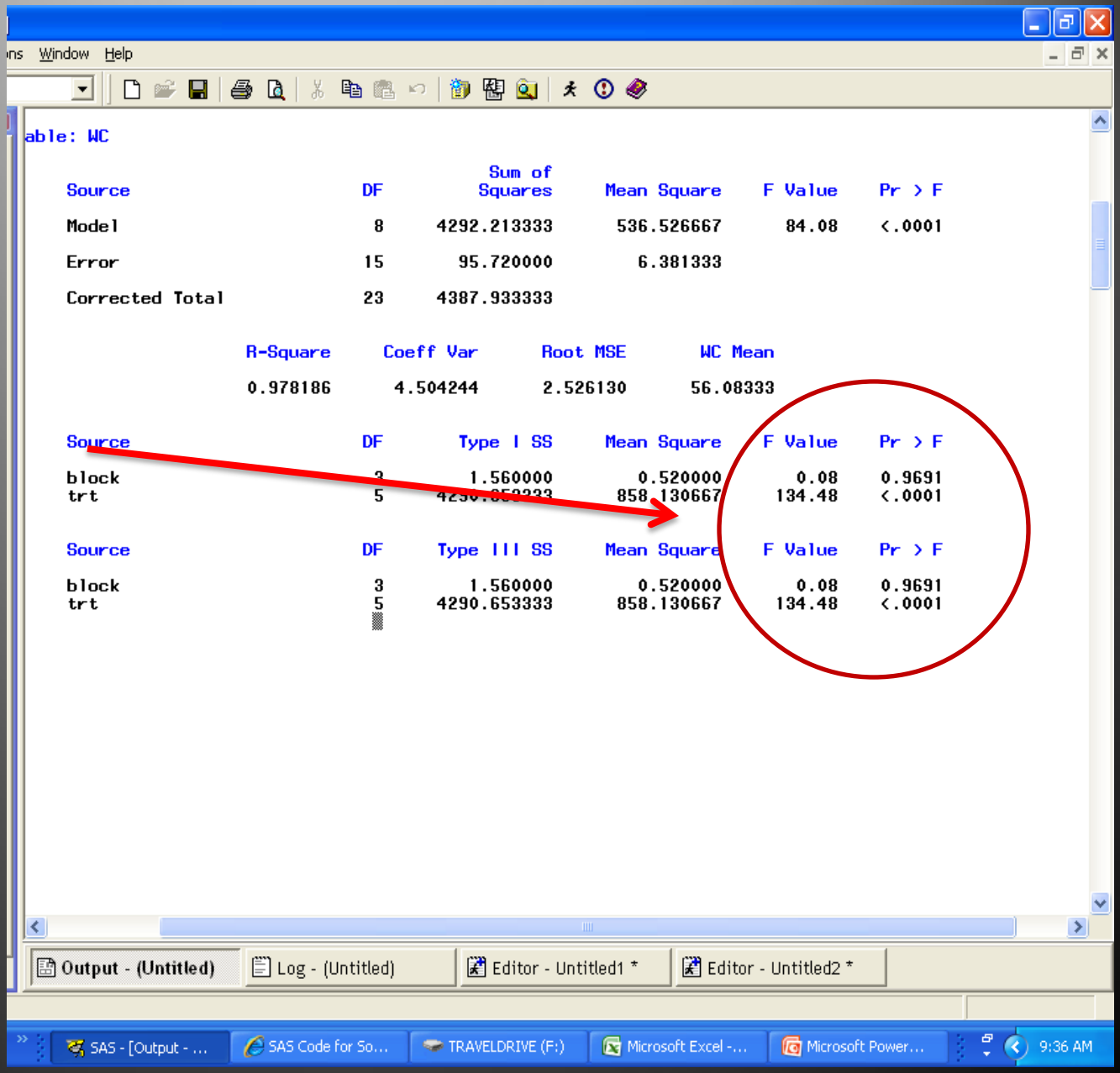
Provides degrees of freedom, sums of squares, F values and probabilities



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



able: 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

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

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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			
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.