Randomized Complete Block Designs

Researchers were interested in comparing the effects of four diets (A, B, C, and D) on the average daily gain of calves. On each of 6 farms, 4 pens, each containing 5 calves, were set aside for use in an experiment. Each farm engaged in slightly different management practices. Furthermore farms were spread out over a wide geographic area so that weather conditions and other variables that could affect average daily gain varied from farm to farm. Due to logistical constraints all 5 calves in any pen must be fed the same diet.

1. Describe how you would assign diets to pens.

2. What are the experimental units in this experiment?

3. The researchers used a **randomized complete block design** (RCBD) in this experiment. They randomly assigned the four diets to the 4 pens on each farm so that each diet was used exactly once on each farm. The word *complete* in *randomized complete block design* refers to the fact that all treatments appear in each block. A *block* is just a group of experimental units. Blocks are chosen in such a way that experimental units within a block are more similar to each other than experimental units in different blocks. Describe the blocks in this experiment.

4. The back of this handout contains data, SAS code, and SAS output for the analysis of this experiment. Why is the first *glm* statement inappropriate for the analysis of this data?

5. There is a big difference between the results of the two analyses. What features of the data cause the results to differ?

6. Earlier this semester, we considered data on 8 pairs of trees in an orchard. The pairs of trees had suffered varying amounts of damage due to insect attack. One of the trees in each pair was randomly selected to receive chemical treatment A while the other received chemical treatment B. Three weeks after the initial application of the chemicals, damage was recorded for each tree with higher numbers indicating greater damage. Can you use the data on the damage sustained by each tree to fill in the missing entries in the ANOVA table?

Tree Pair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Chemical A	9	7	6	5	4	5	6	1
Chemical B	8	7	4	4	3	4	3	2

Source	DF	SS	MS	F	P-VALUE
Tree Pair	_____	_____	_____	_____	_____
Chemical	_____	_____	_____	_____	_____
Error	_____	5.00	_____		
C. Total	_____	71.75			

```
/* adg is the mean average daily gain of all calves in a pen.                    */
/* Average daily gain is (final weight minus initial weight)/number of days on study. */

data one;
  input farm pen diet $ adg;
  cards;
1  1 C 2.19
1  2 D 2.44
1  3 B 3.02
1  4 A 2.66
2  5 D 2.36
2  6 C 2.60
2  7 A 2.85
2  8 B 3.37
3  9 B 2.01
3 10 C 1.30
3 11 D 1.57
3 12 A 1.88
4 13 A 2.63
4 14 B 2.99
4 15 D 2.45
4 16 C 2.17
5 17 D 2.43
5 18 C 2.18
5 19 B 2.82
5 20 A 2.55
6 21 A 1.73
6 22 D 1.49
6 23 B 1.96
6 24 C 1.33
;

proc glm;
  class diet;
  model adg=diet;
  lsmeans diet / pdiff adjust=tukey;
run;
```

The GLM Procedure

Class Level Information

Class	Levels	Values
diet	4	A B C D

Number of observations 24

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	1.84988333	0.61662778	2.38	0.1003
Error	20	5.18830000	0.25941500		
Corrected Total	23	7.03818333			

R-Square	Coeff Var	Root MSE	adg Mean
0.262835	22.23331	0.509328	2.290833

Source	DF	Type I SS	Mean Square	F Value	Pr > F
diet	3	1.84988333	0.61662778	2.38	0.1003

Source	DF	Type III SS	Mean Square	F Value	Pr > F
diet	3	1.84988333	0.61662778	2.38	0.1003

Least Squares Means
Adjustment for Multiple Comparisons: Tukey

diet	adg LSMEAN	LSMEAN Number
A	2.38333333	1
B	2.69500000	2
C	1.96166667	3
D	2.12333333	4

Least Squares Means for effect diet
Pr > |t| for H0: LSMean(i)=LSMean(j)

i/j	1	2	3	4
1		0.7170	0.4939	0.8130
2	0.7170		0.0916	0.2421
3	0.4939	0.0916		0.9455
4	0.8130	0.2421	0.9455	

```
proc glm;
  class farm diet;
  model adg=farm diet;
  lsmeans diet / pdiff adjust=tukey;
run;
```

The GLM Procedure
Class Level Information

Class	Levels	Values
farm	6	1 2 3 4 5 6
diet	4	A B C D

Number of observations 24

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	6.85591667	0.85698958	70.53	<.0001
Error	15	0.18226667	0.01215111		
Corrected Total	23	7.03818333			

R-Square	Coeff Var	Root MSE	adg Mean
0.974103	4.811877	0.110232	2.290833

Source	DF	Type I SS	Mean Square	F Value	Pr > F
farm	5	5.00603333	1.00120667	82.40	<.0001
diet	3	1.84988333	0.61662778	50.75	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
farm	5	5.00603333	1.00120667	82.40	<.0001
diet	3	1.84988333	0.61662778	50.75	<.0001

Least Squares Means
Adjustment for Multiple Comparisons: Tukey

diet	adg LSMEAN	LSMEAN Number
A	2.38333333	1
B	2.69500000	2
C	1.96166667	3
D	2.12333333	4

Least Squares Means for effect diet
Pr > |t| for H0: LSMean(i)=LSMean(j)

i/j	1	2	3	4
1		0.0010	<.0001	0.0048
2	0.0010		<.0001	<.0001
3	<.0001	<.0001		0.0936
4	0.0048	<.0001	0.0936	