STAT 6167 FINAL EXAM – December 13, 2010

Problem 1. (70 points) In an experiment to investigate the effect of four fertilizers (A, B, C, D) on the phosphorous content of the leaves of three varieties of apple trees (v1, v2, v3) it was necessary to apply the fertilizer across blocks of three plots because of the width of the applicator. The data are presented in the table below.

Block 1	B v1 17.0	C v3 23.8	D v3 15.9	A v2 17.2
	B v3 17.3	C v2 19.2	D v1 16.7	A v3 19.4
	B v2 14.8	C v1 19.1	D v2 14.5	A v1 19.0
Block 2	D v2 16.3	C v3 18.0	A v3 17.4	B v3 19.3
	D v1 17.6	C v2 14.7	A v2 14.7	B v2 17.4
	D v3 17.8	C v1 16.1	A v1 19.5	B v1 15.8
Block 3	B v1 19.0	D v2 17.0	A v1 21.4	C v1 21.8
	B v3 19.9	D v3 19.6	A v2 20.0	C v2 18.8
	B v2 19.5	D v1 16.2	A v3 22.3	C v3 22.4

1. (10 points) Specify the design and treatment structure of this experiment. What is the number of replications for each of the main treatment factors and their interaction?

2. (15 points) Write the linear model corresponding to this model, defining each of its components.   Also, construct a dummy ANOVA table identifying each model term and its corresponding degrees of freedom.

For the following, assume the assumptions for ANOVA are met. Any reference to "adjusted" or "unadjusted" here are referring to multiple comparisons adjustments.

3. (12 points total) **Fertilizer**:
a. (2 points) State and test the null hypothesis for Fertilizer.

b. (1 points) Report a standard error for the mean (SEM) of each Fertilizer treatment.

c. (1 points) Report the (unadjusted) standard error for the difference (SED) between all pairs of Fertilizer means.

d. (2 points) Report the corresponding LSD for Fertilizer at a 5% level.

e. (2 points) What does this Least Significant Difference tell you?

f. (2 points) Which Fertilizer treatment means are significantly different at the unadjusted 5% level?

g. (2 points) Look at the Tukey-adjusted p-values. Which Fertilizer treatment means are significantly different at the *adjusted* 5% level?

4. (11 points total) **Variety**:
a. (2 points) State and test the null hypothesis for Variety.

b. (1 points) Report a standard error for the mean (SEM) of each Variety treatment.

c. (1 points) Report the (unadjusted) standard error for the difference (SED) between all pairs of Variety means.

d. (2 points) Report the corresponding LSD for Variety at a 5% level.

e. (1 points) What does this Least Significant Difference tell you?

f. (2 points) Which Variety treatment means are significantly different at the unadjusted 5% level?

g. (2 points) Look at the Tukey-adjusted p-values. Which Variety treatment means are significantly different at the *adjusted* 5% level?

5. (12 points total) **Interaction**:
a. (2 points) State and test the null hypothesis for the interaction between Fertilizer and Variety.

b. (2 points) Report a standard error for the mean (SEM) of each treatment combination.

c. (1 points) Report the (unadjusted) standard error for the difference (SED) between all pairs of treatment combination means.

d. (2 points) Report the corresponding LSD for each treatment combination at a 5% level.

e. (1 points) What does this Least Significant Difference tell you?

f. (2 points) Which treatment combination means are significantly different at the unadjusted 5% level?

g. (2 points) Look at the Tukey-adjusted p-values. Which treatment combination means are significantly different at the *adjusted* 5% level?

Problem 2. An experiment is being planned to investigate the effect of inoculating soil (yes or no) with the bacteria Spirillum lipoferum on the growth rate of pearl millet, and whether this effects depends on the amount of nitrogen applied. Three rates of nitrogen have been selected (0, 20 and 40 kg/ha). The nitrogen fertilization effect on growth rate is well documented, hence is of secondary interest to the experimenter. This experiment will be carried out in a greenhouse containing a large number of benches, each accommodating a maximum of six pots each. However, she only has a total of 36 pots, and is planning on using all available material (i.e. pots). The experimenter asks for your advice on how to design this experiment.

a) (20 points) The experimenter tells you that it is possible to apply a different combination of inoculation and nitrogen rate to each individual plot. However, she is concerned about the presence of bench to bench variation. Suggest an experiment for this scenario indicating the design and treatment structure, together with the linear model and a dummy ANOVA table. In addition, produce a "randomization."

b) (20 points) You later learn that difficulties in the application of nitrogen indicate that it is only possible to apply a given rate to a complete bench of six pots. But no restrictions exist for the inoculation application. Therefore, she suggests using six benches each with three replicates of the two inoculation levels. Indicate the design and treatment structure for this experiment, together with the linear model and a dummy ANOVA table. In addition, produce a randomization.

Extra credit (10 points):
c) Which of the two designs, part (a) or (b), do you think is better? (Hint: compare degrees of freedom to evaluate all hypothesis of interest, and compare LSDs by assuming fixed and known error variances).