School of Mathematics and Statistics
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STAT 292 Assignment 3 Due by 12pm (midday), Wed 27 May 2020

There are five questions, worth a total of 100 marks. Question 1 starts on page 2.

Assignment Guidelines (one more time)

You are encouraged to discuss assignments with other students, but your submitted work must be your own.

The following Assignment Guidelines are helpful for all the assignments in Parts 2 and 3 of the course.

When you carry out a statistical test of hypothesis, you should state the following, **when relevant**:

- Model equation.
- Assumptions about the data, and comments about whether diagnostic graphs support those assumptions.
- Null and alternative hypotheses.
- ANOVA Table (if relevant), p-value.
- Statistical conclusions. For example, "We reject H_0 and conclude H_A, that μ_1 and μ_2 differ at the 5% significance level".
- Interpretation of the statistical conclusions back to the original problem, using the original meaning of the response variable and any factors or covariates. For example, if comparing heights of two groups, "Female and male adults have different mean heights, with males being taller on average".

1. **Skink Temperatures**

Skinks are tested for their preferred daytime temperature. Each one is placed in a long tank which is warmer at one end, cooler at the other. The temperature at the position where it settles is recorded. There are four different species of skink, and we wish to test (at the 5% level of significance) whether the species differ in their preferred temperature.

The following table gives the data.

Species	Preferred temperatures (^{o}C)										Total	Mean
A	18	21	22	18	20	19	19	23	17	22	199	19.9
B	24	18	19	21	20	17	23	22	22	19	205	20.5
C	22	21	24	19	25	18	23	21	24	22	219	21.9
D	21	19	26	24	25	21	20	20	27	25	228	22.8

SAS output is given on pages 3 and 4.

(a) When running the experiment, other possible factors such as time of day, light, amount of food recently eaten, are kept as near constant as possible. Why?

(b) The skinks are not put in the tank together. Why?

(c) Give values of n and p (the number of treatments) for this experiment. How many degrees of freedom are in the `Treatments` row, the `Error` row and the `Total` row of the ANOVA table? (Give the algebraic expressions and the actual values for this experiment.)

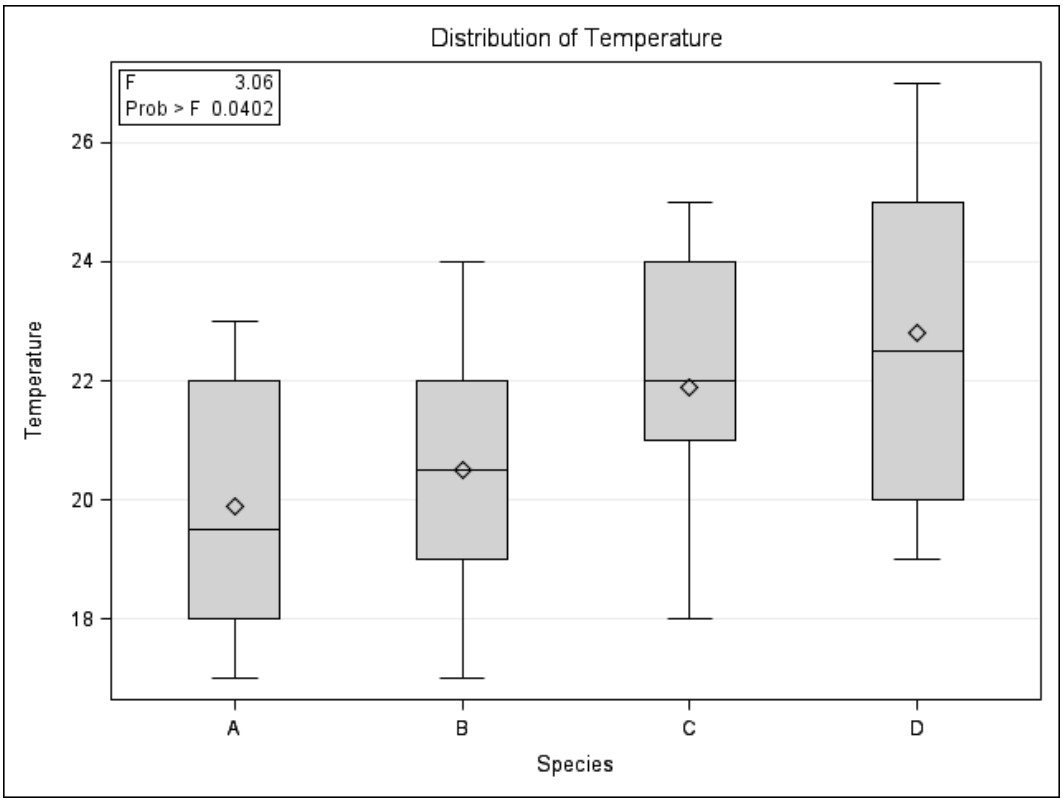
(d) Use the output to write up the ANOVA in the style suggested in the Assignment Guidelines on page 1. You should include a statement of the (complete) model equation, and also comments on whether the assumptions are satisfied. Use a 5% significance level for the ANOVA test.

One-Way Analysis of Variance

Dependent Variable: Temperature

Source	*DF*	*Sum of Squares*	*Mean Square*	*F Value*	*Pr > F*
Model	3	52.0750000	17.3583333	3.06	0.0402
Error	36	203.9000000	5.6638889		
Corrected Total	39	255.9750000			

R-Square	*Coeff Var*	*Root MSE*	*Temperature Mean*
0.203438	11.18633	2.379893	21.27500



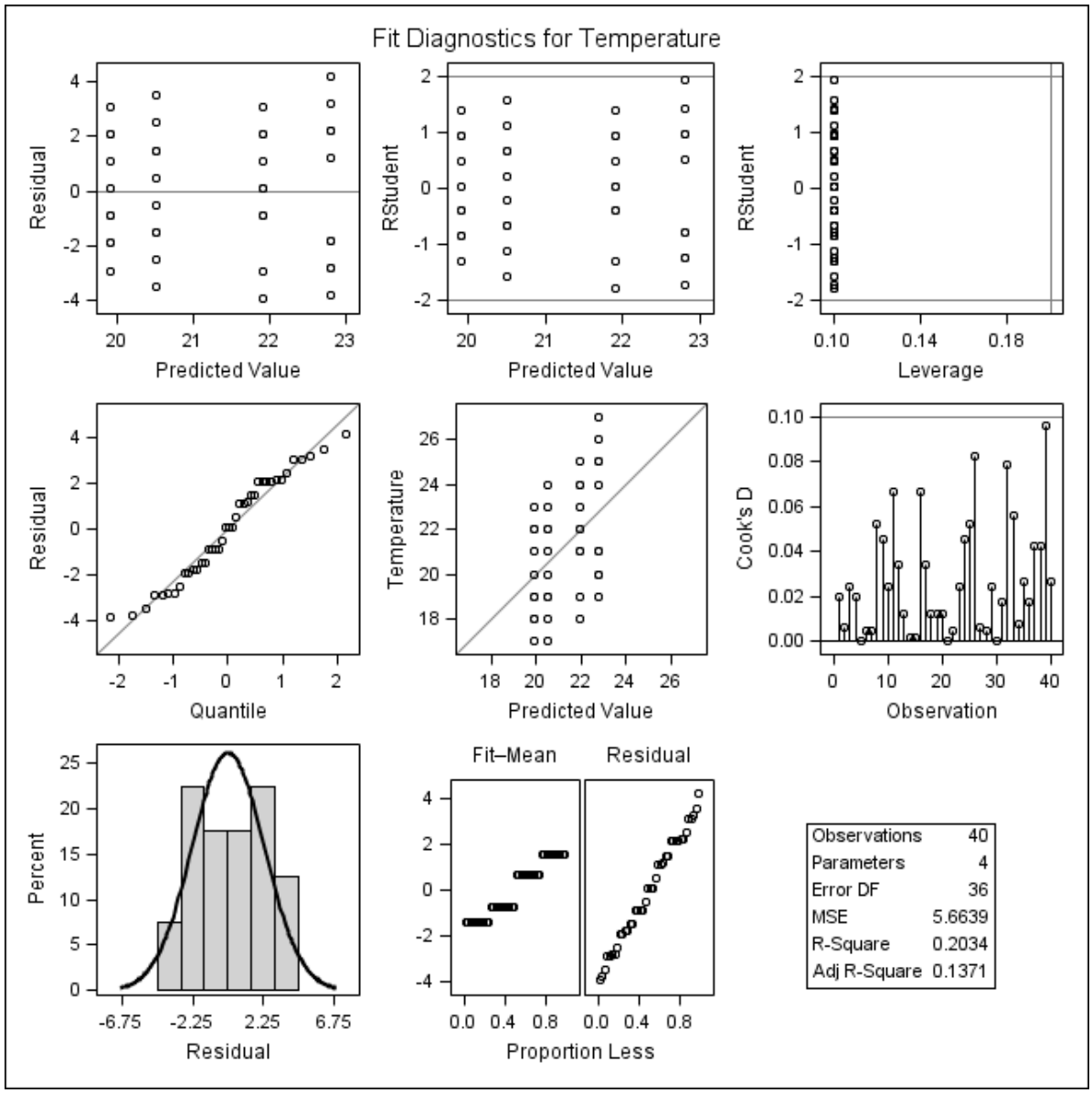
One-Way Analysis of Variance

Levene's Test for Homogeneity of Temperature Variance
ANOVA of Squared Deviations from Group Means

Source	*DF*	*Sum of Squares*	*Mean Square*	*F Value*	*Pr > F*
Species	3	86.1428	28.7143	1.36	0.2691
Error	36	757.4	21.0391		

Means and Descriptive Statistics

Species	*Mean of Temperature*	*Std. Dev. of Temperature*	*Minimum of Temperature*	*Maximum of Temperature*
	21.275	2.5619253577	17	27
A	19.9	2.0248456731	17	23
B	20.5	2.2730302828	17	24
C	21.9	2.2335820757	18	25
D	22.8	2.8982753492	19	27



2. **Nasal Sprays**

   Improvement in breathing airflow is measured for twenty-five people suffering from nasal congestion. They were treated with either a saline spray (A) or one of four nasal sprays (B, C, D, E) available over the counter in pharmacies.

Spray	Airflow improvement					Total	Mean
A	15	10	16	14	8	63	12.6
B	25	41	37	44	26	173	34.6
C	21	6	9	15	14	65	13.0
D	16	7	24	22	15	84	16.8
E	24	15	39	34	30	142	28.4
						527	21.08

Relevant SAS output follows, on pages 5 to 7.

Write a report that compares the five treatments using the guidelines on page 1. Ensure that you comment on all the included SAS output. Use a 5% significance level for all statistical tests. Make a recommendation for either a single best nasal spray, or a group of best choices which are similar in their effects; refer to the Tukey test to justify your decision.

One-Way Analysis of Variance
Results: Nasal Spray Example

The ANOVA Procedure

Class Level Information

Class	Levels	Values
Spray	5	A B C D E

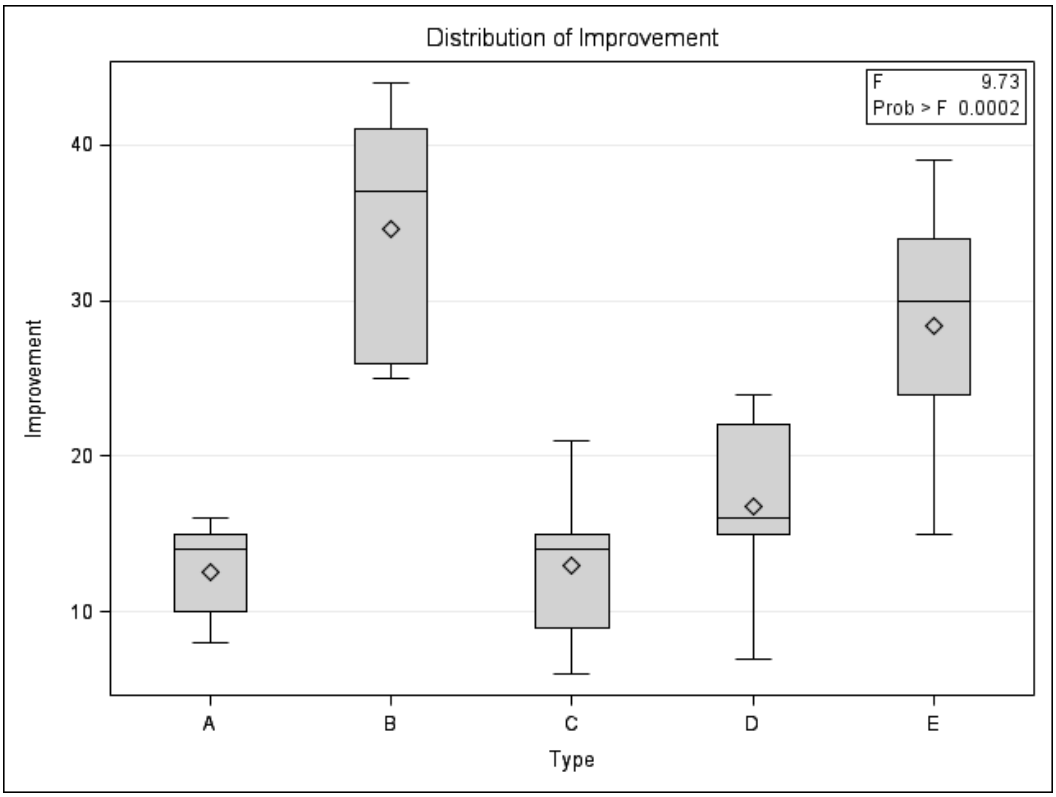
Number of Observations Read	25
Number of Observations Used	25

Dependent Variable: Improvement

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	1959.440000	489.860000	9.73	0.0002
Error	20	1006.400000	50.320000		
Corrected Total	24	2965.840000			

R-Square	Coeff Var	Root MSE	Improvement Mean
0.660669	33.65113	7.093659	21.08000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Spray	4	1959.440000	489.860000	9.73	0.0002



The ANOVA Procedure

Nasal Spray Example

Levene's Test for Homogeneity of Improvement Variance
ANOVA of Squared Deviations from Group Means

Source	*DF*	*Sum of Squares*	*Mean Square*	*F Value*	*Pr > F*
Type	4	11893.9	2973.5	1.59	0.2156
Error	20	37393.0	1869.6		

Level of Type	*N*	*Improvement Mean*	*Std Dev*
A	5	12.6000000	3.43511281
B	5	34.6000000	8.67755726
C	5	13.0000000	5.78791845
D	5	16.8000000	6.68580586
E	5	28.4000000	9.28977933

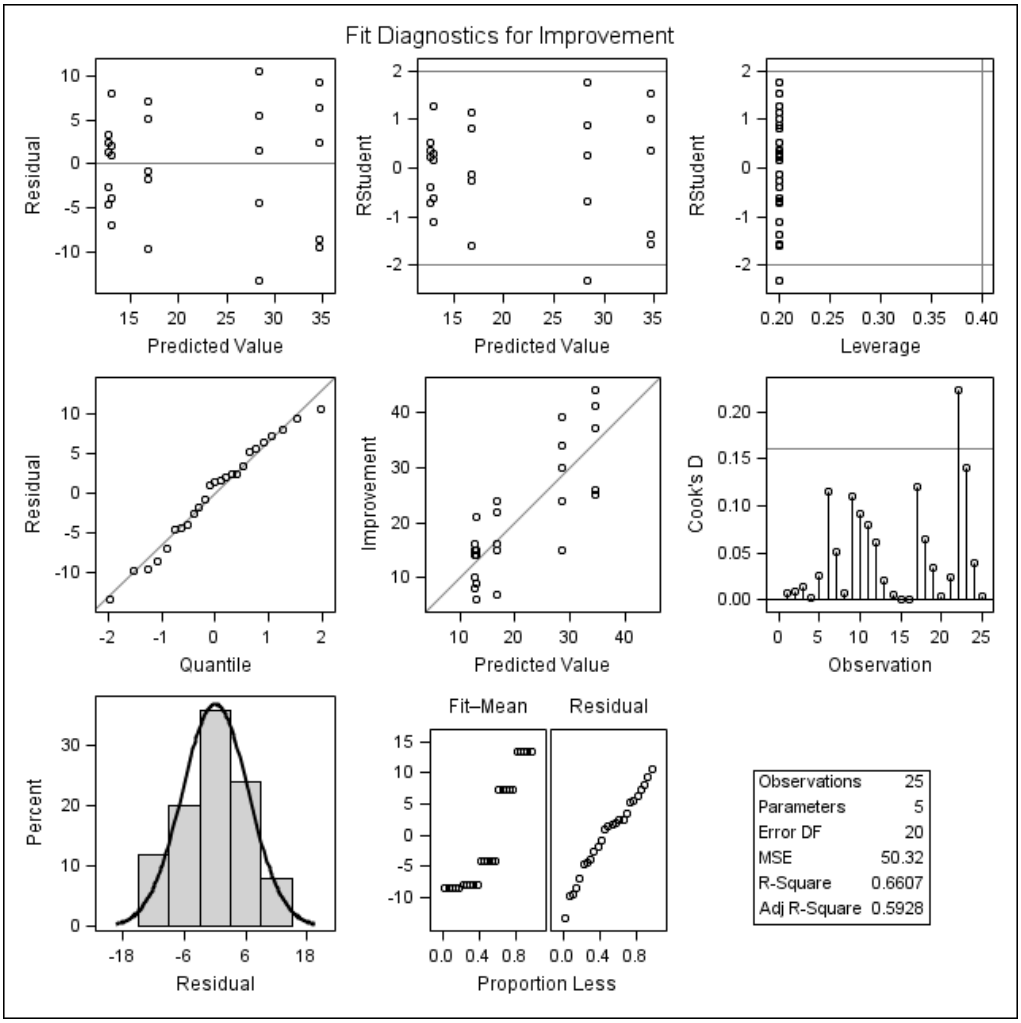
Tukey's Studentized Range (HSD) Test for Improvement

Note: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	20
Error Mean Square	50.32
Critical Value of Studentized Range	4.23186
Minimum Significant Difference	13.425

Means with the same letter are not significantly different.

Tukey Grouping		*Mean*	*N*	*Type*
	A	34.600	5	B
	A			
B	A	28.400	5	E
B				
B	C	16.800	5	D
	C			
	C	13.000	5	C
	C			
	C	12.600	5	A



Nonparametric One-Way ANOVA

The NPAR1WAY Procedure: Nasal Spray Example

Wilcoxon Scores (Rank Sums) for Variable Improvement Classified by Variable Type

Type	*N*	*Sum of Scores*	*Expected Under H0*	*Std Dev Under H0*	*Mean Score*
A	5	36.50	65.0	14.682756	7.30
B	5	108.00	65.0	14.682756	21.60
C	5	35.00	65.0	14.682756	7.00
D	5	55.50	65.0	14.682756	11.10
E	5	90.00	65.0	14.682756	18.00

Average scores were used for ties.

Kruskal-Wallis Test

Chi-Square	15.8695
DF	4
Pr > Chi-Square	0.0032

3. **Forensic dental X-rays**

The extent to which X-rays can penetrate tooth enamel has been suggested as a suitable mechanism for differentiating between females and males in forensic medicine (e.g., think about shows like 'CSI' and parts of 'NCIS'). The table below gives *spectropenetration gradients* for one tooth from each of eight females and eight males.

Gender	Y = spectropenetration gradient								Mean	Std. dev.
Female	4.8	5.3	3.7	4.1	5.6	4.0	3.6	5.0	4.5125	0.7605
Male	4.9	5.4	5.0	5.5	5.4	6.6	6.3	4.3	5.4250	0.7440

Note that a high reading reflects a fast drop-off in X-ray penetration, with less penetration by X-rays.

(a) Explain why the teeth have been sampled from eight different people of each sex, and not eight teeth from one female and eight from one male.

(b) Given that the researcher could afford to test $n = 16$ subjects, explain the advantages of choosing eight from each group.

(c) SAS output from an ANOVA is on pages 9 and 10. Write a report, following the guidelines on page 1.

(d) Explain why there is no point doing a Tukey test with this data.

One-Way Analysis of Variance
Results: X-ray Penetration Gradient

The ANOVA Procedure

Class Level Information

Class	*Levels*	*Values*
Gender	2	Female Male

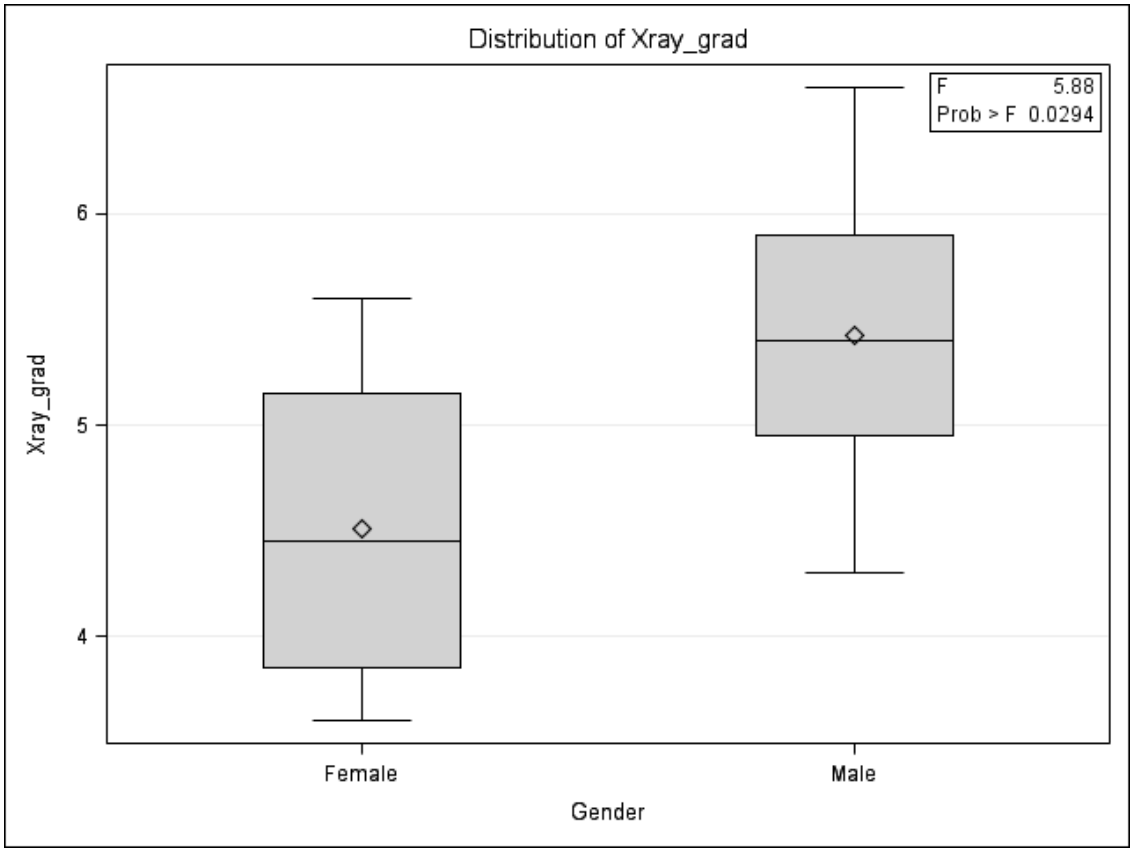
Number of Observations Read	16
Number of Observations Used	16

Dependent Variable: Xray_grad

Source	*DF*	*Sum of Squares*	*Mean Square*	*F Value*	*Pr > F*
Model	1	3.33062500	3.33062500	5.88	0.0294
Error	14	7.92375000	0.56598214		
Corrected Total	15	11.25437500			

R-Square	*Coeff Var*	*Root MSE*	*Xray_grad Mean*
0.295940	15.14099	0.752318	4.968750

Source	*DF*	*Anova SS*	*Mean Square*	*F Value*	*Pr > F*
Gender	1	3.33062500	3.33062500	5.88	0.0294



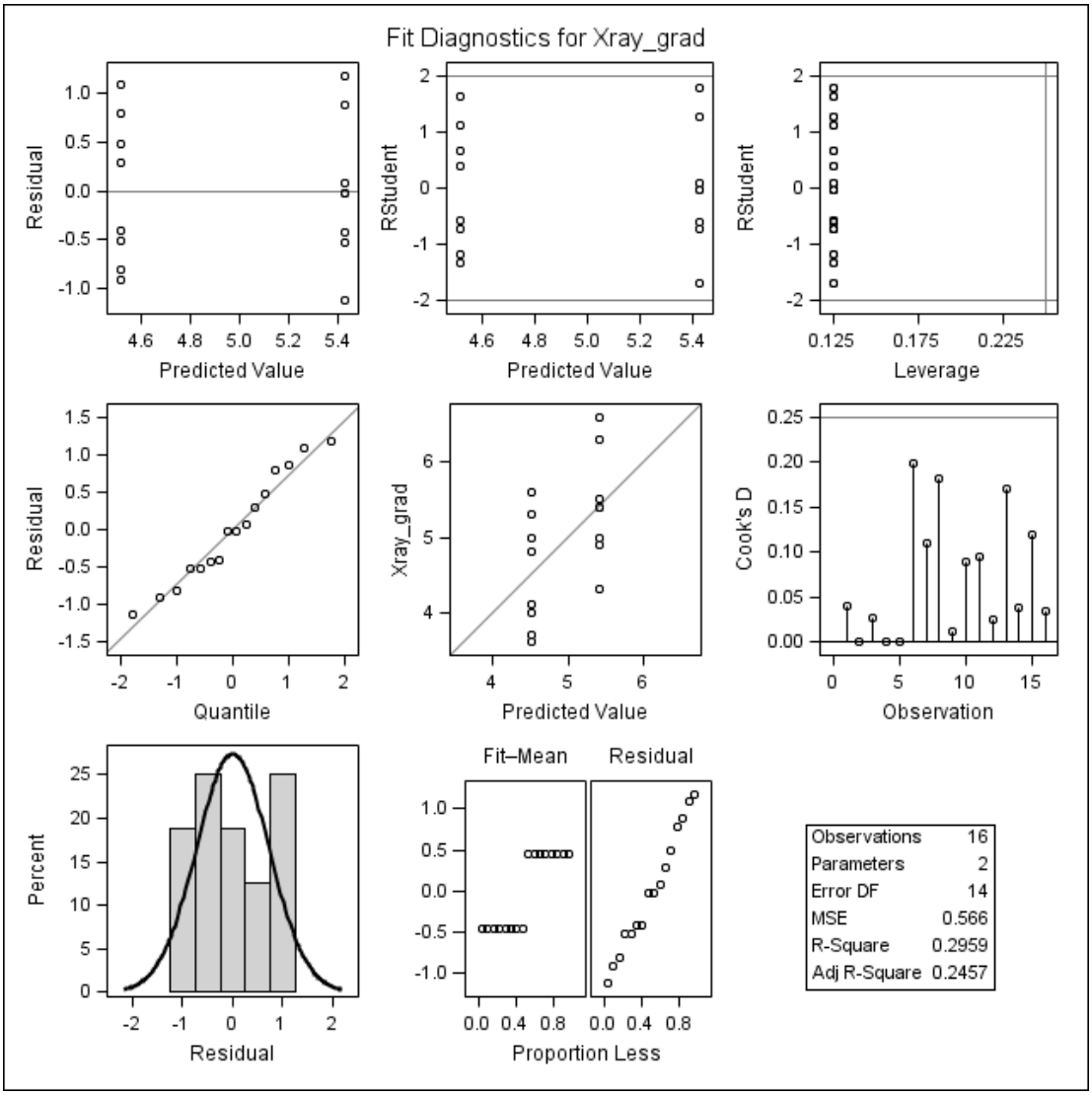
The ANOVA Procedure

X-ray Penetration Gradient

Levene's Test for Homogeneity of Xray_grad Variance
ANOVA of Squared Deviations from Group Means

Source	*DF*	*Sum of Squares*	*Mean Square*	*F Value*	*Pr > F*
Gender	1	0.00189	0.00189	0.01	0.9305
Error	14	3.3504	0.2393		

Level of Gender	*N*	*Xray_grad Mean*	*Xray_grad Std Dev*
Female	8	4.51250000	0.76052144
Male	8	5.42500000	0.74402381



4. **Personality types**

In psychology, there are tests to classify people into one of many personality types. An experiment is run to find the extent of the influence of personality type on the subject's score in a certain test. A random sample of four personality types is taken, and within each type a random sample of ten subjects is taken. Each subject is given the test, and the score Y is recorded, with data as follows:

Type	Test Score, Y									
T1	50	52	44	49	60	51	40	41	54	39
T2	63	45	48	49	65	55	47	58	57	56
T3	50	52	47	48	44	56	55	39	51	53
T4	39	38	51	50	53	53	59	41	45	48

(a) Explain why this is a random effects design, rather than a fixed effects design.

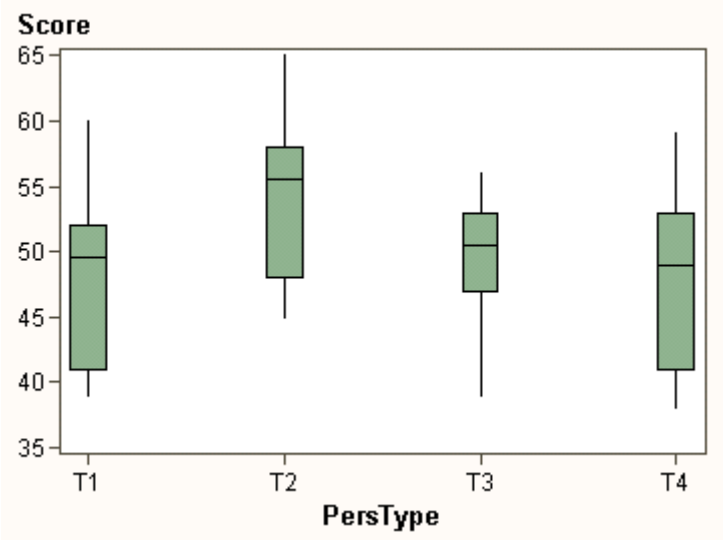
(b) Some SAS output is given on pages 12 and 13. Note that the boxplots do not include estimates of group means, since any differences in population means are not the focus of this investigation.

Present a report and your conclusions. Include in your report comments on whether the relevant assumptions seem satisfied. Give your estimated components of variance, plus the percentage of the total variance of Y that is due to personality, along with the percentage unexplained,

Do you think personality type is important in determining the score on this particular test?

SAS Output for Personality Type Example

Box Plot



One-Way Analysis of Variance

Results

The ANOVA Procedure

Class Level Information		
Class	Levels	Values
PersType	4	T1 T2 T3 T4

Number of Observations Read	40
Number of Observations Used	40

Dependent Variable: Score

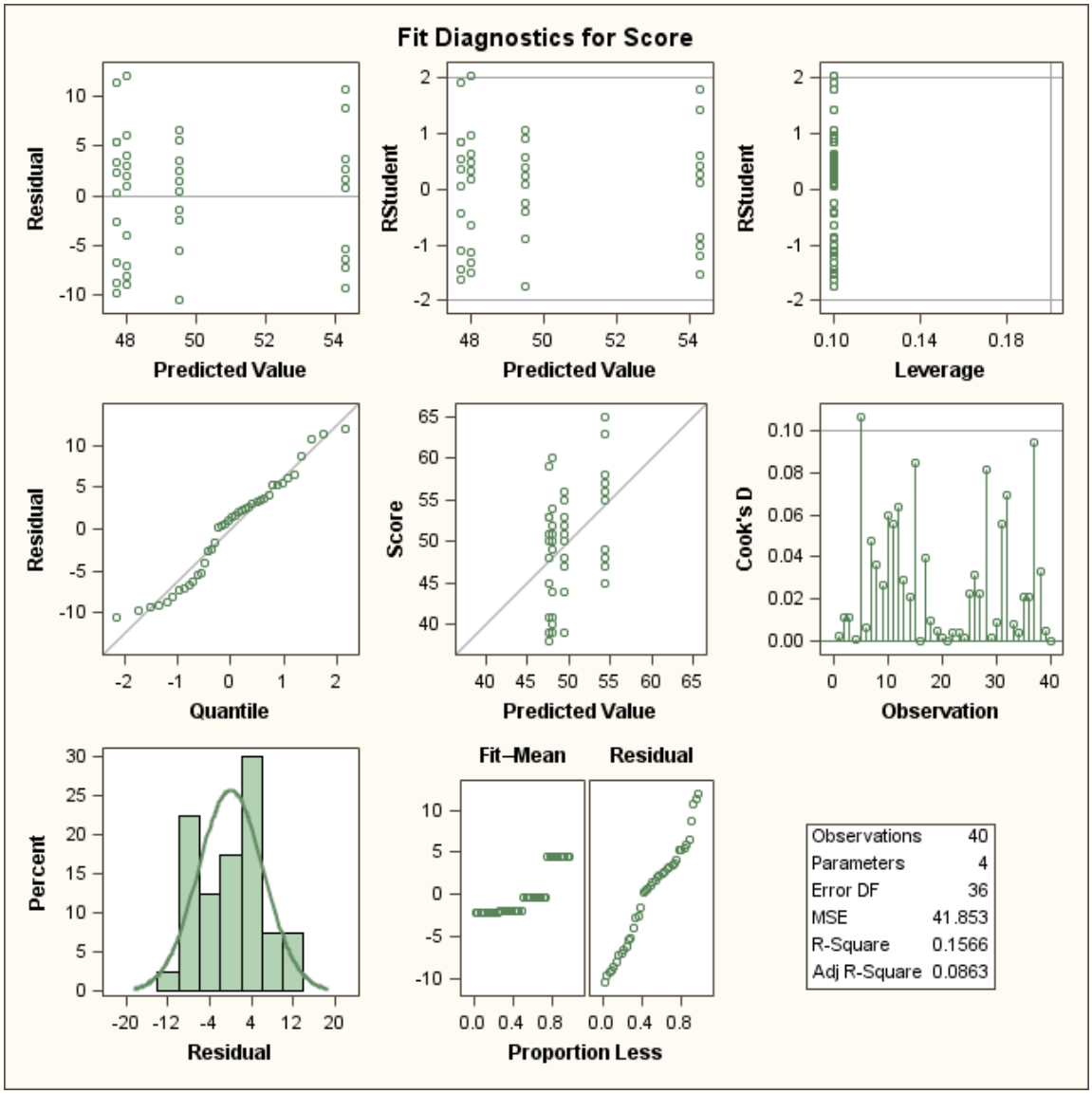
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	279.675000	93.225000	2.23	0.1017
Error	36	1506.700000	41.852778		
Corrected Total	39	1786.375000			

R-Square	Coeff Var	Root MSE	Score Mean
0.156560	12.97117	6.469372	49.87500

Source	DF	Anova SS	Mean Square	F Value	Pr > F
PersType	3	279.6750000	93.2250000	2.23	0.1017

SAS Output for Personality Type Example

Levene's Test for Homogeneity of Score Variance ANOVA of Squared Deviations from Group Means					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
PersType	3	2400.7	800.2	0.49	0.6926
Error	36	59004.7	1639.0		



5. **Phytoremediation**

Phytoremediation (New Scientist, 20 Dec 1997, p.26) is a process by which plants are used to remove toxic metals from the soil. For example, sunflowers were used around Chernobyl, where there was radioactive contamination from a nuclear power station accident.

Certain plants take up toxic metals (e.g. zinc, cadmium, uranium) and accumulate them in their vacuoles as protection against chewing insects and infection.

Suppose that four species of plant were tested, at lower and higher soil pH, for their uptake of zinc, Y, measured in parts per million (ppm) of dry plant weight at the end of the trial.

Uptake of zinc, Y, (ppm):

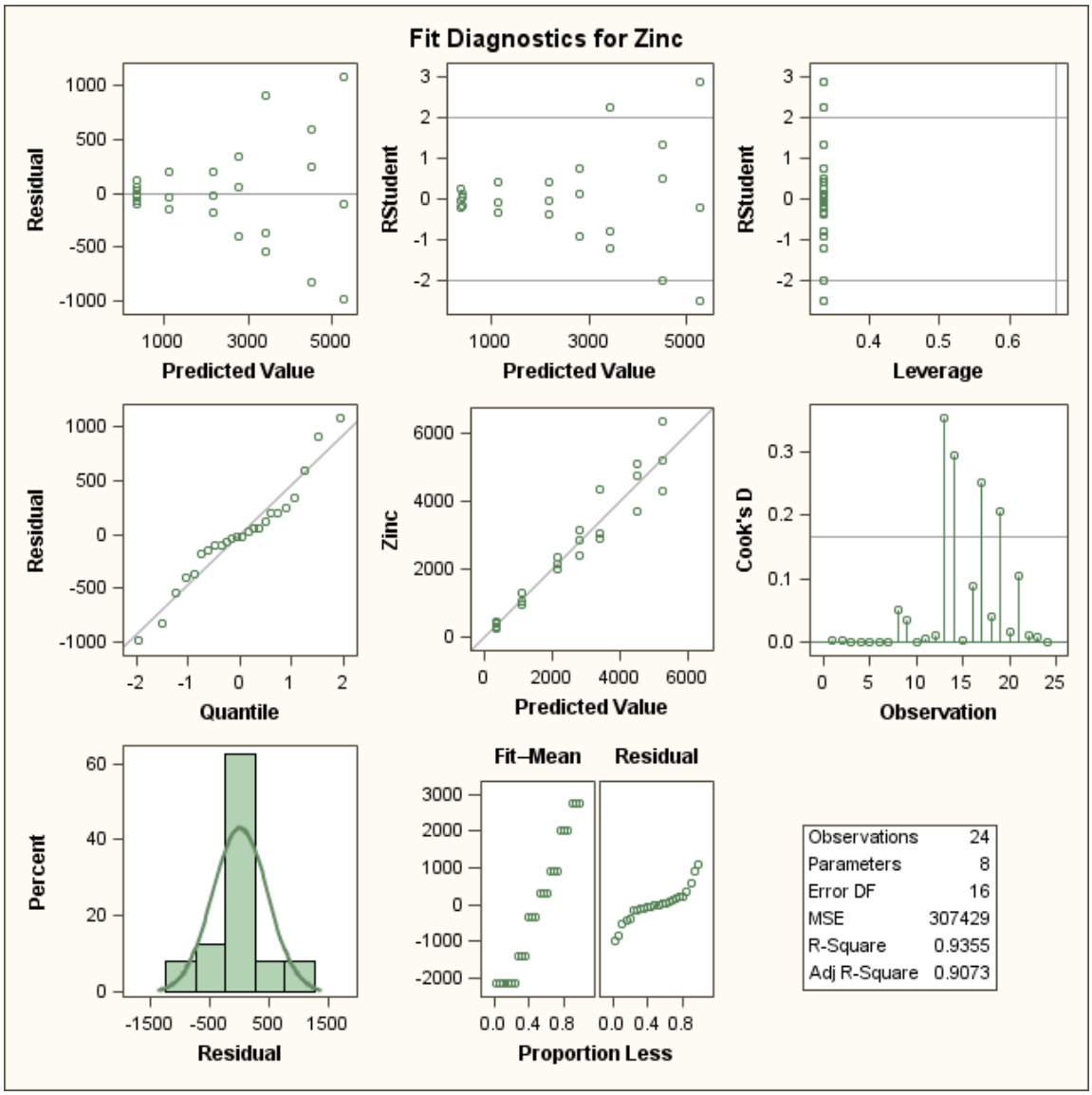
	Soil pH					
Plant Name	5.5 (acid)			7 (neutral)		
Lettuce	250	470	330	400	310	430
Martin red fescue	2850	2380	3130	1070	960	1300
Alpine pennycress	6340	4280	5170	2880	4330	3050
Bladder campion	3690	4750	5100	2360	1990	2140

(a) What kind of design is this? Give the model equation, including an interaction term.

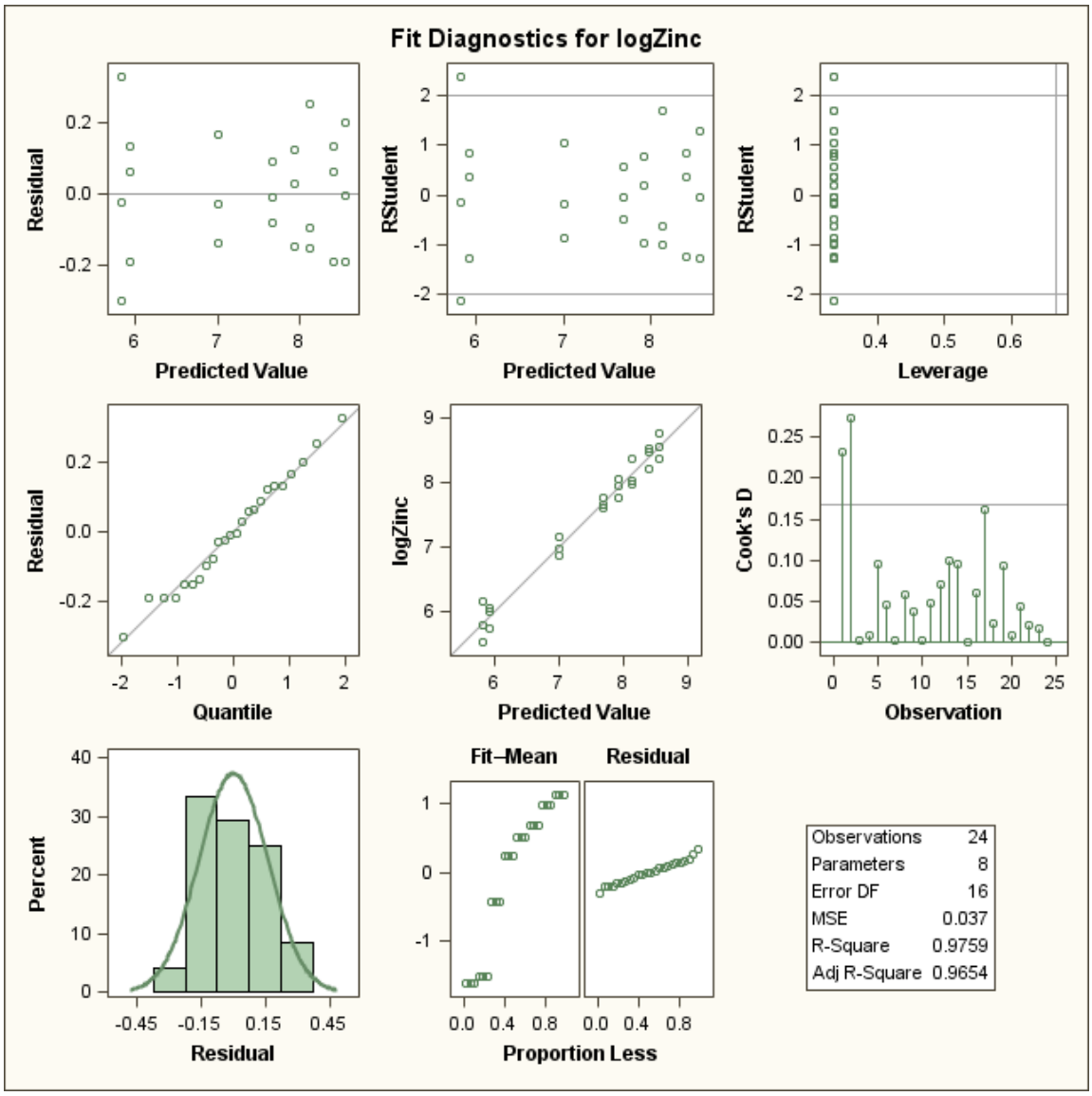
(b) SAS analysis of the data using the model from part (a) was tried on both raw data Y and transformed data $\log Y$. Diagnostic graphs from both analyses are given on pages 15 and 16. Explain, with reasons, whether it is better to analyse Y or $\log Y$.

(c) Further SAS output is given on pages 17 to 19. Present a report and your conclusions, following the usual guidelines. Use a 5% significance level.

SAS Output for Phytoremediation Example



SAS Output for Phytoremediation Example



SAS Output for Phytoremediation Example

Linear Models

The GLM Procedure

Class Level Information		
Class	Levels	Values
pH	2	acid neutral
Plant	4	AlpineP BladderC Lettuce MartinRF

Number of Observations Read	24
Number of Observations Used	24

Dependent Variable: logZinc

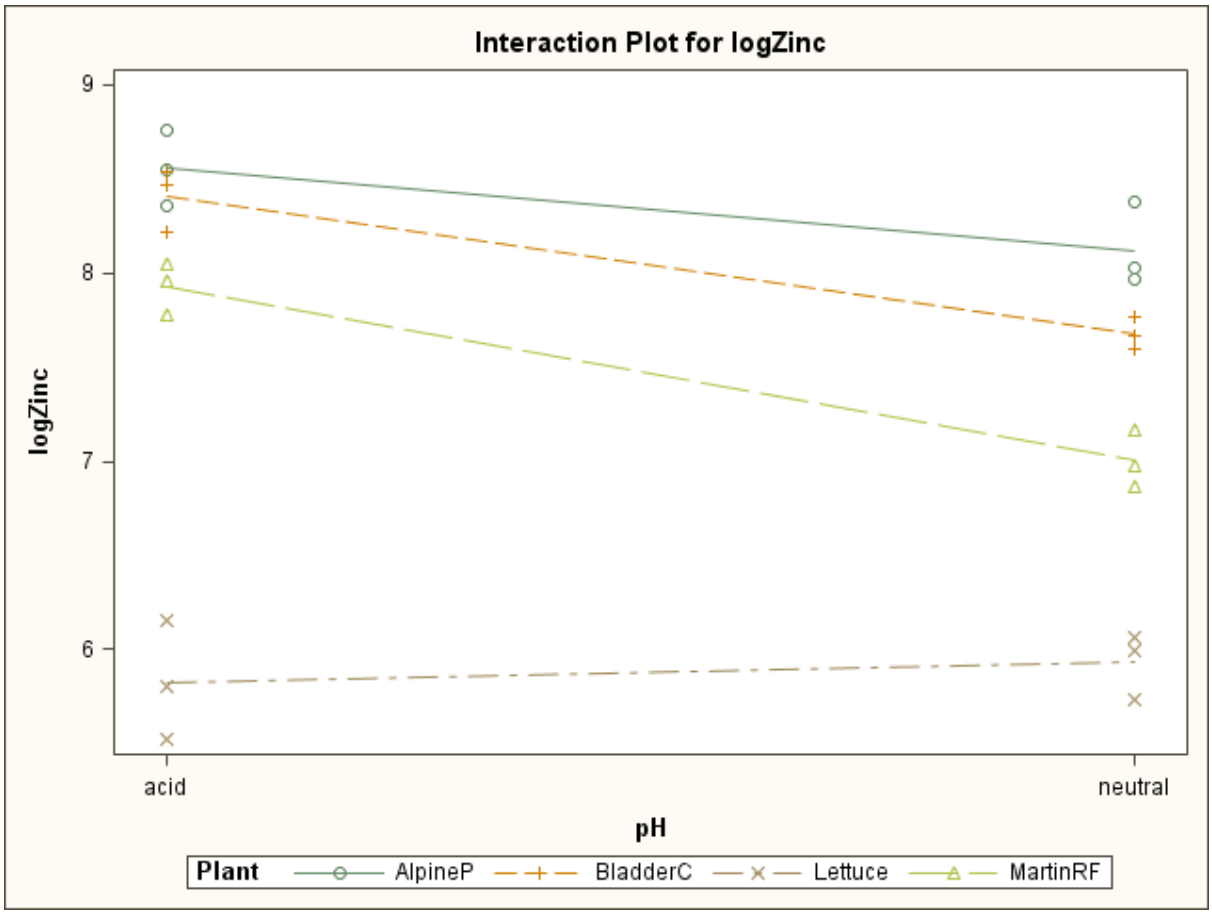
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	24.03027190	3.43289599	92.71	<.0001
Error	16	0.59245521	0.03702845		
Corrected Total	23	24.62272711			

R-Square	Coeff Var	Root MSE	logZinc Mean
0.975939	2.589699	0.192428	7.430507

Source	DF	Type I SS	Mean Square	F Value	Pr > F
pH	1	1.46932364	1.46932364	39.68	<.0001
Plant	3	21.65807393	7.21935798	194.97	<.0001
pH*Plant	3	0.90287433	0.30095811	8.13	0.0016

Source	DF	Type III SS	Mean Square	F Value	Pr > F
pH	1	1.46932364	1.46932364	39.68	<.0001
Plant	3	21.65807393	7.21935798	194.97	<.0001
pH*Plant	3	0.90287433	0.30095811	8.13	0.0016

SAS Output for Phytoremediation Example



Alternative interaction graph for phytoremediation example