

```

1      TITLE1 'Analysis of Variance (One-way ANOVA)';
2      dm'log;clear;output;clear';
3
4      ODS HTML style=minimal body='C:\EXST 7005\SAS\Example05.html' ;
NOTE: Writing HTML Body file: C:\EXST 7005\SAS\Example05.html
5      ODS RTF style=minimal body='C:\EXST 7005\SAS\Example05.rtf';
NOTE: Writing RTF Body file: C:\EXST 7005\SAS\Example05.rtf
6      ODS PDF style=minimal body='C:\EXST 7005\SAS\Example05.PDF';
NOTE: Writing ODS PDF output to DISK destination
      "C:\EXST 7005\SAS\Example05.PDF", printer "PDF".
7
8      *****;
9      *** Steele & Torrie (1980) Table 7.1 ***;
10     *** Nitrogen content of red clover plants inoculated ***;
11     *** with combination cultures of Rhizobium strains ***;
12     *****;
13     options ps=256 ls=99 nocenter nodate nonumber nlabel;
14
15     data clover; infile cards missover;
16         TITLE2 'Nitrogen content of red clover (S&T 1980)';
17         LABEL treatment = 'Rhizobium inoculum';
18         LABEL percent = 'Percent N content';
19         input treatment $ 1-6 percent;
20     cards;
NOTE: The data set WORK.CLOVER has 25 observations and 2 variables.
NOTE: DATA statement used (Total process time):
      real time          0.01 seconds
      cpu time           0.01 seconds
20     !           run;
46     ;
47     proc print data=clover; var treatment percent;
48         TITLE3 'Raw data list (unsorted)'; run;
NOTE: There were 25 observations read from the data set WORK.CLOVER.
NOTE: The PROCEDURE PRINT printed page 1.
NOTE: PROCEDURE PRINT used (Total process time):
      real time          0.13 seconds
      cpu time           0.01 seconds

```

Analysis of Variance (One-way ANOVA)  
 Nitrogen content of red clover (S&T 1980)  
 Raw data list (unsorted)

Obs	treatment	percent			
			13	3D0k5	27.9
1	3D0k1	19.4	14	3D0k5	25.2
2	3D0k1	32.6	15	3D0k5	24.3
3	3D0k1	27.0	16	3D0k7	20.7
4	3D0k1	32.1	17	3D0k7	21.0
5	3D0k1	33.0	18	3D0k7	20.5
6	3D0k4	17.0	19	3D0k7	18.8
7	3D0k4	19.4	20	3D0k7	18.6
8	3D0k4	9.1	21	3D0k13	14.3
9	3D0k4	11.9	22	3D0k13	14.4
10	3D0k4	15.8	23	3D0k13	11.8
11	3D0k5	17.7	24	3D0k13	11.6
12	3D0k5	24.8	25	3D0k13	14.2

```

49
50     proc mixed data=clover order=data; class treatment;
51         TITLE3 'ANOVA with PROC MIXED';
52         model percent = treatment /DDFM=Satterthwaite;
53     run;
NOTE: The PROCEDURE MIXED printed page 2.
NOTE: PROCEDURE MIXED used (Total process time):
      real time          0.09 seconds
      cpu time           0.03 seconds
53     !         quit;

```

Analysis of Variance (One-way ANOVA)  
Nitrogen content of red clover (S&T 1980)  
ANOVA with PROC MIXED

#### The Mixed Procedure

##### Model Information

Data Set	WORK.CLOVER
Dependent Variable	percent
Covariance Structure	Diagonal
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Residual

##### Class Level Information

Class	Levels	Values
treatment	5	3D0k1 3D0k4 3D0k5 3D0k7 3D0k13

##### Dimensions

Covariance Parameters	1
Columns in X	6
Columns in Z	0
Subjects	1
Max Obs Per Subject	25

##### Number of Observations

Number of Observations Read	25
Number of Observations Used	25
Number of Observations Not Used	0

##### Covariance Parameter

###### Estimates

Cov Parm	Estimate
Residual	13.6334

##### Fit Statistics

-2 Res Log Likelihood	117.1
AIC (smaller is better)	119.1
AICC (smaller is better)	119.3
BIC (smaller is better)	120.1

##### Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
treatment	4	20	15.38	<.0001

```

54
55     proc mixed data=clover order=data; class treatment;
56         TITLE3 'ANOVA with PROC MIXED - separate variances';
57         model percent = treatment / htype=3 DDFM=Satterthwaite outp=resids;
58         repeated / group = treatment;
59         lsmeans treatment / adjust=tukey pdiff;
60         ** treatments in order=data =====> 3DOK1 3DOK4 3DOK5 3DOK7 3DOK13;
61         contrast '3 low vrs 2 high' treatment -2 -2 -2 3 3;
62         contrast 'odd vrs even' treatment -1 4 -1 -1 -1;
63         contrast '1st vrs 2nd' treatment -1 1 0 0 0;
64         ods output diffs=ppp lsmeans=mmm;
65         ods listing exclude diffs ;* but not lsmeans;
66     run;
NOTE: Convergence criteria met.
NOTE: The data set WORK.MMM has 5 observations and 7 variables.
NOTE: The data set WORK.PPP has 10 observations and 10 variables.
NOTE: The data set WORK.RESIDS has 25 observations and 9 variables.
NOTE: The PROCEDURE MIXED printed page 3.
NOTE: PROCEDURE MIXED used (Total process time):
      real time          0.18 seconds
      cpu time           0.10 seconds
67     TITLE4 'Post hoc adjustment with macro by Arnold Saxton';
68     * SAS Macro by Arnold Saxton: Saxton, A.M. 1998. A macro for ;
69     * converting mean separation output to letter groupings in Proc Mixed. ;
70     * In Proc. 23rd SAS Users Group Intl., SAS Inst., Cary, NC, pp1243-246.;
71     %include 'C:\Geaghan\EXST\EXST7005New\Fall2003\Sas\pdmix800.sas';
699    %pdmix800(ppp,mmm,alpha=0.05,sort=yes);
PDMIX800 03.26.2002 processing
4.8945350075
Tukey-Kramer values for treatment are 7.72803 (avg) 2.81808 (min) 11.0084
(max).
700    run;

```

Analysis of Variance (One-way ANOVA)  
Nitrogen content of red clover (S&T 1980)  
ANOVA with PROC MIXED - separate variances

#### The Mixed Procedure

##### Model Information

Data Set	WORK.CLOVER
Dependent Variable	percent
Covariance Structure	Variance Components
Group Effect	treatment
Estimation Method	REML
Residual Variance Method	None
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Satterthwaite

##### Class Level Information

Class	Levels	Values
treatment	5	3DOK1 3DOK4 3DOK5 3DOK7 3DOK13

Dimensions

Covariance Parameters 5  
 Columns in X 6  
 Columns in Z 0  
 Subjects 25  
 Max Obs Per Subject 1

Number of Observations

Number of Observations Read 25  
 Number of Observations Used 25  
 Number of Observations Not Used 0

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	117.05518418	
1	1	104.64497787	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Group	Estimate
Residual	treatment 3DOK1	33.6420
Residual	treatment 3DOK4	16.9430
Residual	treatment 3DOK5	14.2670
Residual	treatment 3DOK7	1.2770
Residual	treatment 3DOK13	2.0380

Fit Statistics

-2 Res Log Likelihood 104.6  
 AIC (smaller is better) 114.6  
 AICC (smaller is better) 118.9  
 BIC (smaller is better) 120.7

Null Model Likelihood Ratio Test

DF	Chi-Square	Pr > ChiSq
4	12.41	0.0145

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
treatment	4	7.08	25.64	0.0003

Contrasts

Label	Num DF	Den DF	F Value	Pr > F
3 low vrs 2 high	1	12.7	21.59	0.0005
odd vrs even	1	5.55	11.66	0.0161
1st vrs 2nd	1	7.21	19.87	0.0027

Least Squares Means

Effect	treatment	Estimate	Standard Error	DF	t Value	Pr >  t
treatment	3DOK1	28.8200	2.5939	4	11.11	0.0004
treatment	3DOK4	14.6400	1.8408	4	7.95	0.0014
treatment	3DOK5	23.9800	1.6892	4	14.20	0.0001
treatment	3DOK7	19.9200	0.5054	4	39.42	<.0001
treatment	3DOK13	13.2600	0.6384	4	20.77	<.0001

Analysis of Variance (One-way ANOVA)  
 Nitrogen content of red clover (S&T 1980)  
 ANOVA with PROC MIXED - separate variances  
 Post hoc adjustment with macro by Arnold Saxton

Effect=treatment ADJUSTMENT=Tukey-Kramer(P<0.05) BYGROUP=1

Obs	treatment	Estimate	StdErr	MSGROUP
1	3Dok1	28.8200	2.5939	A
2	3Dok5	23.9800	1.6892	A
3	3Dok7	19.9200	0.5054	AB
4	3Dok4	14.6400	1.8408	BC
5	3Dok13	13.2600	0.6384	C

701

702           proc univariate data=resids normal plot; var resid;

703                    TITLE4 'Univariate analysis of residuals';

704           run;

NOTE: The PROCEDURE UNIVARIATE printed page 5.

NOTE: PROCEDURE UNIVARIATE used (Total process time):

real time               0.18 seconds

cpu time                0.09 seconds

Analysis of Variance (One-way ANOVA)  
 Nitrogen content of red clover (S&T 1980)  
 ANOVA with PROC MIXED - separate variances  
 Univariate analysis of residuals

The UNIVARIATE Procedure

Variable: Resid

Moments

N	25	Sum Weights	25
Mean	0	Sum Observations	0
Std Deviation	3.37063298	Variance	11.3611667
Skewness	-1.1101822	Kurtosis	1.50767295
Uncorrected SS	272.668	Corrected SS	272.668
Coeff Variation	.	Std Error Mean	0.6741266

Basic Statistical Measures

Location		Variability	
Mean	0.000000	Std Deviation	3.37063
Median	0.820000	Variance	11.36117
Mode	.	Range	14.18000
		Interquartile Range	2.68000

Tests for Location: Mu0=0

Test	-Statistic-	-----p Value-----	
Student's t	t       0	Pr >  t	1.0000
Sign	M       3.5	Pr >=  M	0.2295
Signed Rank	S       11.5	Pr >=  S	0.7639

Tests for Normality

Test	--Statistic--	-----p Value-----	
Shapiro-Wilk	W       0.908103	Pr < W	0.0277
Kolmogorov-Smirnov	D       0.177818	Pr > D	0.0406
Cramer-von Mises	W-Sq   0.143275	Pr > W-Sq	0.0271
Anderson-Darling	A-Sq   0.822014	Pr > A-Sq	0.0298

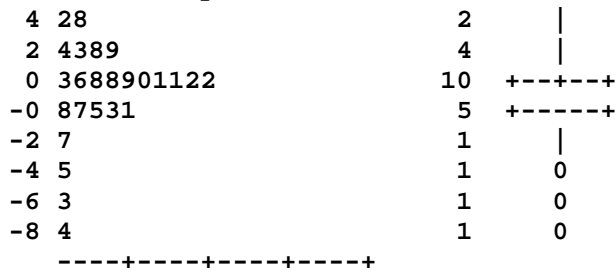
Quantiles (Definition 5)

Quantile	Estimate
100% Max	4.76
99%	4.76
95%	4.18
90%	3.92
75% Q3	1.22
50% Median	0.82
25% Q1	-1.46
10%	-5.54
5%	-6.28
1%	-9.42
0% Min	-9.42

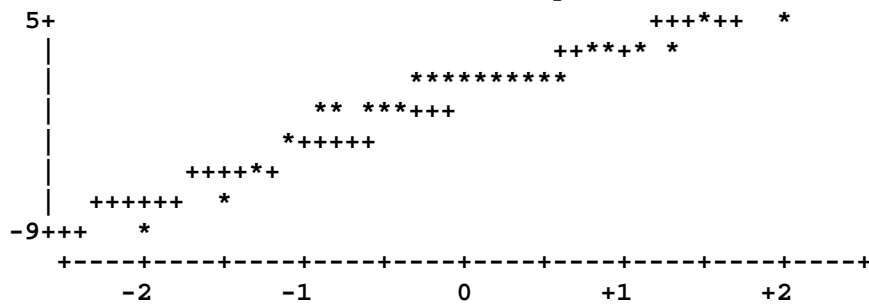
Extreme Observations

----Lowest----		----Highest---	
Value	Obs	Value	Obs
-9.42	1	3.28	4
-6.28	11	3.78	2
-5.54	8	3.92	13
-2.74	9	4.18	5
-1.82	3	4.76	7

Stem Leaf Boxplot



Normal Probability Plot



```

705
706      proc sort data=clover; by treatment; run;
NOTE: There were 25 observations read from the data set WORK.CLOVER.
NOTE: The data set WORK.CLOVER has 25 observations and 2 variables.
NOTE: PROCEDURE SORT used (Total process time):
      real time          0.03 seconds
      cpu time           0.03 seconds
707      proc means noprint data=clover; by treatment; var percent;
708      output out=next1 mean=mean var=var; run;
NOTE: There were 25 observations read from the data set WORK.CLOVER.
NOTE: The data set WORK.NEXT1 has 5 observations and 5 variables.
NOTE: PROCEDURE MEANS used (Total process time):
      real time          0.01 seconds
      cpu time           0.01 seconds
709      options ps=45;
709      !          proc plot data=next1; plot var*mean;
710      TITLE3 'Variance mean plot to examine homogeneity';
711      run;
712      options ps=61;
713
NOTE: There were 5 observations read from the data set WORK.NEXT1.
NOTE: The PROCEDURE PLOT printed page 6.
NOTE: PROCEDURE PLOT used (Total process time):
      real time          0.21 seconds
      cpu time           0.04 seconds

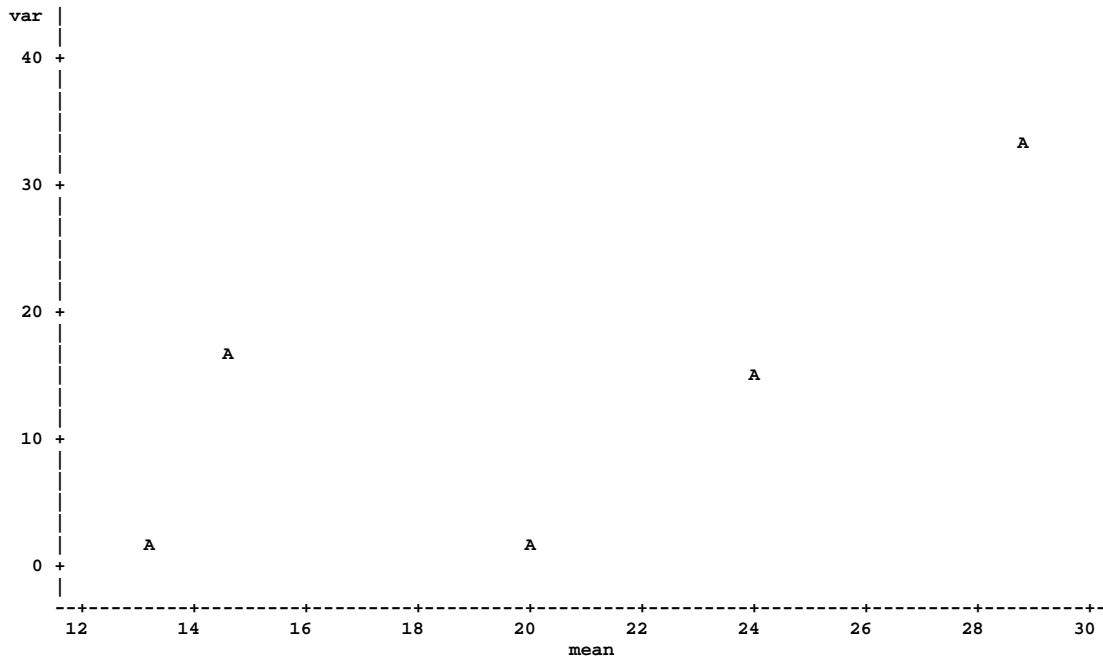
```

#### Analysis of Variance (One-way ANOVA)

Nitrogen content of red clover (S&T 1980)

Variance mean plot to examine homogeneity

Plot of var\*mean. Legend: A = 1 obs, B = 2 obs, etc.



```

714      proc glm data=clover order=data; class treatment;
715          TITLE3 'ANOVA with SAS PROC GLM with post hoc and HOV tests';
716          model percent = treatment / SS3;
717          MEANS treatment/HOVTEST=BARTLETT HOVTEST=BF HOVTEST=LEVENE(TYPE=ABS)
718              HOVTEST=LEVENE(TYPE=SQUARE) HOVTEST=OBRIEN WELCH;
719          means treatment / lsd tukey bon scheinfe duncan lines;
720          means treatment / dunnett('3Dok1');
721          means treatment / lsd tukey bon scheinfe duncan cldiff;
722      run;
723      quit;
NOTE: The PROCEDURE GLM printed pages 7-20.
NOTE: PROCEDURE GLM used (Total process time):
      real time          0.43 seconds
      cpu time           0.26 seconds
724
725      ods html close;
726      ods rtf close;
727      ods PDF close;
NOTE: ODS PDF printed 26 pages to C:\EXST 7005\SAS\Example05.PDF.
728
729      run;
730      quit;

```

#### Analysis of Variance (One-way ANOVA)

Nitrogen content of red clover (S&T 1980)

ANOVA with SAS PROC GLM with post hoc and HOV tests

#### The GLM Procedure

##### Class Level Information

Class	Levels	Values
treatment	5	3Dok1 3Dok13 3Dok4 3Dok5 3Dok7

Number of Observations Read 25

Number of Observations Used 25

#### Analysis of Variance (One-way ANOVA)

Nitrogen content of red clover (S&T 1980)

ANOVA with SAS PROC GLM with post hoc and HOV tests

#### The GLM Procedure

Dependent Variable: percent

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	838.597600	209.649400	15.38	<.0001
Error	20	272.668000	13.633400		
Corrected Total	24	1111.265600			

R-Square	Coeff Var	Root MSE	percent Mean
0.754633	18.34796	3.692343	20.12400

Source	DF	Type III SS	Mean Square	F Value	Pr > F
treatment	4	838.5976000	209.6494000	15.38	<.0001



Analysis of Variance (One-way ANOVA)  
 Nitrogen content of red clover (S&T 1980)  
 ANOVA with SAS PROC GLM with post hoc and HOV tests

The GLM Procedure

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

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	4	2236.3	559.1	1.68	0.1943
Error	20	6661.1	333.1		

O'Brien's Test for Homogeneity of percent Variance  
 ANOVA of O'Brien's Spread Variable, W = 0.5

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	4	3494.2	873.5	1.23	0.3285
Error	20	14166.4	708.3		

Brown and Forsythe's Test for Homogeneity of percent Variance  
 ANOVA of Absolute Deviations from Group Medians

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	4	32.7944	8.1986	0.87	0.4966
Error	20	187.5	9.3766		

Bartlett's Test for Homogeneity of percent Variance

Source	DF	Chi-Square	Pr > ChiSq
treatment	4	11.2820	0.0236

Welch's ANOVA for percent

Source	DF	F Value	Pr > F
treatment	4.0000	21.12	0.0001
Error	9.3550		

Analysis of Variance (One-way ANOVA)  
 Nitrogen content of red clover (S&T 1980)  
 ANOVA with SAS PROC GLM with post hoc and HOV tests

The GLM Procedure

Level of treatment	N	Mean	Std Dev
3Dok1	5	28.8200000	5.80017241
3Dok13	5	13.2600000	1.42758537
3Dok4	5	14.6400000	4.11618756
3Dok5	5	23.9800000	3.77716825
3Dok7	5	19.9200000	1.13004425

## Analysis of Variance (One-way ANOVA)

Nitrogen content of red clover (S&amp;T 1980)

ANOVA with SAS PROC GLM with post hoc and HOV tests

## The GLM Procedure

t Tests (LSD) for percent

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

Alpha	0.05
Error Degrees of Freedom	20
Error Mean Square	13.6334
Critical Value of t	2.08596
Least Significant Difference	4.8712

Means with the same letter are not significantly different.

t	Grouping	Mean	N	treatment
	A	28.820	5	3Dok1
	A			
B	A	23.980	5	3Dok5
B				
B		19.920	5	3Dok7
	C	14.640	5	3Dok4
	C			
	C	13.260	5	3Dok13

## Duncan's Multiple Range Test for percent

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

Alpha	0.05
Error Degrees of Freedom	20
Error Mean Square	13.6334

Number of Means	2	3	4	5
Critical Range	4.871	5.113	5.267	5.374

Means with the same letter are not significantly different.

## Duncan Grouping

	Mean	N	treatment
A	28.820	5	3Dok1
A			
B	23.980	5	3Dok5
B			
B	19.920	5	3Dok7
C	14.640	5	3Dok4
C			
C	13.260	5	3Dok13

## Analysis of Variance (One-way ANOVA)

Nitrogen content of red clover (S&amp;T 1980)

ANOVA with SAS PROC GLM with post hoc and HOV tests

## The GLM Procedure

## Tukey's Studentized Range (HSD) Test for percent

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	13.6334
Critical Value of Studentized Range	4.23186
Minimum Significant Difference	6.9879

Means with the same letter are not significantly different.

## Tukey Grouping

	Mean	N	treatment
A	28.820	5	3DOK1
A			
B A	23.980	5	3DOK5
B			
B C	19.920	5	3DOK7
C			
C	14.640	5	3DOK4
C			
C	13.260	5	3DOK13

## Bonferroni (Dunn) t Tests for percent

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	13.6334
Critical Value of t	3.15340
Minimum Significant Difference	7.364

Means with the same letter are not significantly different.

## Bon Grouping

	Mean	N	treatment
A	28.820	5	3DOK1
A			
B A	23.980	5	3DOK5
B			
B C	19.920	5	3DOK7
C			
C	14.640	5	3DOK4
C			
C	13.260	5	3DOK13

## Analysis of Variance (One-way ANOVA)

Nitrogen content of red clover (S&amp;T 1980)

ANOVA with SAS PROC GLM with post hoc and HOV tests

## The GLM Procedure

## Scheffe's Test for percent

NOTE: This test controls the Type I experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	20
Error Mean Square	13.6334
Critical Value of F	2.86608
Minimum Significant Difference	7.9069

Means with the same letter are not significantly different.

## Scheffe Grouping

	Mean	N	treatment
A	28.820	5	3Dok1
A			
B A	23.980	5	3Dok5
B			
B C	19.920	5	3Dok7
C			
C	14.640	5	3Dok4
C			
C	13.260	5	3Dok13

## The GLM Procedure

## Dunnett's t Tests for percent

NOTE: This test controls the Type I experimentwise error for comparisons of all treatments against a control.

Alpha	0.05
Error Degrees of Freedom	20
Error Mean Square	13.6334
Critical Value of Dunnett's t	2.65112
Minimum Significant Difference	6.191

Comparisons significant at the 0.05 level are indicated by \*\*\*.

treatment Comparison	Difference Between Means	Simultaneous 95% Confidence Limits	
3Dok5 - 3Dok1	-4.840	-11.031 1.351	
3Dok7 - 3Dok1	-8.900	-15.091 -2.709	***
3Dok4 - 3Dok1	-14.180	-20.371 -7.989	***
3Dok13 - 3Dok1	-15.560	-21.751 -9.369	***

Analysis of Variance (One-way ANOVA)  
 Nitrogen content of red clover (S&T 1980)  
 ANOVA with SAS PROC GLM with post hoc and HOV tests

The GLM Procedure

t Tests (LSD) for percent

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

Alpha	0.05
Error Degrees of Freedom	20
Error Mean Square	13.6334
Critical Value of t	2.08596
Least Significant Difference	4.8712

Comparisons significant at the 0.05 level are indicated by \*\*\*.

treatment Comparison	Difference Between Means	95% Confidence Limits		
3D0k1 - 3D0k5	4.840	-0.031	9.711	
3D0k1 - 3D0k7	8.900	4.029	13.771	***
3D0k1 - 3D0k4	14.180	9.309	19.051	***
3D0k1 - 3D0k13	15.560	10.689	20.431	***
3D0k5 - 3D0k1	-4.840	-9.711	0.031	
3D0k5 - 3D0k7	4.060	-0.811	8.931	
3D0k5 - 3D0k4	9.340	4.469	14.211	***
3D0k5 - 3D0k13	10.720	5.849	15.591	***
3D0k7 - 3D0k1	-8.900	-13.771	-4.029	***
3D0k7 - 3D0k5	-4.060	-8.931	0.811	
3D0k7 - 3D0k4	5.280	0.409	10.151	***
3D0k7 - 3D0k13	6.660	1.789	11.531	***
3D0k4 - 3D0k1	-14.180	-19.051	-9.309	***
3D0k4 - 3D0k5	-9.340	-14.211	-4.469	***
3D0k4 - 3D0k7	-5.280	-10.151	-0.409	***
3D0k4 - 3D0k13	1.380	-3.491	6.251	
3D0k13 - 3D0k1	-15.560	-20.431	-10.689	***
3D0k13 - 3D0k5	-10.720	-15.591	-5.849	***
3D0k13 - 3D0k7	-6.660	-11.531	-1.789	***
3D0k13 - 3D0k4	-1.380	-6.251	3.491	