

```

> Wheat <- c(5.2,4.5,6.0,6.1,6.7,5.7)
> Barley <- c(6.5,8.0,6.1,7.5,5.9,5.6)
> Maize <- c(5.8,4.7,6.4,4.9,6.0,5.2)
> Oats <- c(8.3,6.1,7.8,7.0,5.6,7.2)

> Grain <- c(rep("Wheat", 6), rep("Barley", 6), rep("Maize", 6), rep("Oats", 6))
> Thiamin <- c(Wheat, Barley, Maize, Oats)

> Grain
[1] "Wheat" "Wheat" "Wheat" "Wheat" "Wheat" "Wheat" "Barley" "Barley"
[9] "Barley" "Barley" "Barley" "Barley" "Maize" "Maize" "Maize" "Maize"
[17] "Maize" "Maize" "Oats" "Oats" "Oats" "Oats" "Oats" "Oats"
> Thiamin
[1] 5.2 4.5 6.0 6.1 6.7 5.7 6.5 8.0 6.1 7.5 5.9 5.6 5.8 4.7 6.4 4.9 6.0 5.2 8.3
[20] 6.1 7.8 7.0 5.6 7.2

> results <- glm(Thiamin ~ factor(Grain))
> results

```

```
Call: glm(formula = Thiamin ~ factor(Grain))
```

```
Coefficients:
```

(Intercept)	factor(Grain)Maize	factor(Grain)Oats	factor(Grain)Wheat
6.6	-1.1	0.4	-0.9

```
Degrees of Freedom: 23 Total (i.e. Null); 20 Residual
```

```
Null Deviance: 24.08
```

```
Residual Deviance: 14.84 AIC: 66.57
```

```
> summary(results)
```

```
Call:
```

```
glm(formula = Thiamin ~ factor(Grain))
```

```
Deviance Residuals:
```

Min	1Q	Median	3Q	Max
-1.400e+00	-6.250e-01	-1.776e-15	5.750e-01	1.400e+00

```
Coefficients:
```

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	6.6000	0.3517	18.768	3.62e-14 ***
factor(Grain)Maize	-1.1000	0.4973	-2.212	0.0388 *
factor(Grain)Oats	0.4000	0.4973	0.804	0.4307
factor(Grain)Wheat	-0.9000	0.4973	-1.810	0.0854 .

```
---
```

```
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
(Dispersion parameter for gaussian family taken to be 0.742)
```

```
Null deviance: 24.08 on 23 degrees of freedom
```

```
Residual deviance: 14.84 on 20 degrees of freedom
```

```
AIC: 66.572
```

```
Number of Fisher Scoring iterations: 2
```

```
> summary(aov(results))
```

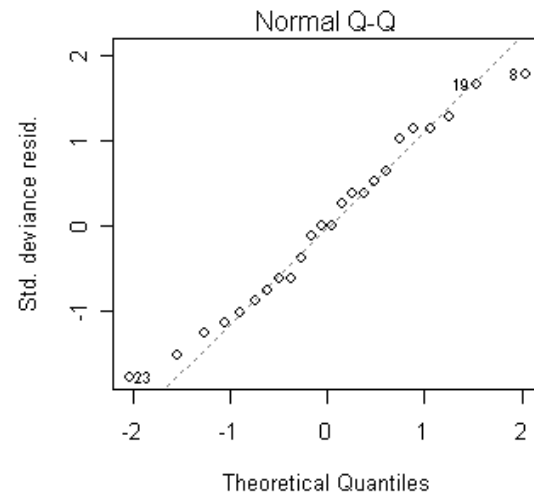
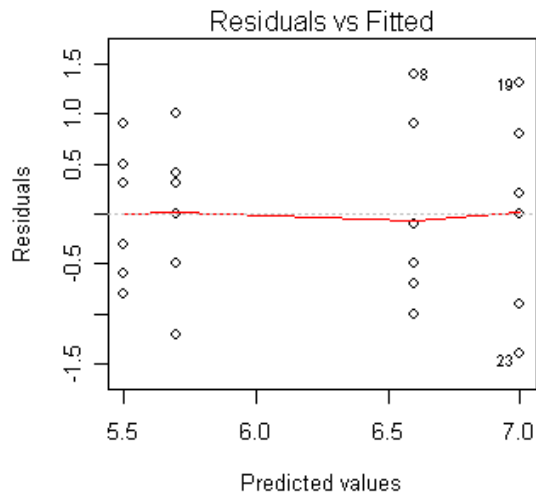
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
factor(Grain)	3	9.240	3.080	4.1509	0.01936 *
Residuals	20	14.840	0.742		

```
---
```

```
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

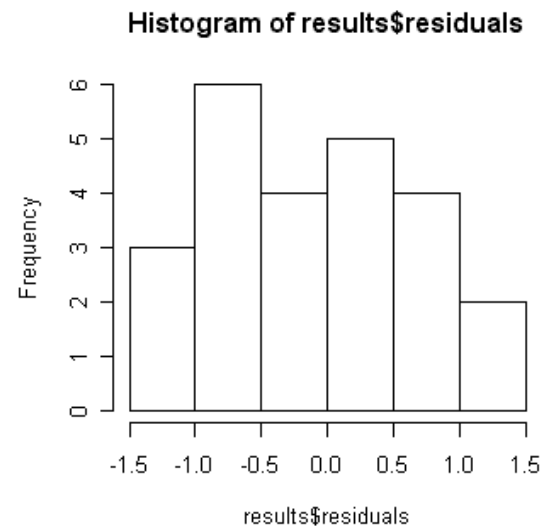
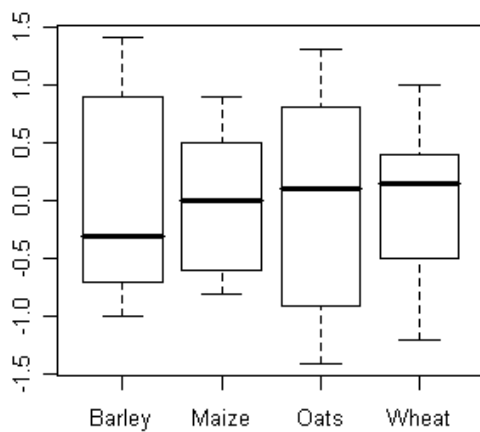
```
> par(mfrow=c(2,2))
```

```
> plot(results)
```



```
> boxplot(results$residuals ~ Grain)
```

```
> hist(results$residuals)
```



```
> shapiro.test(results$residuals)
```

```
Shapiro-Wilk normality test
```

```
data: results$residuals
```

```
W = 0.9704, p-value = 0.6775
```

```

=====

> maize <- c(rep(0,12),rep(1,6),rep(0,6))
> oats <- c(rep(0,18),rep(1,6))
> wheat <- c(rep(1,6),rep(0,18))
>
> maize
[1] 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 0 0 0 0 0 0
> oats
[1] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1
> wheat
[1] 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

```

```

> results2 <- lm(Thiamin ~ maize + oats + wheat)
> summary(results2)

```

Call:

```
lm(formula = Thiamin ~ maize + oats + wheat)
```

Residuals:

	Min	1Q	Median	3Q	Max
	-1.400e+00	-6.250e-01	-6.126e-16	5.750e-01	1.400e+00

Coefficients:

	Estimate	Std. Error	t value	Pr(> t)	
(Intercept)	6.6000	0.3517	18.768	3.62e-14	***
maize	-1.1000	0.4973	-2.212	0.0388	*
oats	0.4000	0.4973	0.804	0.4307	
wheat	-0.9000	0.4973	-1.810	0.0854	.

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.8614 on 20 degrees of freedom

Multiple R-Squared: 0.3837, Adjusted R-squared: 0.2913

F-statistic: 4.151 on 3 and 20 DF, p-value: 0.01936

```
> anova(lm(Thiamin ~ 1), results2)
```

Analysis of Variance Table

Model 1: Thiamin ~ 1

Model 2: Thiamin ~ maize + oats + wheat

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	23	24.08				
2	20	14.84	3	9.24	4.1509	0.01936 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

$$Y_i = \beta_0 + \beta_1 \text{maize}_i + \beta_2 \text{oats}_i + \beta_3 \text{wheat}_i + \varepsilon_i, \quad i = 1, 2, \dots, 24.$$

μ_{Barley}	β_0	$H_0: \mu_{\text{Barley}} = \mu_{\text{Maize}} = \mu_{\text{Oats}} = \mu_{\text{Wheat}}$	
μ_{Maize}	$\beta_0 + \beta_1$		
μ_{Oats}	$\beta_0 + \beta_2$		$\Leftrightarrow H_0: \beta_1 = \beta_2 = \beta_3 = 0$
μ_{Wheat}	$\beta_0 + \beta_3$		

=====

```
> barley <- c(rep(0,6),rep(1,6),rep(0,12))
> barley
[1] 0 0 0 0 0 0 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0

> results3 <- lm(Thiamin ~ maize + oats + wheat + barley)
> summary(results3)
```

```
Call:
lm(formula = Thiamin ~ maize + oats + wheat + barley)
```

```
Residuals:
      Min       1Q   Median       3Q      Max
-1.400e+00 -6.250e-01 -6.126e-16  5.750e-01  1.400e+00
```

```
Coefficients: (1 not defined because of singularities)
              Estimate Std. Error t value Pr(>|t|)
(Intercept)   6.6000      0.3517  18.768 3.62e-14 ***
maize         -1.1000      0.4973  -2.212  0.0388 *
oats           0.4000      0.4973   0.804  0.4307
wheat         -0.9000      0.4973  -1.810  0.0854 .
barley         NA           NA      NA      NA
---

```

```
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
Residual standard error: 0.8614 on 20 degrees of freedom
Multiple R-Squared: 0.3837,    Adjusted R-squared: 0.2913
F-statistic: 4.151 on 3 and 20 DF,  p-value: 0.01936
```

=====

```
> Grain2 <- c(rep(1,6),rep(2,6),rep(3,6),rep(4,6))
> results4 <- glm(Thiamin ~ factor(Grain2))
> summary(aov(results4))
```

```
              Df Sum Sq Mean Sq F value    Pr(>F)
factor(Grain2)  3   9.240    3.080   4.1509 0.01936 *
Residuals      20  14.840     0.742
---

```

```
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```