Flax Example: Balanced RCB

This example is taken from Steele and Torrie. We consider oil content in Redwing flaxseed inoculated at five different growth stages with the organism that causes "pasmo" (plus control). We have six treatments (t=6) randomly assigned in four blocks (b=4).

Notes:

1. The primary research questions are focused on comparing means for the 6 treatments. This can be done using the ANOVA table (using Anova) and pairwise comparisons (using emmeans).

2. Block is included in the model to account for the experimental design. In this example, we treat blocks as FIXED. Later (in Random2 notes), we will discuss treating blocks as RANDOM.

3. Due to balance, simple means are the same as the emmeans. Also Type 1 (anova) and Type 3 (Anova) tests are the same.

4. Summary() info (Coefficients table) and model.matrix not of much interest for typical analysis. Shown here for illustration.

```r
library(dplyr)
library(car)
library(emmeans)
Flax <- read.csv("C:/hess/STAT512/RNotes/ExpDesign1/ED1_FlaxRCB.csv")
str(Flax)
```

```
## 'data.frame':    24 obs. of  3 variables:
##  $ block: int  1 1 1 1 1 1 2 2 2 2 ...
##  $ oil  : num  34.4 33.3 34.4 36.8 36.3 36.4 35.9 31.9 34 36.6 ...
##  $ stage: Factor w/ 6 levels "1seeding","2earlybl",..: 1 2 3 4 5 6 1 2 3 4 ...
```

```r
#Important: Need to define block as.factor!
Flax$block <- as.factor(Flax$block)
SumStats <- summarise(group_by(Flax, stage),
                      n = n(),
                      mean = mean(oil),
                      sd = sd(oil),
                      SE = sd/sqrt(n))
SumStats
```

```
## # A tibble: 6 x 5
##   stage        n  mean    sd    SE
##   <fct>    <int> <dbl> <dbl> <dbl>
## 1 1seeding     4  35.1 0.990 0.495
## 2 2earlybl     4  34.3 2.23  1.12
## 3 3fullblm     4  34   0.638 0.319
## 4 4full100     4  36.7 0.258 0.129
## 5 5ripenin     4  36.0 0.915 0.457
## 6 6uninoc      4  37.0 0.585 0.293
```

```r
Model1 <- lm(oil ~ block + stage, data = Flax)
Anova(Model1, type = 3)
```

```
## Anova Table (Type III tests)
##
## Response: oil
##                 Sum Sq Df   F value     Pr(>F)
```

```
## (Intercept) 3236.4  1 2462.2358 < 2.2e-16 ***
## block         3.1   3    0.7966  0.514715
## stage        31.7   5    4.8161  0.007964 **
## Residuals    19.7  15
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
emmeans(Model1, pairwise ~ stage)
```

```
## $emmeans
##  stage     emmean        SE df lower.CL upper.CL
##  1seeding 35.100 0.5732401 15 33.87817 36.32183
##  2earlybl 34.300 0.5732401 15 33.07817 35.52183
##  3fullblm 34.000 0.5732401 15 32.77817 35.22183
##  4full100 36.700 0.5732401 15 35.47817 37.92183
##  5ripenin 36.050 0.5732401 15 34.82817 37.27183
##  6uninoc  37.025 0.5732401 15 35.80317 38.24683
##
## Results are averaged over the levels of: block
## Confidence level used: 0.95
##
## $contrasts
##  contrast            estimate        SE df t.ratio p.value
##  1seeding - 2earlybl    0.800 0.8106839 15   0.987  0.9152
##  1seeding - 3fullblm    1.100 0.8106839 15   1.357  0.7504
##  1seeding - 4full100   -1.600 0.8106839 15  -1.974  0.3997
##  1seeding - 5ripenin   -0.950 0.8106839 15  -1.172  0.8432
##  1seeding - 6uninoc    -1.925 0.8106839 15  -2.375  0.2257
##  2earlybl - 3fullblm    0.300 0.8106839 15   0.370  0.9989
##  2earlybl - 4full100   -2.400 0.8106839 15  -2.960  0.0845
##  2earlybl - 5ripenin   -1.750 0.8106839 15  -2.159  0.3110
##  2earlybl - 6uninoc    -2.725 0.8106839 15  -3.361  0.0406
##  3fullblm - 4full100   -2.700 0.8106839 15  -3.331  0.0430
##  3fullblm - 5ripenin   -2.050 0.8106839 15  -2.529  0.1767
##  3fullblm - 6uninoc    -3.025 0.8106839 15  -3.731  0.0202
##  4full100 - 5ripenin    0.650 0.8106839 15   0.802  0.9628
##  4full100 - 6uninoc    -0.325 0.8106839 15  -0.401  0.9984
##  5ripenin - 6uninoc    -0.975 0.8106839 15  -1.203  0.8290
##
## Results are averaged over the levels of: block
## P value adjustment: tukey method for comparing a family of 6 estimates
```

```
par(mfrow=c(2,2))
plot(Model1)
```
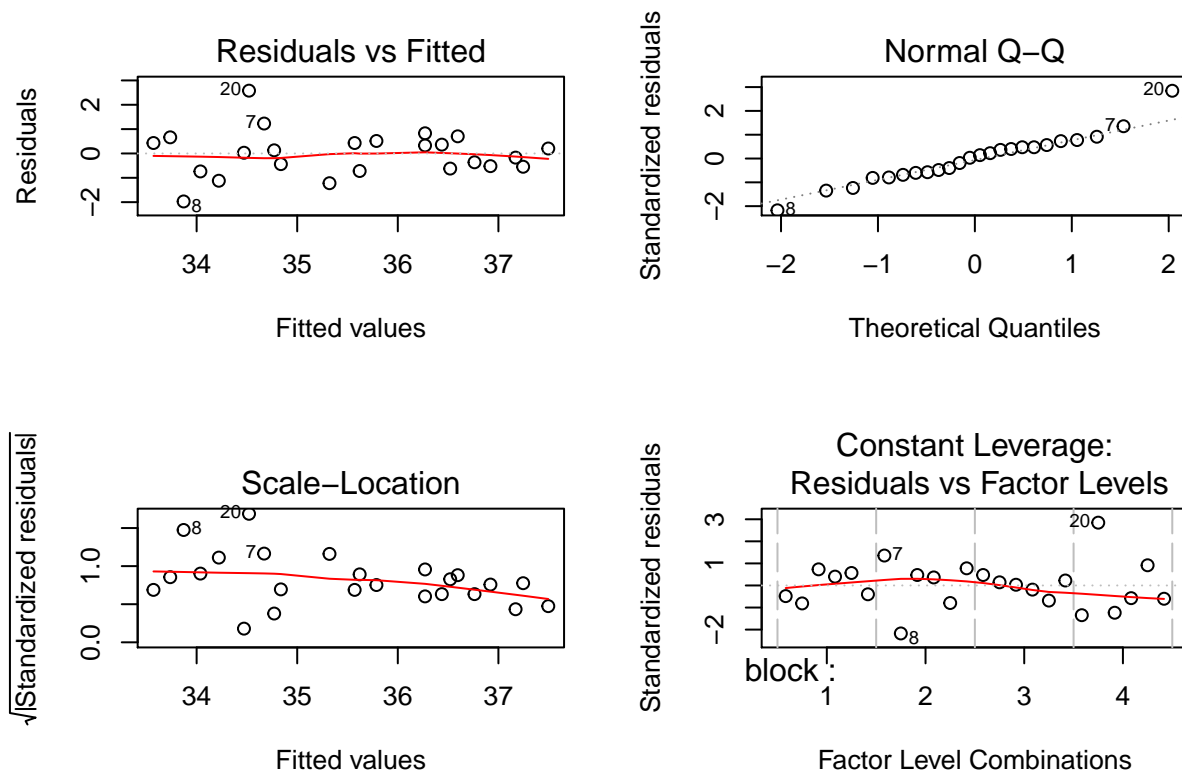
The rest of the output is primarily for illustration.

Summary() info (Coefficients table) and model.matrix not of much interest for typical analysis.

```r
anova(Model1)
```

```
## Analysis of Variance Table
##
## Response: oil
##           Df Sum Sq Mean Sq F value    Pr(>F)
## block      3  3.141  1.0471  0.7966 0.514715
## stage      5 31.652  6.3304  4.8161 0.007964 **
## Residuals 15 19.716  1.3144
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
summary(Model1)
```

```
##
## Call:
## lm(formula = oil ~ block + stage, data = Flax)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.97083 -0.56458  0.07917  0.45000  2.57917
##
```

3

```
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)    34.8375     0.7021  49.621   <2e-16 ***
## block2         -0.1667     0.6619  -0.252   0.8046
## block3          0.7333     0.6619   1.108   0.2854
## block4          0.4833     0.6619   0.730   0.4765
## stage2earlybl  -0.8000     0.8107  -0.987   0.3394
## stage3fullblm  -1.1000     0.8107  -1.357   0.1949
## stage4full100   1.6000     0.8107   1.974   0.0671 .
## stage5ripenin   0.9500     0.8107   1.172   0.2595
## stage6uninoc    1.9250     0.8107   2.375   0.0313 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.146 on 15 degrees of freedom
## Multiple R-squared:  0.6383, Adjusted R-squared:  0.4454
## F-statistic: 3.309 on 8 and 15 DF,  p-value: 0.02193
```

```
model.matrix(Model1)
```

```
##    (Intercept) block2 block3 block4 stage2earlybl stage3fullblm
## 1            1      0      0      0             0             0
## 2            1      0      0      0             1             0
## 3            1      0      0      0             0             1
## 4            1      0      0      0             0             0
## 5            1      0      0      0             0             0
## 6            1      0      0      0             0             0
## 7            1      1      0      0             0             0
## 8            1      1      0      0             1             0
## 9            1      1      0      0             0             1
## 10           1      1      0      0             0             0
## 11           1      1      0      0             0             0
## 12           1      1      0      0             0             0
## 13           1      0      1      0             0             0
## 14           1      0      1      0             1             0
## 15           1      0      1      0             0             1
## 16           1      0      1      0             0             0
## 17           1      0      1      0             0             0
## 18           1      0      1      0             0             0
## 19           1      0      0      1             0             0
## 20           1      0      0      1             1             0
## 21           1      0      0      1             0             1
## 22           1      0      0      1             0             0
## 23           1      0      0      1             0             0
## 24           1      0      0      1             0             0
##    stage4full100 stage5ripenin stage6uninoc
## 1              0             0            0
## 2              0             0            0
## 3              0             0            0
## 4              1             0            0
## 5              0             1            0
## 6              0             0            1
## 7              0             0            0
## 8              0             0            0
## 9              0             0            0
```

```
## 10                1            0            0
## 11                0            1            0
## 12                0            0            1
## 13                0            0            0
## 14                0            0            0
## 15                0            0            0
## 16                1            0            0
## 17                0            1            0
## 18                0            0            1
## 19                0            0            0
## 20                0            0            0
## 21                0            0            0
## 22                1            0            0
## 23                0            1            0
## 24                0            0            1
## attr(,"assign")
## [1] 0 1 1 1 2 2 2 2 2
## attr(,"contrasts")
## attr(,"contrasts")$block
## [1] "contr.treatment"
##
## attr(,"contrasts")$stage
## [1] "contr.treatment"
```