Poplar Example: Four-way Factorial Analysis

Four way factorial experiment run in a blocked design.

```
library(dplyr)
library(ggplot2)
library(car)
library(emmeans)
Poplar <- read.csv("C:/hess/STAT512/RNotes/ExpDesign2/ED2_Poplar.csv")
str(Poplar)
```

```
## 'data.frame':    48 obs. of  6 variables:
##  $ block: int  1 1 1 1 1 1 1 1 1 1 ...
##  $ L    : int  1 1 1 1 1 1 1 1 2 2 ...
##  $ N    : int  1 1 1 1 2 2 2 2 1 1 ...
##  $ K    : int  1 1 2 2 1 1 2 2 1 1 ...
##  $ P    : int  1 2 1 2 1 2 1 2 1 2 ...
##  $ drywt: num  13.9 14.2 14.7 13.6 31.7 57.9 49.5 49.7 15.3 11.8 ...
```

```
#Important: Define things as.factor!
Poplar$block <- as.factor(Poplar$block)
Poplar$L <- as.factor(Poplar$L)
Poplar$N <- as.factor(Poplar$N)
Poplar$K <- as.factor(Poplar$K)
Poplar$P <- as.factor(Poplar$P)
str(Poplar)
```

```
## 'data.frame':    48 obs. of  6 variables:
##  $ block: Factor w/ 3 levels "1","2","3": 1 1 1 1 1 1 1 1 1 1 ...
##  $ L    : Factor w/ 2 levels "1","2": 1 1 1 1 1 1 1 1 2 2 ...
##  $ N    : Factor w/ 2 levels "1","2": 1 1 1 1 2 2 2 2 1 1 ...
##  $ K    : Factor w/ 2 levels "1","2": 1 1 2 2 1 1 2 2 1 1 ...
##  $ P    : Factor w/ 2 levels "1","2": 1 2 1 2 1 2 1 2 1 2 ...
##  $ drywt: num  13.9 14.2 14.7 13.6 31.7 57.9 49.5 49.7 15.3 11.8 ...
```

```
SumStats <- summarize(group_by(Poplar, N, L, K, P),
              n    = n(),
              mean = mean(drywt),
              sd   = sd(drywt),
              SE   = sd/sqrt(n))
SumStats
```

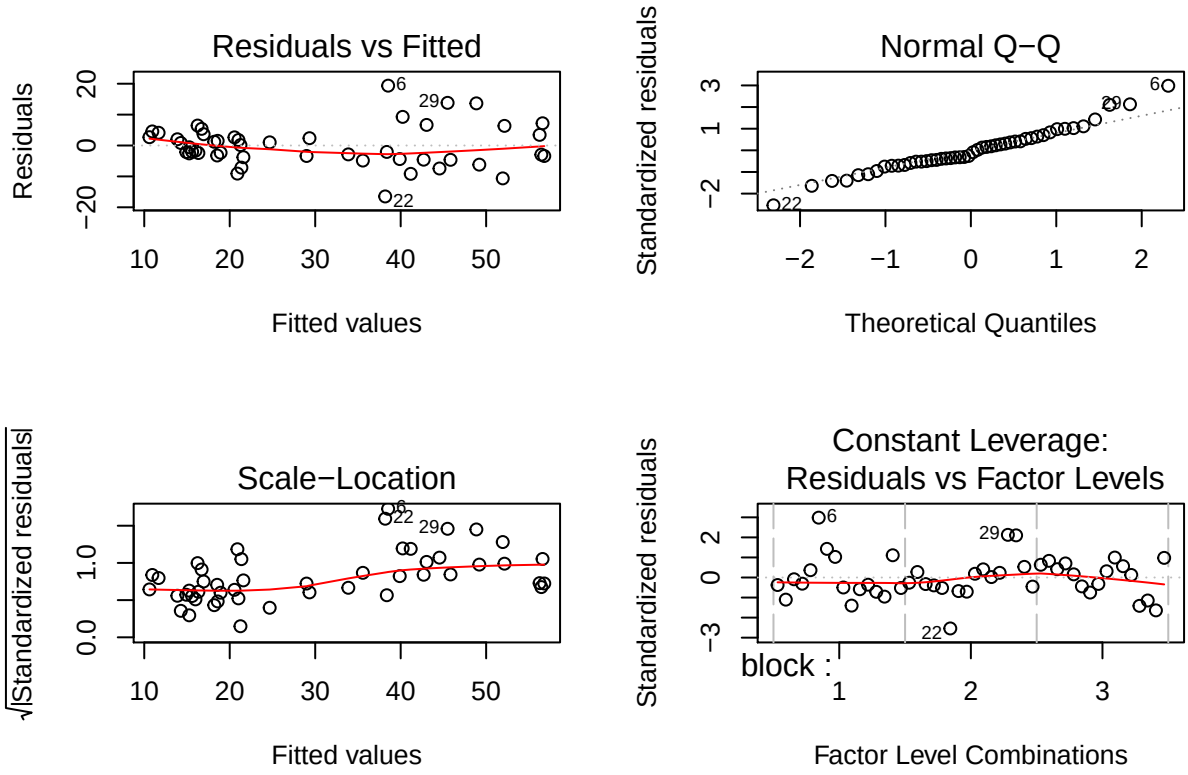
```
## # A tibble: 16 x 8
## # Groups:   N, L, K [?]
##    N     L     K     P         n  mean     sd     SE
##    <fct> <fct> <fct> <fct> <int> <dbl>  <dbl>  <dbl>
##  1 1     1     1     1         3  14.7  1.00   0.578
##  2 1     1     1     2         3  19.7  4.78   2.76
##  3 1     1     2     1         3  13.6  0.985  0.569
##  4 1     1     2     2         3  13.9  1.43   0.825
##  5 1     2     1     1         3  16.9  2.21   1.28
##  6 1     2     1     2         3  19.2  6.44   3.72
##  7 1     2     2     1         3  19.9  1.89   1.09
##  8 1     2     2     2         3  17.3  2.57   1.48
##  9 2     1     1     1         3  27.7  3.49   2.02
```

```
## 10 2     1     1     2         3  36.9 18.8   10.9
## 11 2     1     2     1         3  38.6  9.77   5.64
## 12 2     1     2     2         3  41.4  7.27   4.20
## 13 2     2     1     1         3  44.2 13.9    8.02
## 14 2     2     1     2         3  47.5 13.3    7.67
## 15 2     2     2     1         3  54.9 12.0    6.92
## 16 2     2     2     2         3  55.1  2.92   1.68
```

```
#Change contrasts options to get meaningful Type 3 tests!
options(contrasts = c("contr.sum", "contr.poly"))
Model1 <- lm(drywt ~ block + L*N*K*P, data = Poplar)
Anova(Model1, type = 3)
```

```
## Anova Table (Type III tests)
##
## Response: drywt
##             Sum Sq Df  F value    Pr(>F)
## (Intercept)  43458  1 644.5710 < 2.2e-16 ***
## block          215  2   1.5978  0.219094
## L              885  1  13.1254  0.001064 **
## N             8350  1 123.8513  3.58e-12 ***
## K              147  1   2.1855  0.149741
## P               80  1   1.1840  0.285216
## L:N            395  1   5.8590  0.021761 *
## L:K             22  1   0.3304  0.569705
## N:K            293  1   4.3390  0.045870 *
## L:P             37  1   0.5529  0.462924
## N:P             21  1   0.3066  0.583876
## K:P             70  1   1.0359  0.316918
## L:N:K            5  1   0.0686  0.795175
## L:N:P            1  1   0.0213  0.884976
## L:K:P            2  1   0.0234  0.879476
## N:K:P            0  1   0.0001  0.993046
## L:N:K:P          2  1   0.0354  0.852074
## Residuals     2023 30
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
par(mfrow = c(2, 2))
plot(Model1)
```



After looking at the ANOVA table, follow up with some pairwise comparisons and graphs.

```
emmeans(Model1, pairwise ~ L|N)
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

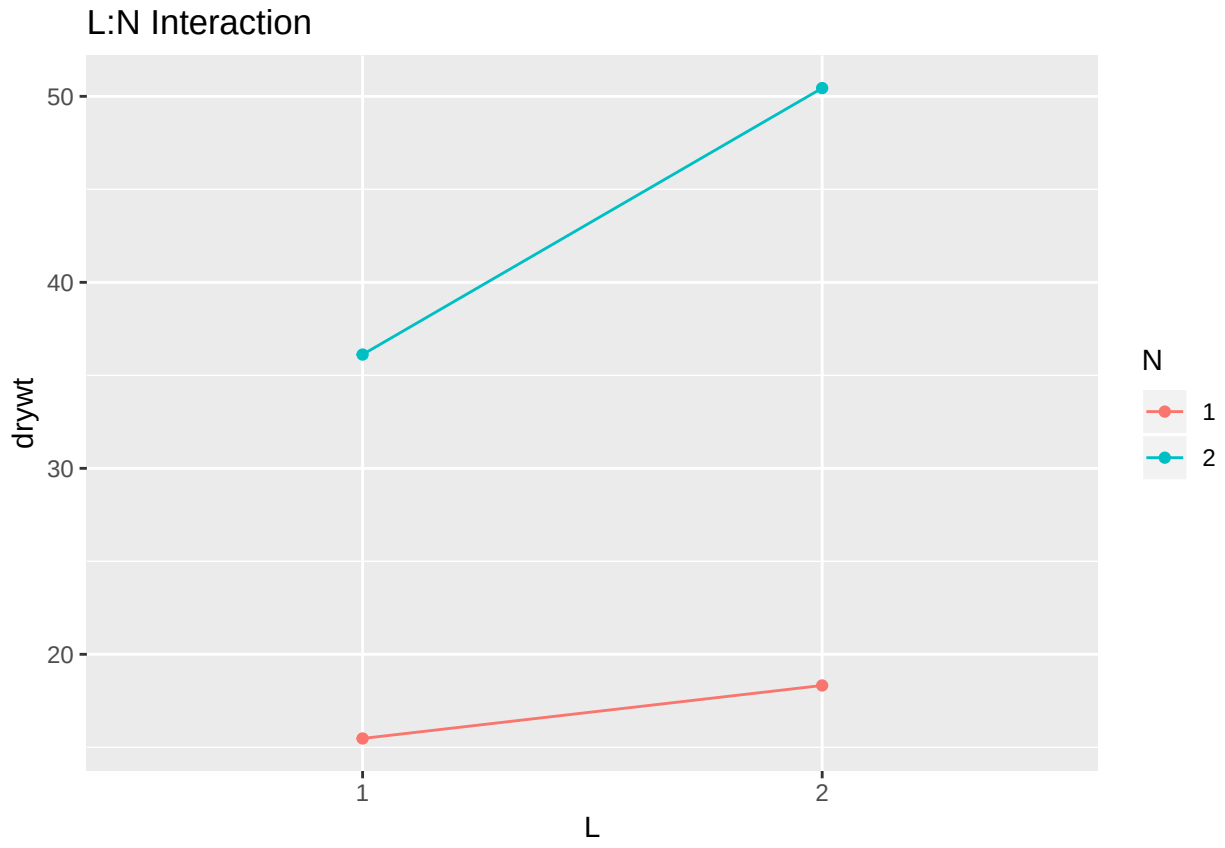
```
## $emmeans
## N = 1:
##  L emmean   SE df lower.CL upper.CL
##  1   15.5 2.37 30     10.6     20.3
##  2   18.3 2.37 30     13.5     23.2
##
## N = 2:
##  L emmean   SE df lower.CL upper.CL
##  1   36.1 2.37 30     31.3     41.0
##  2   50.4 2.37 30     45.6     55.3
##
## Results are averaged over the levels of: block, K, P
## Confidence level used: 0.95
##
## $contrasts
## N = 1:
##  contrast estimate   SE df t.ratio p.value
##  1 - 2       -2.85 3.35 30 -0.850  0.4020
##
## N = 2:
##  contrast estimate   SE df t.ratio p.value
```

```
##  1 - 2      -14.32 3.35 30 -4.273  0.0002
##
## Results are averaged over the levels of: block, K, P
```

```
SSLN <- aggregate(drywt ~ L + N, data = Poplar, FUN = mean)
SSLN
```

```
##   L N    drywt
## 1 1 1 15.47500
## 2 2 1 18.32500
## 3 1 2 36.11667
## 4 2 2 50.44167
```

```
qplot(x = L, y = drywt, colour = N, group = N, data = SSLN) +
  geom_line() + ggtitle("L:N Interaction")
```




```
emmeans(Model1, pairwise ~ K|N)
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

```
## $emmeans
## N = 1:
##  K emmean   SE df lower.CL upper.CL
##  1   17.6 2.37 30     12.8     22.5
##  2   16.2 2.37 30     11.3     21.0
##
## N = 2:
##  K emmean   SE df lower.CL upper.CL
##  1   39.1 2.37 30     34.2     43.9
```

```
##  2   47.5 2.37 30     42.7     52.3
##
## Results are averaged over the levels of: block, L, P
## Confidence level used: 0.95
##
## $contrasts
## N = 1:
##  contrast estimate   SE df t.ratio p.value
##  1 - 2        1.43 3.35 30  0.428  0.6720
##
## N = 2:
##  contrast estimate   SE df t.ratio p.value
##  1 - 2       -8.44 3.35 30 -2.518  0.0174
##
## Results are averaged over the levels of: block, L, P
```

```
SSKN <- aggregate(drywt ~ K + N, data = Poplar, FUN = mean)
SSKN
```

```
##   K N    drywt
## 1 1 1 17.61667
## 2 2 1 16.18333
## 3 1 2 39.05833
## 4 2 2 47.50000
```

```
qplot(x = K, y = drywt, colour = N, group = N, data = SSKN) +
  geom_line() + ggtitle("K:N Interaction")
```