

Objective: Use multiway anova to analyze crop.data.csv. Show all work and comment on what the code is doing. Are all 3 main effects (including blocks) significant? Are any interaction effects significant? Which pairs of means show significance under Tukey's HSD?

To use multi-way ANOVA on crop.data.csv, I first read the csv file as a data frame called crop.data. I then specified the col_types to set the data type of each column in the data frame. This way, I could set density, block, and fertilizer as factors, and yield as a double (a decimal number).

```
crop.data <- read_csv("crop.data.csv",
                      col_types = cols(density = col_factor(),
                                       block = col_factor(),
                                       fertilizer = col_factor(),
                                       yield = col_double()))
crop.aov <- aov(yield ~ density * fertilizer * block, data = crop.data)
```

I then printed out the summary of the ANOVA model.

```
      Df Sum Sq Mean Sq F value    Pr(>F)
density    1  5.122    5.122   14.854 0.000226 ***
fertilizer  2  6.068    3.034    8.799 0.000339 ***
block       2  0.486    0.243    0.705 0.497028
density:fertilizer  2  0.428    0.214    0.620 0.540182
fertilizer:block    4  0.887    0.222    0.643 0.633043
Residuals    84 28.963    0.345
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Then, to calculate Tukey's HSD (Honest Significant Difference), I used the TukeyHSD() function to compare the average yield for each fertilizer level and found which pairs of averages are significantly different from one another. I set the confidence level for the comparisons to 95%.

```
TukeyHSD(crop.aov, which = "fertilizer", conf.level = 0.95)
```

The output is as follows:

```

Tukey multiple comparisons of means
 95% family-wise confidence level

Fit: aov(formula = yield ~ density * fertilizer * block, data = crop.data)

$fertilizer
      diff      lwr      upr    p adj
2-1 0.1761687 -0.17408761 0.5264251 0.4564613
3-1 0.5991256  0.24886924 0.9493819 0.0002969
3-2 0.4229569  0.07270052 0.7732132 0.0137889

```

Not all three main effects are significant. The output shows that density (p-value = 0.000226) and fertilizer (p-value = 0.000339) are highly significant (p-value < 0.001), but the block effect is not significant (p-value = 0.497028). Therefore, while density and fertilizer have a significant effect on crop yield, the block effect is not statistically significant.

None of the interaction effects (density:fertilizer and fertilizer:block) are significant. The output shows p-values of 0.540182 and 0.633043 for the two interaction effects which are both greater than 0.05. This means that the effects of density and fertilizer on crop yield are not significantly different across the levels of the other factor.

The Tukey's HSD test compares the average crop yield for each level of the fertilizer factor. The output shows that the average yield for fertilizer level 3 is significantly different from both fertilizer level 1 (p-value = 0.0002969) and fertilizer level 2 (p-value = 0.0137889). However, the average yield for both fertilizer levels 1 and 2 are not significantly different from each other (p-value = 0.4564613).