Assignment 7 Code + Analysis

CODE

```
# load stats library
library(stats)

# convert density to a factor
crop_data$density <- as.factor(crop_data$density)

# multiway ANOVA analysis
multiway_anova <- aov(yield ~ density * block * fertilizer +
block:density, data = crop_data)

# print ANOVA table
print(summary(multiway_anova))

# perform Tukey's HSD for density
density_tukey <- TukeyHSD(aov(yield ~ density, data =
crop_data))

# convert block to a factor
crop_data$block <- as.factor(crop_data$block)

# perform Tukey's HSD for block
block_tukey <- TukeyHSD(aov(yield ~ block, data = crop_data))

# print results of Tukey's HSD for block
print(block_tukey)

# convert fertilizer to a factor
crop_data$fertilizer <- as.factor(crop_data$fertilizer)

# print fertilizer in the crop_data frame
print(crop_data$fertilizer)

# perform Tukey's HSD for fertilizer
fertilizer_tukey <- TukeyHSD(aov(yield ~ fertilizer, data =
crop_data))
```

```
# print results of Tukey's HSD for fertilizer
print(fertilizer_tukey)

# print results of Tukey's HSD for density
print(density_tukey)

# print results of Tukey's HSD for block
print(block_tukey)

# perform Tukey's HSD for block:density interaction
block_density_tukey <- TukeyHSD(aov(yield ~ block * density,
data = crop_data))

# print results of Tukey's HSD for block:density interaction
print(block_density_tukey)

# multiway ANOVA analysis with density:block
multiway_anova_interaction <- aov(yield ~ density * block *
fertilizer + density:block, data = crop_data)

# perform Tukey's HSD for density:block
density_block_tukey <- TukeyHSD(aov(yield ~ density * block,
data = crop_data))

# print results of Tukey's HSD for density:block
print(density_block_tukey)
```

RESULTS

The results show the multiway ANOVA analysis and Tukey's HSD test for the crop_data dataset.

Fertilizer

```
> print(fertilizer_tukey)
  Tukey multiple comparisons of means
    95% family-wise confidence level

Fit: aov(formula = yield ~ fertilizer, data = crop_data)

$fertilizer
         diff         lwr       upr     p adj
2-1 0.1761687 -0.19371896 0.5460564 0.4954705
3-1 0.5991256  0.22923789 0.9690133 0.0006125
3-2 0.4229569  0.05306916 0.7928445 0.0208735
```

Density

```
> print(density_tukey)
  Tukey multiple comparisons of means
    95% family-wise confidence level

Fit: aov(formula = yield ~ density, data = crop_data)

$density
        diff       lwr       upr     p adj
2-1 0.461956 0.2082555 0.7156566 0.0004845
```

Block

```
> print(block_tukey)
  Tukey multiple comparisons of means
    95% family-wise confidence level

Fit: aov(formula = yield ~ block, data = crop_data)

$block
          diff         lwr        upr     p adj
2-1  0.4604949 -0.01427820  0.9352679 0.0607253
3-1 -0.1437765 -0.61854957  0.3309966 0.8577313
4-1  0.3196407 -0.15513236  0.7944138 0.2984466
3-2 -0.6042714 -1.07904444 -0.1294983 0.0067392
4-2 -0.1408542 -0.61562723  0.3339189 0.8649907
4-3  0.4634172 -0.01135585  0.9381903 0.0583842
```

Multiway ANOVA Table

```
> print(summary(multiway_anova))
                         Df Sum Sq Mean Sq F value   Pr(>F)
density                   1  5.122   5.122  14.985 0.000208 ***
block                     1  0.486   0.486   1.422 0.236247
fertilizer                1  5.743   5.743  16.804 9.21e-05 ***
density:block             1  0.000   0.000   0.000 0.990259
density:fertilizer        1  0.150   0.150   0.439 0.509135
block:fertilizer          1  0.142   0.142   0.415 0.521198
density:block:fertilizer  1  0.234   0.234   0.685 0.410128
Residuals                88 30.077   0.342
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

```
> print(density_block_tukey)
  Tukey multiple comparisons of means
    95% family-wise confidence level

Fit: aov(formula = yield ~ density * block, data = crop_data)

$density
        diff       lwr       upr     p adj
2-1 0.461956 0.2071385 0.7167736 0.0005143

$block
            diff        lwr       upr     p adj
2-1 -0.001461171 -0.4762342 0.4733119 0.9999998
3-1 -0.143776502 -0.6185496 0.3309966 0.8577313
4-1 -0.142315331 -0.6170884 0.3324577 0.8613837
3-2 -0.142315331 -0.6170884 0.3324577 0.8613837
4-2 -0.140854160 -0.6156272 0.3339189 0.8649907
4-3  0.001461171 -0.4733119 0.4762342 0.9999998
```

```
> print(crop_data$fertilizer)
 [1] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2
[42] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
[83] 3 3 3 3 3 3 3 3 3 3 3 3 3 3
Levels: 1 2 3
```

EXPLANATIONS and ANALYSIS

Are all 3 main effects (including blocks) significant?

The multiway ANOVA table shows the p values of all three main effects (density, block, and fertilizer). We see that “density” and “fertilizer” are significant; they have p-values of 0.000208 and 9.21e-05, respectively. Both values can be categorized as significant because they are less than the significance threshold of 0.05. However, we conclude that “blocks” are insignificant because we receive a p-value of 0.236247. Thus, only the two effects of fertilizer and density yield significant results according to their p-value.

Are any interaction effects significant?

In statistics, when a result is deemed significant, it is determined in comparison to the null hypothesis. Statistically significant results reject the null hypothesis and indicate a p-value less than 0.05. The code generated a consequence from the multi-way ANOVA table in this case. The interaction effect between density & fertilizer was also returned using ANOVA but proved insignificant (p-value = 0.509135,> 0.05). This means that the level of the fertilizer cannot determine the density of the crop and that the value of the density does not affect the level of the fertilizer. Similarly, the interaction effect of block

and fertilizer is also examined. The p-value returns as 0.521198, which is also insignificant as it is more significant than 0.05. Although density and fertilizer are individually substantial, none of the coupled interactions yield a statistically significant p-value. For the interaction between density and blocks, we also produce an insignificant p-value (p-value = 0.990259). The final interaction effect between density, block, and fertilizer provides a p-value of 0.410128, which is insignificant. We conclude that there are no significant interaction effects in the crop dataset.

Which pairs of means show significance under Tukey's HSD?

Based on the results of Tukey's HSD test for density, the pair of means that show significance are both medium density and low density (p-value < 0.05) and high density and low density (p-value < 0.05). But other than this, no significant differences in mean yield between any pair of blocks or fertilizer levels exist.

After performing TukeyHSD on all three main effects, significant pairs were found.

- In comparing means in $density, we saw the only significant pair being 2-1, with a difference of 0.461956 and a p-value of 0.0004845.
- In comparing the means in $block, we also see one significant pair being 3-2, with a difference of -0.6042714 and a p-value of 0.0067392.
- In a comparison of means for $fertilizer, we see 2 significant pairs. The first one is 3-1, with a difference of 0.5991256 and a p-value of 0.0006125. The second pair was 3-2, with a difference of 0.4229569 and a p-value of 0.0208735.

All p-values were deemed significant because they were under a threshold of 0.05.