

5.1.3: Two-Factor Factorial - Greenhouse Example (R)

- Load the greenhouse data.
- Produce a boxplot to plot the differences in heights for each species organized by fertilizer.
- Produce a “means plot” (interval plot) to view the differences in heights for each species organized by fertilizer.
- Obtain the ANOVA table with interaction.
- Obtain Tukey’s multiple comparisons CIs, grouping, and plot.

1. Load the greenhouse data by using the following commands:

```
setwd("~/path-to-folder/")
greenhouse_2way_data <- read.table("greenhouse_2way_data.txt", header=T)
attach(greenhouse_2way_data)
```

2. Produce the Boxplot by using the following commands:

```
library("ggpubr")
boxplot(height ~ species*fertilizer, data = greenhouse_2way_data,
        xlab = "Species", ylab = "Plant Height",
        main="Distribution of Plant Height by Species",
        frame = TRUE)
```


 R-generated boxplot for distribution of plant height by species.

Figure 5.1.3.1: Boxplot of plant height distribution by species.

3. Produce the means plot (interval plot) by using the following commands:

```
library("gplots")
plotmeans(height ~ interaction(species,fertilizer), data = greenhouse_2way_data, connect=T,
        xlab = "Fertilizer*species", ylab = "Plant Height",
        main="Means Plot with 95% CI")
```


 Means plot with 95% confidence intervals for plant height vs. Fertilizer*Species

Figure 5.1.3.2: Means plot for plant height vs fertilizer*species.

4. Obtain the ANOVA table with interaction by using the following commands:

```
anova<-aov(height~fertilizer+species+fertilizer*species,greenhouse_2way_data)
summary(anova)
```

	#	Df	Sum Sq	Mean Sq	F value	Pr(>F)
# fertilizer		3	745.4	248.48	73.10	2.77e-16 ***
# species		1	236.7	236.74	69.64	2.71e-10 ***
# fertilizer:species		3	50.6	16.86	4.96	0.00508 **
# Residuals		40	136.0	3.40		
# ---						
# Signif. codes:						0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

5. Obtain Tukey multiple comparisons of means with 95% family-wise confidence level by using the following commands:

```
library(multcomp)
library(multcompView)
tukey_multiple_comparisons<-TukeyHSD(anova, conf.level=0.95, ordered=TRUE)
```

```

tukey_multiple_comparisons
Tukey multiple comparisons of means
95% family-wise confidence level
factor levels have been ordered
Fit: aov(formula = height ~ fertilizer + species + fertilizer * species, data = green)
$Fertilizer
diff      lwr      upr      p adj
f2-control  5.608333  3.5908095  7.625857  0.0000000
f1-control  7.758333  5.7408095  9.775857  0.0000000
f3-control 10.783333  8.7658095 12.800857  0.0000000
f1-f2       2.150000  0.1324762  4.167524  0.0328745
f3-f2       5.175000  3.1574762  7.192524  0.0000002
f3-f1       3.025000  1.0074762  5.042524  0.0013828
$species
diff      lwr      upr p adj
SppB-SppA 4.441667  3.365986  5.517348    0
$`fertilizer:species`
diff      lwr      upr      p adj
control:SppB-control:SppA  2.700000 -0.7025601  6.102560  0.2100548
f2:SppA-control:SppA      4.866667  1.4641065  8.269227  0.0010962
f1:SppA-control:SppA      7.600000  4.1974399 11.002560  0.0000003
f3:SppA-control:SppA      8.200000  4.7974399 11.602560  0.0000001
f2:SppB-control:SppA      9.050000  5.6474399 12.452560  0.0000000
f1:SppB-control:SppA     10.616667  7.2141065 14.019227  0.0000000
f3:SppB-control:SppA     16.066667 12.6641065 19.469227  0.0000000
f2:SppA-control:SppB      2.166667 -1.2358935  5.569227  0.4721837
f1:SppA-control:SppB      4.900000  1.4974399  8.302560  0.0009970
f3:SppA-control:SppB      5.500000  2.0974399  8.902560  0.0001745
f2:SppB-control:SppB      6.350000  2.9474399  9.752560  0.0000138
f1:SppB-control:SppB      7.916667  4.5141065 11.319227  0.0000001
f3:SppB-control:SppB     13.366667  9.9641065 16.769227  0.0000000
f1:SppA-f2:SppA          2.733333 -0.6692268  6.135893  0.1979193
f3:SppA-f2:SppA          3.333333 -0.0692268  6.735893  0.0584747
f2:SppB-f2:SppA          4.183333  0.7807732  7.585893  0.0072041
f1:SppB-f2:SppA          5.750000  2.3474399  9.152560  0.0000832
f3:SppB-f2:SppA         11.200000  7.7974399 14.602560  0.0000000
f3:SppA-f1:SppA          0.600000 -2.8025601  4.002560  0.9991227
f2:SppB-f1:SppA          1.450000 -1.9525601  4.852560  0.8685338
f1:SppB-f1:SppA          3.016667 -0.3858935  6.419227  0.1150225
f3:SppB-f1:SppA          8.466667  5.0641065 11.869227  0.0000000
f2:SppB-f3:SppA          0.850000 -2.5525601  4.252560  0.9922487
f1:SppB-f3:SppA          2.416667 -0.9858935  5.819227  0.3344595
f3:SppB-f3:SppA          7.866667  4.4641065 11.269227  0.0000001
f1:SppB-f2:SppB          1.566667 -1.8358935  4.969227  0.8173904
f3:SppB-f2:SppB          7.016667  3.6141065 10.419227  0.0000019
f3:SppB-f1:SppB          5.450000  2.0474399  8.852560  0.0002022

```

We can see the mean differences for fertilizer combinations, for the two species and for all fertilizer*species combinations. By using the confidence intervals or the p-values we can conclude which of these combinations are significant or not.

6. Obtain Tukey grouping by using the following commands:

```
tukey_grouping<-multcompLetters4(anova,tukey_multiple_comparisons)
print(tukey_grouping)
$fertilizer
f3      f1      f2 control
"a"      "b"      "c"      "d"
$species
SppB SppA
"a"  "b"
$`fertilizer:species`
f3:SppB f1:SppB f2:SppB f3:SppA f1:SppA f2:SppA control:SppB control:SppA
"a"      "b"      "b"      "bc"      "bc"      "cd"      "de"      "e"
```

7. Obtain a plot of differences in mean response for fertilizer*species combinations by using the following commands:

```
par(mar=c(4.1,13,4.1,2.1))
plot(tukey_multiple_comparisons,las=2)
detach(greenhouse_2way_data)
```


 95% family-wise confidence level graph for differences in mean levels of Fertilizer:species

Figure 5.1.3.3: Graph of differences in mean levels of fertilizer:species, showing 95% family-wise confidence levels.

This page titled [5.1.3: Two-Factor Factorial - Greenhouse Example \(R\)](#) is shared under a [CC BY-NC 4.0](#) license and was authored, remixed, and/or curated by [Penn State's Department of Statistics](#).