HW4

1

From the description, we have $a = 2,\ b = 3,\ n = 3$. So the table is as following:

Source	df	SS	MS	F
Popper (A)	1	4.5	4.5	32.374
Corn (B)	2	15.75	7.875	56.655
Interaction (A*B)	2	0.08	0.04	0.288
Error	12	1.67	0.139	1
Total	17	22.00		

```
pf(0.288, df1=2, df2=12,lower.tail=F)
```

```
## [1] 0.7548007
```

Since p-value is larger than 0.05, we cannot reject H_0.

Source	df	SS	MS	F
Popper (A)	1	4.5	4.5	36
Corn (B)	2	15.75	7.875	63
Error	14	1.75	0.125	1
Total	17	22.00		

```
pf(36, 1, 14,lower.tail=F)
```

```
## [1] 3.254776e-05
```

Since p-value is much smaller than 0.05, we reject H_0.

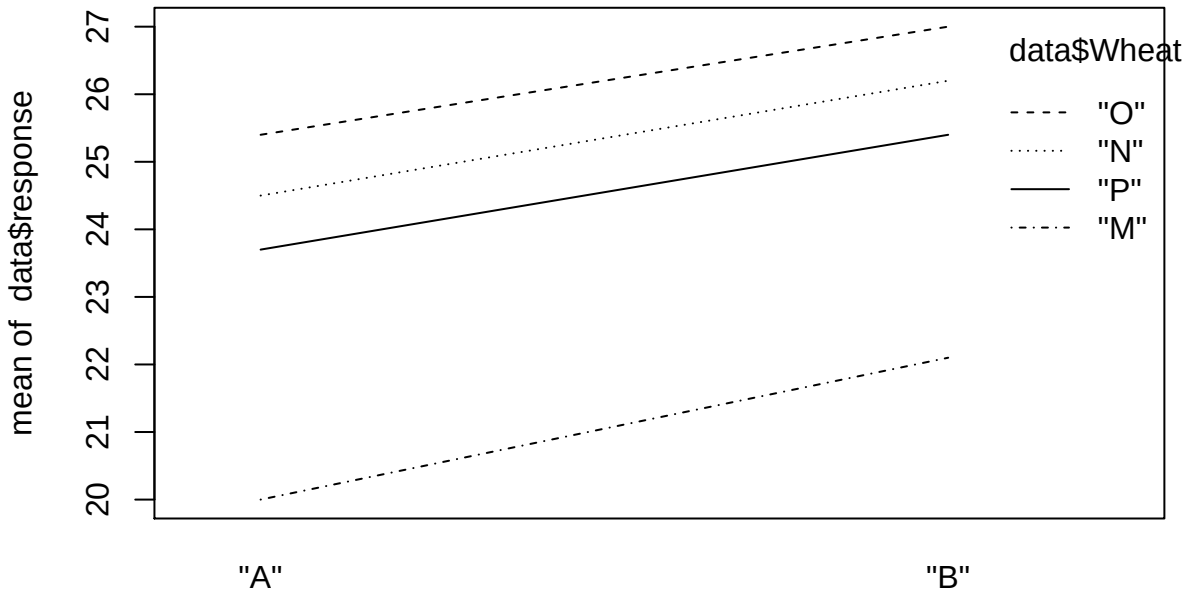
```
pf(63, 2, 14,lower.tail=F)
```

```
## [1] 1e-07
```

Since p-value is much smaller than 0.05, we reject H_0.

2

```
data<-read.csv('~/Documents/columbia/TA/2019_spring/hw4/HW4DATA.csv', header=TRUE)
interaction.plot(data$fertilizer,data$Wheat,data$response)
```



The plot suggests that there is no interaction between fertilizer type and wheat type.

```
summary(aov(data$response~data$fertilizer*data$Wheat))
```

```
##                             Df Sum Sq Mean Sq F value   Pr(>F)
## data$fertilizer              1  18.90  18.904   48.63 3.14e-06 ***
## data$Wheat                   3  92.02  30.674   78.90 8.37e-10 ***
## data$fertilizer:data$Wheat   3   0.22   0.074    0.19    0.902
## Residuals                   16   6.22   0.389
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

In the above ANOVA table, we could see that Pr(>F) for interaction is 0.902, which is larger than $\alpha = 0.05$. So we could not reject H_0 and there is no interaction between fertilizer and wheat effects.

```
summary(aov(data$response~data$fertilizer+data$Wheat))
```

```
##                 Df Sum Sq Mean Sq F value   Pr(>F)
## data$fertilizer  1  18.90  18.904   55.76 4.59e-07 ***
## data$Wheat       3  92.02  30.674   90.48 1.97e-11 ***
## Residuals       19   6.44   0.339
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

From the above ANOVA table for model without interactions, we could see that Pr(>F) for fertilizer is 4.59e-07, which is smaller than $\alpha = 0.05$. So we could reject H_0 and there is a fertilizer effect.

```
fit<-aov(data$response~data$fertilizer+data$Wheat)
TukeyHSD(fit, "data$fertilizer")
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = data$response ~ data$fertilizer + data$Wheat)
##
## $`data$fertilizer`
```

```
##          diff      lwr      upr p adj
## "B"-"A" 1.775 1.277484 2.272516 5e-07
```

In the above, we use Tukey's method to do pairwise comparisons of different fertilizer types. The p-value is much smaller than 0.05, so we conclude that there is a fertilizer effect.

We find that Pr(>F) for wheat is 1.97e-11, which is smaller than $\alpha = 0.05$. So we could reject H_0 and there is a wheat effect.

```
TukeyHSD(fit, "data$Wheat")
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = data$response ~ data$fertilizer + data$Wheat)
##
## $`data$Wheat`
##          diff         lwr        upr     p adj
## "N"-"M"  4.30  3.35476633  5.2452337 0.0000000
## "O"-"M"  5.15  4.20476633  6.0952337 0.0000000
## "P"-"M"  3.50  2.55476633  4.4452337 0.0000000
## "O"-"N"  0.85 -0.09523367  1.7952337 0.0872269
## "P"-"N" -0.80 -1.74523367  0.1452337 0.1152696
## "P"-"O" -1.65 -2.59523367 -0.7047663 0.0005208
```

The above results suggests that M is in different group from N,O and P. As for whether N,O and P are in the same group or not, Tukey's method does not give us consistent result.