

Assignment 7 407

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```
Density = rep(c('One', 'Two', "Three", "Four"), each=9)

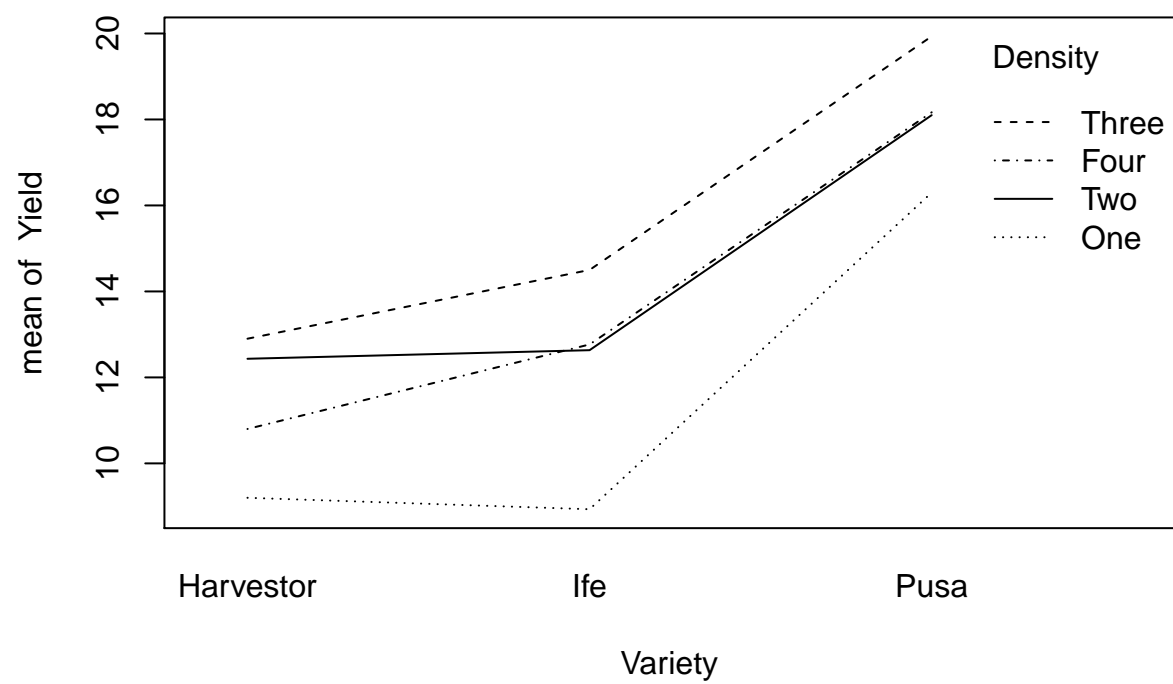
Variety = rep(rep(c("Harvestor", "Ife", "Pusa"), each=3), 4)

Yield = c(10.5, 9.2, 7.9, 8.1, 8.6, 10.1, 16.1, 15.3, 17.5, 12.8, 11.2, 13.3, 12.7, 13.7, 11.5, 16.6, 19.2, 18.5, 12.1, 12.5, 12.8, 13.5, 12.2, 13.1, 12.4, 12.6, 12.9, 13.2, 12.3, 13.4, 12.7, 13.6, 11.4, 16.7, 19.1, 18.4, 12.0, 12.6, 12.9, 13.0, 12.5, 13.8, 12.1, 13.9, 12.0, 13.0, 12.6, 13.6, 11.3, 16.8, 19.3, 18.6, 12.2, 12.7, 13.0, 13.2, 12.4, 13.7, 11.6, 16.9, 19.4, 18.7, 12.3, 12.8, 13.1, 13.3, 12.5, 13.9, 12.2, 14.0, 12.7, 14.1, 12.8, 14.2, 12.9, 14.3, 13.0, 14.4, 13.1, 14.5, 13.2, 14.6, 13.3, 14.7, 13.4, 14.8, 13.5, 14.9, 13.6, 15.0, 13.7, 15.1, 13.8, 15.2, 13.9, 15.3, 14.0, 15.4, 14.1, 15.5, 14.2, 15.6, 14.3, 15.7, 14.4, 15.8, 14.5, 15.9, 14.6, 16.0, 14.7, 16.1, 14.8, 16.2, 14.9, 16.3, 15.0, 16.4, 15.1, 16.5, 15.2, 16.6, 15.3, 16.7, 15.4, 16.8, 15.5, 16.9, 15.6, 17.0, 15.7, 17.1, 15.8, 17.2, 15.9, 17.3, 16.0, 17.4, 16.1, 17.5, 16.2, 17.6, 16.3, 17.7, 16.4, 17.8, 16.5, 17.9, 16.6, 18.0, 16.7, 18.1, 16.8, 18.2, 16.9, 18.3, 17.0, 18.4, 17.1, 18.5, 17.2, 18.6, 17.3, 18.7, 17.4, 18.8, 17.5, 18.9, 17.6, 19.0, 17.7, 19.1, 17.8, 19.2, 17.9, 19.3, 18.0, 19.4, 18.1, 19.5, 18.2, 19.6, 18.3, 19.7, 18.4, 19.8, 18.5, 19.9, 18.6, 20.0, 18.7, 20.1, 18.8, 20.2, 18.9, 20.3, 19.0, 20.4, 19.1, 20.5, 19.2, 20.6, 19.3, 20.7, 19.4, 20.8, 19.5, 20.9, 19.6, 21.0, 19.7, 21.1, 19.8, 21.2, 19.9, 21.3, 20.0, 21.4, 20.1, 21.5, 20.2, 21.6, 20.3, 21.7, 20.4, 21.8, 20.5, 21.9, 20.6, 22.0, 20.7, 22.1, 20.8, 22.2, 20.9, 22.3, 21.0, 22.4, 21.1, 22.5, 21.2, 22.6, 21.3, 22.7, 21.4, 22.8, 21.5, 22.9, 21.6, 23.0, 21.7, 23.1, 21.8, 23.2, 21.9, 23.3, 22.0, 23.4, 22.1, 23.5, 22.2, 23.6, 22.3, 23.7, 22.4, 23.8, 22.5, 23.9, 22.6, 24.0, 22.7, 24.1, 22.8, 24.2, 22.9, 24.3, 23.0, 24.4, 23.1, 24.5, 23.2, 24.6, 23.3, 24.7, 23.4, 24.8, 23.5, 24.9, 23.6, 25.0, 23.7, 25.1, 23.8, 25.2, 23.9, 25.3, 24.0, 25.4, 24.1, 25.5, 24.2, 25.6, 24.3, 25.7, 24.4, 25.8, 24.5, 25.9, 24.6, 26.0, 24.7, 26.1, 24.8, 26.2, 24.9, 26.3, 25.0, 26.4, 25.1, 26.5, 25.2, 26.6, 25.3, 26.7, 25.4, 26.8, 25.5, 26.9, 25.6, 27.0, 25.7, 27.1, 25.8, 27.2, 25.9, 27.3, 26.0, 27.4, 26.1, 27.5, 26.2, 27.6, 26.3, 27.7, 26.4, 27.8, 26.5, 27.9, 26.6, 28.0, 26.7, 28.1, 26.8, 28.2, 26.9, 28.3, 27.0, 28.4, 27.1, 28.5, 27.2, 28.6, 27.3, 28.7, 27.4, 28.8, 27.5, 28.9, 27.6, 29.0, 27.7, 29.1, 27.8, 29.2, 27.9, 29.3, 28.0, 29.4, 28.1, 29.5, 28.2, 29.6, 28.3, 29.7, 28.4, 29.8, 28.5, 29.9, 28.6, 30.0, 28.7, 30.1, 28.8, 30.2, 28.9, 30.3, 29.0, 30.4, 29.1, 30.5, 29.2, 30.6, 29.3, 30.7, 29.4, 30.8, 29.5, 30.9, 29.6, 31.0, 29.7, 31.1, 29.8, 31.2, 29.9, 31.3, 30.0, 31.4, 30.1, 31.5, 30.2, 31.6, 30.3, 31.7, 30.4, 31.8, 30.5, 31.9, 30.6, 32.0, 30.7, 32.1, 30.8, 32.2, 30.9, 32.3, 31.0, 32.4, 31.1, 32.5, 31.2, 32.6, 31.3, 32.7, 31.4, 32.8, 31.5, 32.9, 31.6, 33.0, 31.7, 33.1, 31.8, 33.2, 31.9, 33.3, 32.0, 33.4, 32.1, 33.5, 32.2, 33.6, 32.3, 33.7, 32.4, 33.8, 32.5, 33.9, 32.6, 34.0, 32.7, 34.1, 32.8, 34.2, 32.9, 34.3, 33.0, 34.4, 33.1, 34.5, 33.2, 34.6, 33.3, 34.7, 33.4, 34.8, 33.5, 34.9, 33.6, 35.0, 33.7, 35.1, 33.8, 35.2, 33.9, 35.3, 34.0, 35.4, 34.1, 35.5, 34.2, 35.6, 34.3, 35.7, 34.4, 35.8, 34.5, 35.9, 34.6, 36.0, 34.7, 36.1, 34.8, 36.2, 34.9, 36.3, 35.0, 36.4, 35.1, 36.5, 35.2, 36.6, 35.3, 36.7, 35.4, 36.8, 35.5, 36.9, 35.6, 37.0, 35.7, 37.1, 35.8, 37.2, 35.9, 37.3, 36.0, 37.4, 36.1, 37.5, 36.2, 37.6, 36.3, 37.7, 36.4, 37.8, 36.5, 37.9, 36.6, 38.0, 36.7, 38.1, 36.8, 38.2, 36.9, 38.3, 37.0, 38.4, 37.1, 38.5, 37.2, 38.6, 37.3, 38.7, 37.4, 38.8, 37.5, 38.9, 37.6, 39.0, 37.7, 39.1, 37.8, 39.2, 37.9, 39.3, 38.0, 39.4, 38.1, 39.5, 38.2, 39.6, 38.3, 39.7, 38.4, 39.8, 38.5, 39.9, 38.6, 40.0, 38.7, 40.1, 38.8, 40.2, 38.9, 40.3, 39.0, 40.4, 39.1, 40.5, 39.2, 40.6, 39.3, 40.7, 39.4, 40.8, 39.5, 40.9, 39.6, 41.0, 39.7, 41.1, 39.8, 41.2, 39.9, 41.3, 40.0, 41.4, 40.1, 41.5, 40.2, 41.6, 40.3, 41.7, 40.4, 41.8, 40.5, 41.9, 40.6, 42.0, 40.7, 42.1, 40.8, 42.2, 40.9, 42.3, 41.0, 42.4, 41.1, 42.5, 41.2, 42.6, 41.3, 42.7, 41.4, 42.8, 41.5, 42.9, 41.6, 43.0, 41.7, 43.1, 41.8, 43.2, 41.9, 43.3, 42.0, 43.4, 42.1, 43.5, 42.2, 43.6, 42.3, 43.7, 42.4, 43.8, 42.5, 43.9, 42.6, 44.0, 42.7, 44.1, 42.8, 44.2, 4
```

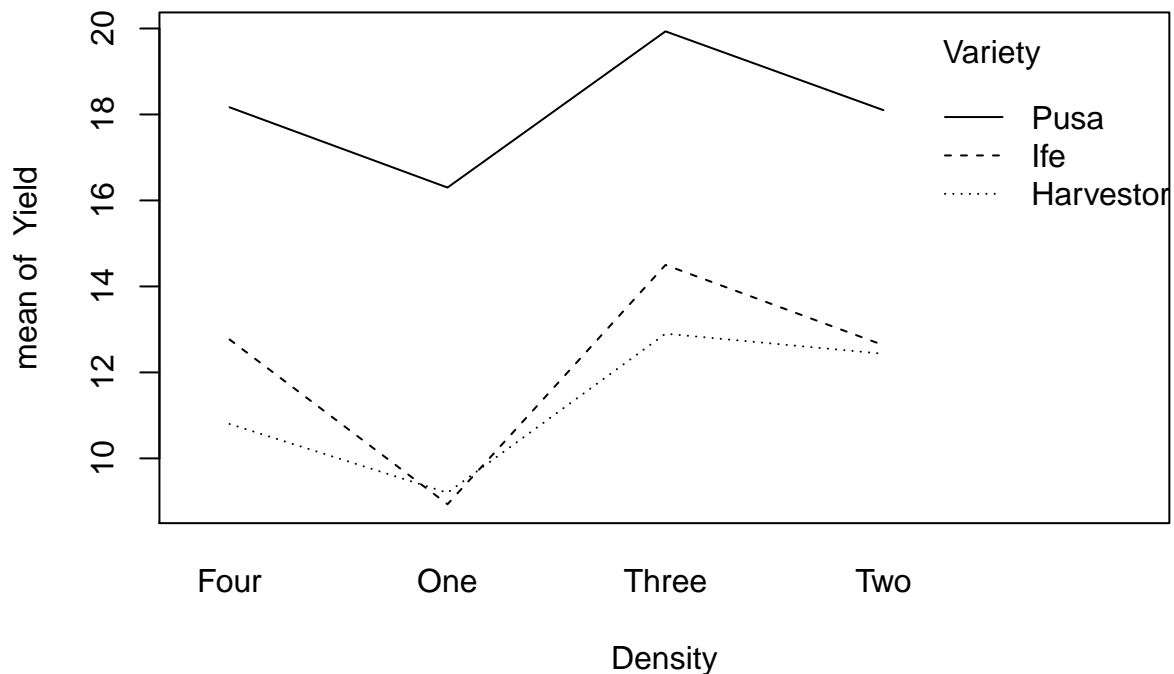
The estimate for the standard deviation of the errors is $\sqrt{MS_E} = \sqrt{1.585} = 1.259$. From the ANOVA table, we can see that f-values for variety and density are very large which results in small p-values. Since these p-values are less than 0.05 there is strong evidence to suggest that yield differs depending on density and yield differs depending on variety. Since the f-value for the interaction of variety and density is small, the p-value is large (>0.05). This large p-value suggests that there is no interaction, meaning density levels do not influence varieties differently.

Question 2

```
means = aggregate(Yield ~ Variety*Density, FUN=mean)
interaction.plot(Variety,Density,Yield)
```



```
interaction.plot(Density,Variety,Yield)
```



```
Densities = levels(as.factor(Density))
Varieties = levels(as.factor(Variety))
```

	One	Two	Three	Four	Mean Variety
Harvestor	9.2	12.433	12.9	10.8	11.333
Ife	8.933	12.633	14.5	12.767	12.208
Pusa	16.3	18.1	19.933	18.167	18.125
Mean Densities	11.478	14.389	15.778	13.911	

As we can see from the table the mean yield for each of the densities (last row) differ which suggests there is a main effect for density. Similarly the mean yield for each of the varieties differ (last column) which suggests there is a main effect for variety.

From the graph where varieties are the lines and density is the x-axis we can see that the slopes are somewhat similar for all three varieties. This suggests that there is not a strong interaction between variety and density.

Question 3

```
#results = aov(Yield~ Variety + Density) Use to not include the interaction in Tukey
TukeyHSD(results, conf.level = 0.95)
```

```
## Tukey multiple comparisons of means
## 95% family-wise confidence level
##
## Fit: aov(formula = Yield ~ Variety * Density)
##
## $Variety
```

```

##          diff      lwr      upr p adj
## Ife-Harvestor  0.875 -0.409  2.16 0.225
## Pusa-Harvestor 6.792  5.508  8.08 0.000
## Pusa-Ife       5.917  4.633  7.20 0.000
##
## $Density
##          diff      lwr      upr p adj
## One-Four    -2.433 -4.071 -0.796 0.002
## Three-Four   1.867  0.229  3.504 0.021
## Two-Four     0.478 -1.159  2.115 0.851
## Three-One    4.300  2.663  5.937 0.000
## Two-One      2.911  1.274  4.548 0.000
## Two-Three   -1.389 -3.026  0.248 0.117
##
## $`Variety:Density`
##          diff      lwr      upr p adj
## Ife:Four-Harvestor:Four  1.9667 -1.73971  5.6730 0.741
## Pusa:Four-Harvestor:Four  7.3667  3.66029 11.0730 0.000
## Harvestor:One-Harvestor:Four -1.6000 -5.30638  2.1064 0.908
## Ife:One-Harvestor:Four    -1.8667 -5.57305  1.8397 0.795
## Pusa:One-Harvestor:Four    5.5000  1.79362  9.2064 0.001
## Harvestor:Three-Harvestor:Four  2.1000 -1.60638  5.8064 0.663
## Ife:Three-Harvestor:Four    3.7000 -0.00638  7.4064 0.051
## Pusa:Three-Harvestor:Four    9.1333  5.42695 12.8397 0.000
## Harvestor:Two-Harvestor:Four  1.6333 -2.07305  5.3397 0.897
## Ife:Two-Harvestor:Four     1.8333 -1.87305  5.5397 0.811
## Pusa:Two-Harvestor:Four     7.3000  3.59362 11.0064 0.000
## Pusa:Four-Ife:Four         5.4000  1.69362  9.1064 0.001
## Harvestor:One-Ife:Four     -3.5667 -7.27305  0.1397 0.067
## Ife:One-Ife:Four          -3.8333 -7.53971 -0.1270 0.038
## Pusa:One-Ife:Four          3.5333 -0.17305  7.2397 0.071
## Harvestor:Three-Ife:Four    0.1333 -3.57305  3.8397 1.000
## Ife:Three-Ife:Four         1.7333 -1.97305  5.4397 0.858
## Pusa:Three-Ife:Four        7.1667  3.46029 10.8730 0.000
## Harvestor:Two-Ife:Four     -0.3333 -4.03971  3.3730 1.000
## Ife:Two-Ife:Four          -0.1333 -3.83971  3.5730 1.000
## Pusa:Two-Ife:Four          5.3333  1.62695  9.0397 0.001
## Harvestor:One-Pusa:Four    -8.9667 -12.67305 -5.2603 0.000
## Ife:One-Pusa:Four          -9.2333 -12.93971 -5.5270 0.000
## Pusa:One-Pusa:Four         -1.8667 -5.57305  1.8397 0.795
## Harvestor:Three-Pusa:Four  -5.2667 -8.97305 -1.5603 0.001
## Ife:Three-Pusa:Four       -3.6667 -7.37305  0.0397 0.054
## Pusa:Three-Pusa:Four       1.7667 -1.93971  5.4730 0.843
## Harvestor:Two-Pusa:Four    -5.7333 -9.43971 -2.0270 0.000
## Ife:Two-Pusa:Four         -5.5333 -9.23971 -1.8270 0.001
## Pusa:Two-Pusa:Four        -0.0667 -3.77305  3.6397 1.000
## Ife:One-Harvestor:One     -0.2667 -3.97305  3.4397 1.000
## Pusa:One-Harvestor:One     7.1000  3.39362 10.8064 0.000
## Harvestor:Three-Harvestor:One  3.7000 -0.00638  7.4064 0.051
## Ife:Three-Harvestor:One    5.3000  1.59362  9.0064 0.001
## Pusa:Three-Harvestor:One  10.7333  7.02695 14.4397 0.000
## Harvestor:Two-Harvestor:One  3.2333 -0.47305  6.9397 0.128
## Ife:Two-Harvestor:One     3.4333 -0.27305  7.1397 0.087
## Pusa:Two-Harvestor:One     8.9000  5.19362 12.6064 0.000

```

## Pusa:One-Ife:One	7.3667	3.66029	11.0730	0.000
## Harvestor:Three-Ife:One	3.9667	0.26029	7.6730	0.029
## Ife:Three-Ife:One	5.5667	1.86029	9.2730	0.001
## Pusa:Three-Ife:One	11.0000	7.29362	14.7064	0.000
## Harvestor:Two-Ife:One	3.5000	-0.20638	7.2064	0.076
## Ife:Two-Ife:One	3.7000	-0.00638	7.4064	0.051
## Pusa:Two-Ife:One	9.1667	5.46029	12.8730	0.000
## Harvestor:Three-Pusa:One	-3.4000	-7.10638	0.3064	0.093
## Ife:Three-Pusa:One	-1.8000	-5.50638	1.9064	0.828
## Pusa:Three-Pusa:One	3.6333	-0.07305	7.3397	0.058
## Harvestor:Two-Pusa:One	-3.8667	-7.57305	-0.1603	0.036
## Ife:Two-Pusa:One	-3.6667	-7.37305	0.0397	0.054
## Pusa:Two-Pusa:One	1.8000	-1.90638	5.5064	0.828
## Ife:Three-Harvestor:Three	1.6000	-2.10638	5.3064	0.908
## Pusa:Three-Harvestor:Three	7.0333	3.32695	10.7397	0.000
## Harvestor:Two-Harvestor:Three	-0.4667	-4.17305	3.2397	1.000
## Ife:Two-Harvestor:Three	-0.2667	-3.97305	3.4397	1.000
## Pusa:Two-Harvestor:Three	5.2000	1.49362	8.9064	0.002
## Pusa:Three-Ife:Three	5.4333	1.72695	9.1397	0.001
## Harvestor:Two-Ife:Three	-2.0667	-5.77305	1.6397	0.683
## Ife:Two-Ife:Three	-1.8667	-5.57305	1.8397	0.795
## Pusa:Two-Ife:Three	3.6000	-0.10638	7.3064	0.062
## Harvestor:Two-Pusa:Three	-7.5000	-11.20638	-3.7936	0.000
## Ife:Two-Pusa:Three	-7.3000	-11.00638	-3.5936	0.000
## Pusa:Two-Pusa:Three	-1.8333	-5.53971	1.8730	0.811
## Ife:Two-Harvestor:Two	0.2000	-3.50638	3.9064	1.000
## Pusa:Two-Harvestor:Two	5.6667	1.96029	9.3730	0.001
## Pusa:Two-Ife:Two	5.4667	1.76029	9.1730	0.001

From Tukeys test we can see that there is no significant difference in mean yield for Ife and Harvestor. There is evidence to suggest Pusa is significantly different in mean yield from both Harvestor and Ife. Since Pusa is significantly different and had the largest sample mean, Pusa is expected to be the variety that would produce the greatest yield.

Question 4

From Tukeys test we can see that the only densities which do not significantly differ in mean yield are densities 2 & 4, and densities 2 & 3. Since density 3 had the largest mean yield from the sample, and density 2 does not significantly differ from density 3, we would expect densities 2 and 3 to produce the maximum yield. That is, farmers should plant 20-30 thousand plants per hectare to get maximum yield, as 40 thousand plants is too dense and plants cant grow as efficiently, and 10 thousand plants is not using all the space it can be using.