ANOVA

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```
library(tidyverse)
```

```
## -- Attaching packages --------------------------------------- tidyverse 1.2.1 --
```

```
## v ggplot2 3.2.1     v purrr   0.3.2
## v tibble  2.1.3     v dplyr   0.8.3
## v tidyr   1.0.0     v stringr 1.4.0
## v readr   1.3.1     v forcats 0.4.0
```

```
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```
library(lme4)
```

```
## Loading required package: Matrix
```

```
##
## Attaching package: 'Matrix'
```

```
## The following objects are masked from 'package:tidyr':
##
##     expand, pack, unpack
```

```
library(nortest)
library(ggpubr)
```

```
## Loading required package: magrittr
```

```
##
## Attaching package: 'magrittr'
```

```
## The following object is masked from 'package:purrr':
##
##     set_names
```

```
## The following object is masked from 'package:tidyr':
##
##     extract
```

```
library(lmerTest)
```

```
##
## Attaching package: 'lmerTest'
```

```
## The following object is masked from 'package:lme4':
##
##     lmer
```

```
## The following object is masked from 'package:stats':
##
##     step
```

```r
library(emmeans)
```

```r
data <- read_csv("Yield.csv")
```

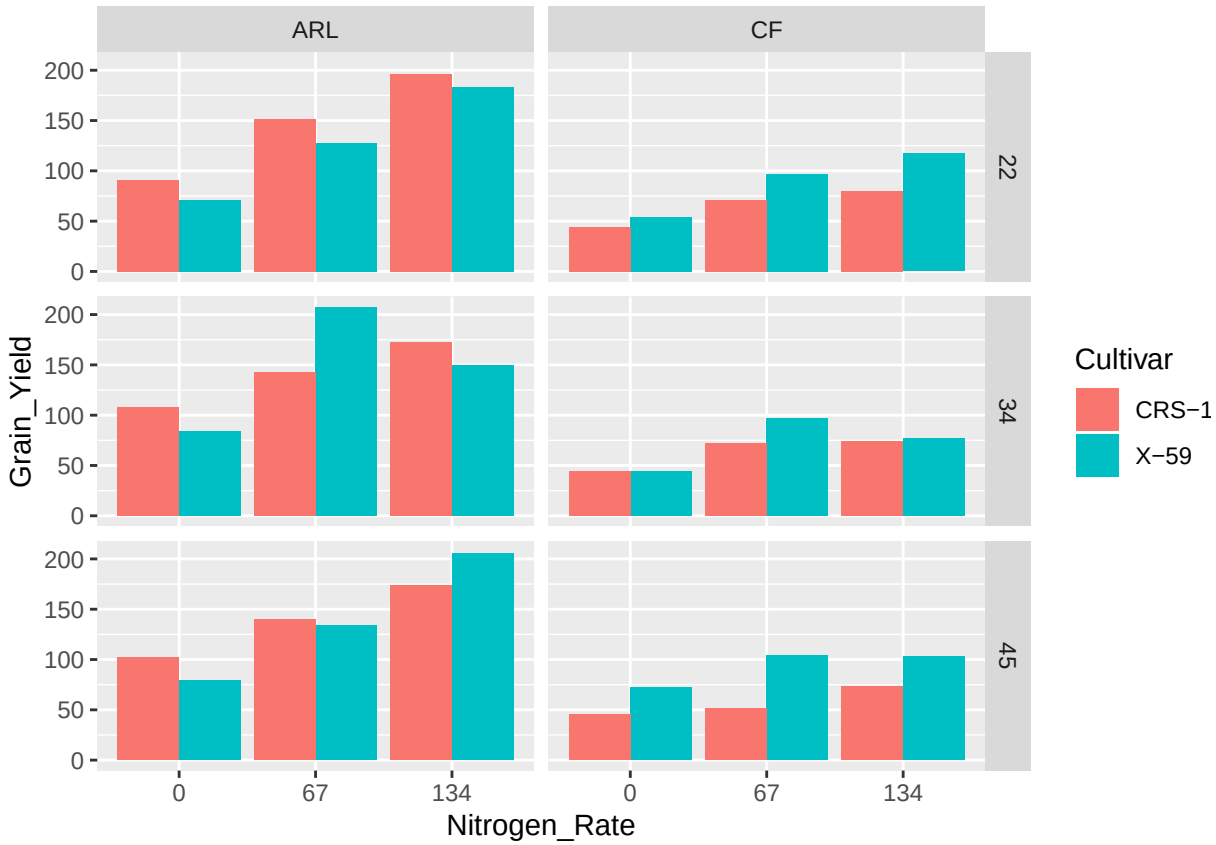
```
## Parsed with column specification:
## cols(
##   Plot = col_double(),
##   Rep = col_double(),
##   Location = col_character(),
##   Treatment = col_double(),
##   Cultivar = col_character(),
##   Seeding_Rate = col_double(),
##   Nitrogen_Rate = col_double(),
##   Grain_Yield = col_double(),
##   Fiber_Yield = col_double()
## )
```

```r
data$Seeding_Rate <- as.factor(data$Seeding_Rate) # put seeding rate as a factor
data$Nitrogen_Rate <- as.factor(data$Nitrogen_Rate)
glimpse(data)
```

```
## Observations: 144
## Variables: 9
## $ Plot          <dbl> 101, 304, 111, 316, 102, 403, 211, 310, 103, 407...
## $ Rep           <dbl> 1, 2, 3, 4, 1, 2, 3, 4, 1, 2, 3, 4, 1, 2, 3, 4, ...
## $ Location      <chr> "ARL", "ARL", "ARL", "ARL", "ARL", "ARL", "ARL",...
## $ Treatment     <dbl> 1, 1, 1, 1, 2, 2, 2, 2, 3, 3, 3, 3, 4, 4, 4, 4, ...
## $ Cultivar      <chr> "X-59", "X-59", "X-59", "X-59", "X-59", "X-59", ...
## $ Seeding_Rate  <fct> 22, 22, 22, 22, 22, 22, 22, 22, 22, 22, 22, 22, ...
## $ Nitrogen_Rate <fct> 0, 0, 0, 0, 67, 67, 67, 67, 134, 134, 134, 134, ...
## $ Grain_Yield   <dbl> 29.09, 109.13, 38.24, 107.32, 180.88, 132.95, 78...
## $ Fiber_Yield   <dbl> 9, 76, 27, 54, 132, 65, 58, 76, 189, 133, 122, 3...
```

```r
ggplot(data, aes(x=Nitrogen_Rate, y=Grain_Yield, fill=Cultivar)) + geom_bar(stat="summary", position =
```

```
## No summary function supplied, defaulting to `mean_se()
## No summary function supplied, defaulting to `mean_se()
## No summary function supplied, defaulting to `mean_se()
## No summary function supplied, defaulting to `mean_se()
## No summary function supplied, defaulting to `mean_se()
## No summary function supplied, defaulting to `mean_se()
```




```
Model <- lmer(Grain_Yield ~ Nitrogen_Rate * Seeding_Rate * Location * Cultivar + (1|Rep), data=data)
summary(Model)
```

```
## Linear mixed model fit by REML. t-tests use Satterthwaite's method [
## lmerModLmerTest]
## Formula:
## Grain_Yield ~ Nitrogen_Rate * Seeding_Rate * Location * Cultivar +
##     (1 | Rep)
##    Data: data
##
## REML criterion at convergence: 1125
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.93097 -0.52780 -0.07465  0.50753  2.17280
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  Rep      (Intercept)    3.523  1.877
##  Residual             1228.573 35.051
## Number of obs: 144, groups:  Rep, 4
##
## Fixed effects:
##                                                    Estimate
## (Intercept)                                          91.308
## Nitrogen_Rate67                                      60.357
## Nitrogen_Rate134                                    104.932
```

```
## Seeding_Rate34                                            16.647
## Seeding_Rate45                                            10.830
## LocationCF                                               -47.543
## CultivarX-59                                             -20.363
## Nitrogen_Rate67:Seeding_Rate34                           -25.950
## Nitrogen_Rate134:Seeding_Rate34                          -40.572
## Nitrogen_Rate67:Seeding_Rate45                           -23.080
## Nitrogen_Rate134:Seeding_Rate45                          -33.887
## Nitrogen_Rate67:LocationCF                               -32.945
## Nitrogen_Rate134:LocationCF                              -68.537
## Seeding_Rate34:LocationCF                                -16.382
## Seeding_Rate45:LocationCF                                 -8.897
## Nitrogen_Rate67:CultivarX-59                              -3.687
## Nitrogen_Rate134:CultivarX-59                              7.243
## Seeding_Rate34:CultivarX-59                               -3.202
## Seeding_Rate45:CultivarX-59                               -2.370
## LocationCF:CultivarX-59                                   30.413
## Nitrogen_Rate67:Seeding_Rate34:LocationCF                 27.015
## Nitrogen_Rate134:Seeding_Rate34:LocationCF                33.935
## Nitrogen_Rate67:Seeding_Rate45:LocationCF                  1.325
## Nitrogen_Rate134:Seeding_Rate45:LocationCF                24.650
## Nitrogen_Rate67:Seeding_Rate34:CultivarX-59               92.480
## Nitrogen_Rate134:Seeding_Rate34:CultivarX-59              -6.040
## Nitrogen_Rate67:Seeding_Rate45:CultivarX-59               21.175
## Nitrogen_Rate134:Seeding_Rate45:CultivarX-59              47.697
## Nitrogen_Rate67:LocationCF:CultivarX-59                   19.435
## Nitrogen_Rate134:LocationCF:CultivarX-59                  19.845
## Seeding_Rate34:LocationCF:CultivarX-59                    -7.025
## Seeding_Rate45:LocationCF:CultivarX-59                    18.572
## Nitrogen_Rate67:Seeding_Rate34:LocationCF:CultivarX-59   -83.815
## Nitrogen_Rate134:Seeding_Rate34:LocationCF:CultivarX-59  -17.770
## Nitrogen_Rate67:Seeding_Rate45:LocationCF:CultivarX-59   -10.365
## Nitrogen_Rate134:Seeding_Rate45:LocationCF:CultivarX-59  -71.235
##                                                          Std. Error      df
## (Intercept)                                                  17.551 107.969
## Nitrogen_Rate67                                              24.785 105.000
## Nitrogen_Rate134                                             24.785 105.000
## Seeding_Rate34                                               24.785 105.000
## Seeding_Rate45                                               24.785 105.000
## LocationCF                                                   24.785 105.000
## CultivarX-59                                                 24.785 105.000
## Nitrogen_Rate67:Seeding_Rate34                               35.051 105.000
## Nitrogen_Rate134:Seeding_Rate34                              35.051 105.000
## Nitrogen_Rate67:Seeding_Rate45                               35.051 105.000
## Nitrogen_Rate134:Seeding_Rate45                              35.051 105.000
## Nitrogen_Rate67:LocationCF                                   35.051 105.000
## Nitrogen_Rate134:LocationCF                                  35.051 105.000
## Seeding_Rate34:LocationCF                                    35.051 105.000
## Seeding_Rate45:LocationCF                                    35.051 105.000
## Nitrogen_Rate67:CultivarX-59                                 35.051 105.000
## Nitrogen_Rate134:CultivarX-59                                35.051 105.000
## Seeding_Rate34:CultivarX-59                                  35.051 105.000
## Seeding_Rate45:CultivarX-59                                  35.051 105.000
## LocationCF:CultivarX-59                                      35.051 105.000
```

```
## Nitrogen_Rate67:Seeding_Rate34:LocationCF                    49.570 105.000
## Nitrogen_Rate134:Seeding_Rate34:LocationCF                   49.570 105.000
## Nitrogen_Rate67:Seeding_Rate45:LocationCF                    49.570 105.000
## Nitrogen_Rate134:Seeding_Rate45:LocationCF                   49.570 105.000
## Nitrogen_Rate67:Seeding_Rate34:CultivarX-59                  49.570 105.000
## Nitrogen_Rate134:Seeding_Rate34:CultivarX-59                 49.570 105.000
## Nitrogen_Rate67:Seeding_Rate45:CultivarX-59                  49.570 105.000
## Nitrogen_Rate134:Seeding_Rate45:CultivarX-59                 49.570 105.000
## Nitrogen_Rate67:LocationCF:CultivarX-59                      49.570 105.000
## Nitrogen_Rate134:LocationCF:CultivarX-59                     49.570 105.000
## Seeding_Rate34:LocationCF:CultivarX-59                       49.570 105.000
## Seeding_Rate45:LocationCF:CultivarX-59                       49.570 105.000
## Nitrogen_Rate67:Seeding_Rate34:LocationCF:CultivarX-59       70.102 105.000
## Nitrogen_Rate134:Seeding_Rate34:LocationCF:CultivarX-59      70.102 105.000
## Nitrogen_Rate67:Seeding_Rate45:LocationCF:CultivarX-59       70.102 105.000
## Nitrogen_Rate134:Seeding_Rate45:LocationCF:CultivarX-59      70.102 105.000
##                                                           t value Pr(>|t|)
## (Intercept)                                                 5.203 9.42e-07
## Nitrogen_Rate67                                             2.435   0.0166
## Nitrogen_Rate134                                            4.234 4.94e-05
## Seeding_Rate34                                              0.672   0.5033
## Seeding_Rate45                                              0.437   0.6630
## LocationCF                                                 -1.918   0.0578
## CultivarX-59                                               -0.822   0.4132
## Nitrogen_Rate67:Seeding_Rate34                             -0.740   0.4607
## Nitrogen_Rate134:Seeding_Rate34                            -1.158   0.2497
## Nitrogen_Rate67:Seeding_Rate45                             -0.658   0.5117
## Nitrogen_Rate134:Seeding_Rate45                            -0.967   0.3359
## Nitrogen_Rate67:LocationCF                                 -0.940   0.3494
## Nitrogen_Rate134:LocationCF                                -1.955   0.0532
## Seeding_Rate34:LocationCF                                  -0.467   0.6412
## Seeding_Rate45:LocationCF                                  -0.254   0.8001
## Nitrogen_Rate67:CultivarX-59                               -0.105   0.9164
## Nitrogen_Rate134:CultivarX-59                               0.207   0.8367
## Seeding_Rate34:CultivarX-59                                -0.091   0.9274
## Seeding_Rate45:CultivarX-59                                -0.068   0.9462
## LocationCF:CultivarX-59                                     0.868   0.3876
## Nitrogen_Rate67:Seeding_Rate34:LocationCF                   0.545   0.5869
## Nitrogen_Rate134:Seeding_Rate34:LocationCF                  0.685   0.4951
## Nitrogen_Rate67:Seeding_Rate45:LocationCF                   0.027   0.9787
## Nitrogen_Rate134:Seeding_Rate45:LocationCF                  0.497   0.6200
## Nitrogen_Rate67:Seeding_Rate34:CultivarX-59                 1.866   0.0649
## Nitrogen_Rate134:Seeding_Rate34:CultivarX-59               -0.122   0.9033
## Nitrogen_Rate67:Seeding_Rate45:CultivarX-59                 0.427   0.6701
## Nitrogen_Rate134:Seeding_Rate45:CultivarX-59                0.962   0.3381
## Nitrogen_Rate67:LocationCF:CultivarX-59                     0.392   0.6958
## Nitrogen_Rate134:LocationCF:CultivarX-59                    0.400   0.6897
## Seeding_Rate34:LocationCF:CultivarX-59                     -0.142   0.8876
## Seeding_Rate45:LocationCF:CultivarX-59                      0.375   0.7087
## Nitrogen_Rate67:Seeding_Rate34:LocationCF:CultivarX-59     -1.196   0.2345
## Nitrogen_Rate134:Seeding_Rate34:LocationCF:CultivarX-59    -0.253   0.8004
## Nitrogen_Rate67:Seeding_Rate45:LocationCF:CultivarX-59     -0.148   0.8827
## Nitrogen_Rate134:Seeding_Rate45:LocationCF:CultivarX-59    -1.016   0.3119
##
```

```
## (Intercept)                                          ***
## Nitrogen_Rate67                                      *
## Nitrogen_Rate134                                     ***
## Seeding_Rate34
## Seeding_Rate45
## LocationCF                                           .
## CultivarX-59
## Nitrogen_Rate67:Seeding_Rate34
## Nitrogen_Rate134:Seeding_Rate34
## Nitrogen_Rate67:Seeding_Rate45
## Nitrogen_Rate134:Seeding_Rate45
## Nitrogen_Rate67:LocationCF
## Nitrogen_Rate134:LocationCF                          .
## Seeding_Rate34:LocationCF
## Seeding_Rate45:LocationCF
## Nitrogen_Rate67:CultivarX-59
## Nitrogen_Rate134:CultivarX-59
## Seeding_Rate34:CultivarX-59
## Seeding_Rate45:CultivarX-59
## LocationCF:CultivarX-59
## Nitrogen_Rate67:Seeding_Rate34:LocationCF
## Nitrogen_Rate134:Seeding_Rate34:LocationCF
## Nitrogen_Rate67:Seeding_Rate45:LocationCF
## Nitrogen_Rate134:Seeding_Rate45:LocationCF
## Nitrogen_Rate67:Seeding_Rate34:CultivarX-59           .
## Nitrogen_Rate134:Seeding_Rate34:CultivarX-59
## Nitrogen_Rate67:Seeding_Rate45:CultivarX-59
## Nitrogen_Rate134:Seeding_Rate45:CultivarX-59
## Nitrogen_Rate67:LocationCF:CultivarX-59
## Nitrogen_Rate134:LocationCF:CultivarX-59
## Seeding_Rate34:LocationCF:CultivarX-59
## Seeding_Rate45:LocationCF:CultivarX-59
## Nitrogen_Rate67:Seeding_Rate34:LocationCF:CultivarX-59
## Nitrogen_Rate134:Seeding_Rate34:LocationCF:CultivarX-59
## Nitrogen_Rate67:Seeding_Rate45:LocationCF:CultivarX-59
## Nitrogen_Rate134:Seeding_Rate45:LocationCF:CultivarX-59
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## Correlation matrix not shown by default, as p = 36 > 12.
## Use print(x, correlation=TRUE)  or
##     vcov(x)        if you need it
```

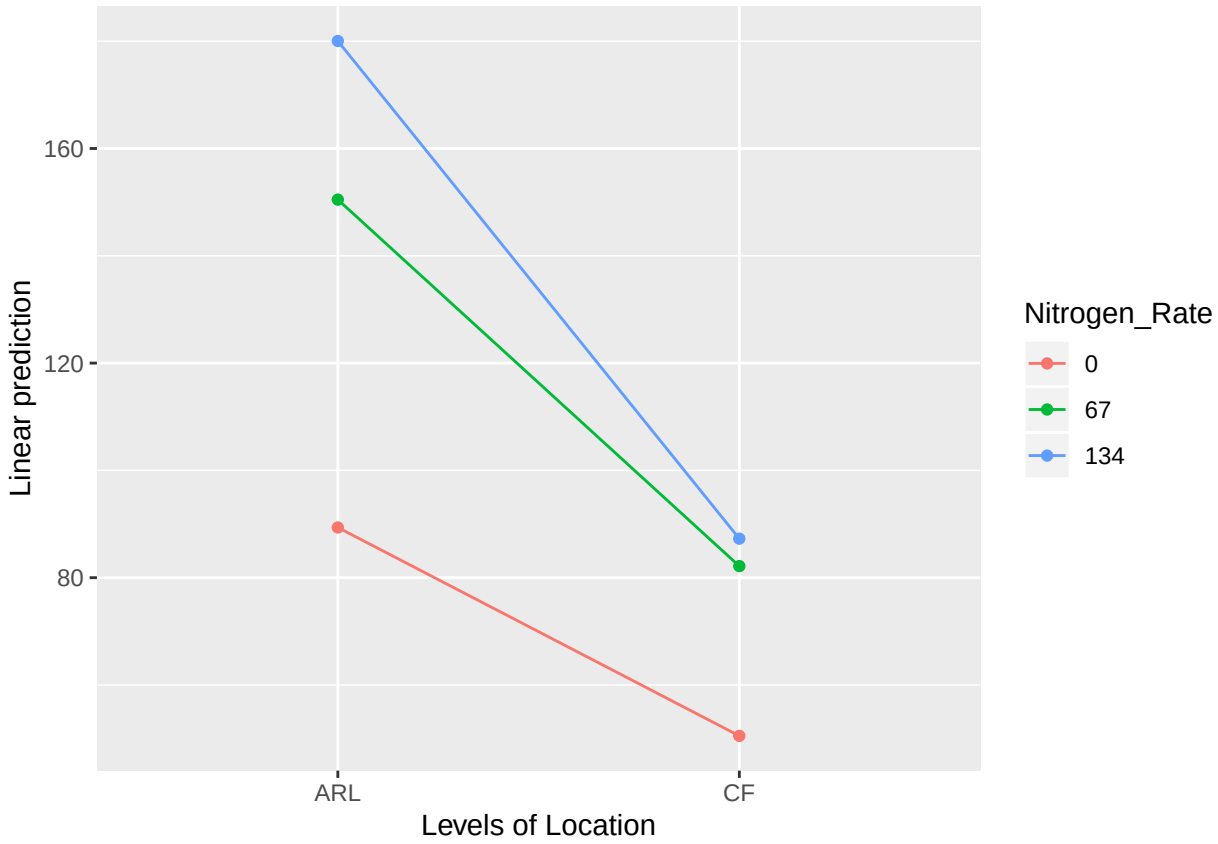
```
anova(Model)
```

```
## Type III Analysis of Variance Table with Satterthwaite's method
##                                          Sum Sq Mean Sq NumDF DenDF
## Nitrogen_Rate                            104177   52089     2   105
## Seeding_Rate                                 27      13     2   105
## Location                                 159861  159861     1   105
## Cultivar                                   3403    3403     1   105
## Nitrogen_Rate:Seeding_Rate                11247    2812     4   105
## Nitrogen_Rate:Location                    17495    8748     2   105
## Seeding_Rate:Location                      1745     872     2   105
```

```
## Nitrogen_Rate:Cultivar                            4813    2407     2   105
## Seeding_Rate:Cultivar                             1660     830     2   105
## Location:Cultivar                                 6562    6562     1   105
## Nitrogen_Rate:Seeding_Rate:Location               2784     696     4   105
## Nitrogen_Rate:Seeding_Rate:Cultivar               5869    1467     4   105
## Nitrogen_Rate:Location:Cultivar                    244     122     2   105
## Seeding_Rate:Location:Cultivar                    2787    1393     2   105
## Nitrogen_Rate:Seeding_Rate:Location:Cultivar      4995    1249     4   105
##                                                 F value    Pr(>F)
## Nitrogen_Rate                                   42.3976  3.18e-14 ***
## Seeding_Rate                                     0.0109   0.98920
## Location                                       130.1196 < 2.2e-16 ***
## Cultivar                                         2.7699   0.09904 .
## Nitrogen_Rate:Seeding_Rate                       2.2885   0.06471 .
## Nitrogen_Rate:Location                           7.1202   0.00126 **
## Seeding_Rate:Location                            0.7101   0.49392
## Nitrogen_Rate:Cultivar                           1.9588   0.14614
## Seeding_Rate:Cultivar                            0.6754   0.51115
## Location:Cultivar                                5.3408   0.02279 *
## Nitrogen_Rate:Seeding_Rate:Location              0.5665   0.68753
## Nitrogen_Rate:Seeding_Rate:Cultivar              1.1942   0.31774
## Nitrogen_Rate:Location:Cultivar                  0.0993   0.90553
## Seeding_Rate:Location:Cultivar                   1.1342   0.32560
## Nitrogen_Rate:Seeding_Rate:Location:Cultivar     1.0163   0.40247
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
emmip(Model, Nitrogen_Rate ~ Location | Location) # see the interactions
```

```
## NOTE: Results may be misleading due to involvement in interactions
```


160
120
80
Linear prediction
ARL
CF
Levels of Location
Nitrogen_Rate
0
67
134