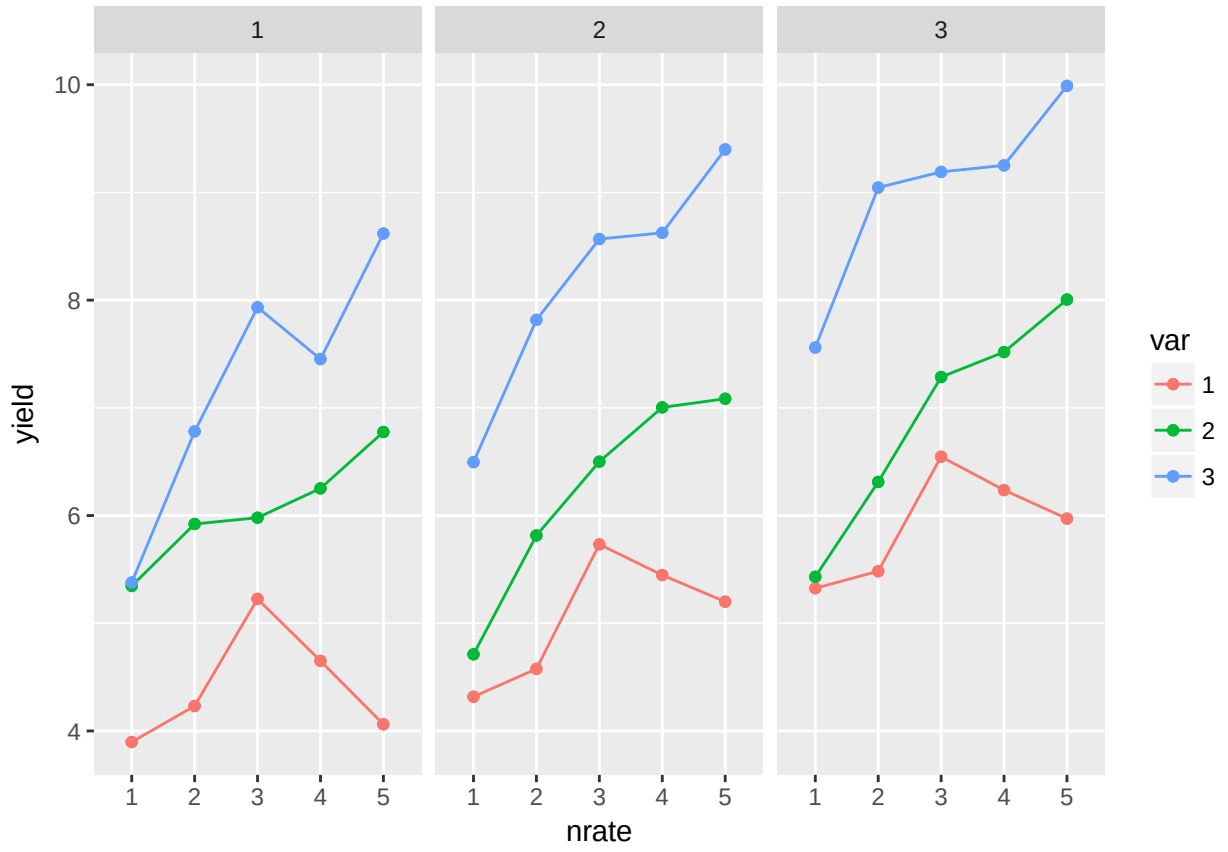
Split-Split-Plot Analysis

This is the split-split plot example from Gomez and Gomez p143. Nitrogen is the whole-plot factor (in 3 blocks). Management is the sup-plot factor and variety is the sub-sub-plot factor.

```
library(ggplot2)
library(lme4)
library(lmerTest)
library(pbkrtest)
library(emmeans)
Rice <- read.csv("C:/hess/STAT512/RNotes/Random2/R2_SplitSplitPlot.csv")
str(Rice)
```

```
## 'data.frame':    135 obs. of  5 variables:
##  $ nrate : int  1 1 1 1 1 1 1 1 1 1 ...
##  $ manage: int  1 1 1 1 1 1 1 1 1 2 ...
##  $ var   : int  1 1 1 2 2 2 3 3 3 1 ...
##  $ block : int  1 2 3 1 2 3 1 2 3 1 ...
##  $ yield : num  3.32 3.86 4.51 6.1 5.12 ...
```

```
#Important: Need to define things as.factor!!!
Rice$nrate <- as.factor(Rice$nrate)
Rice$manage <- as.factor(Rice$manage)
Rice$var <- as.factor(Rice$var)
Rice$block <- as.factor(Rice$block)
#Interaction plot
AvgData <- aggregate(yield ~ nrate + manage + var, data = Rice, mean)
p <- qplot(x = nrate, y = yield, colour = var, group = var, data = AvgData)
p + geom_line() + geom_point() + facet_wrap(~ manage)
```




```
Model1 <- lmer(yield ~ nrate*manage*var + (1|block)
               + (1|block:nrate) + (1|block:nrate:manage), data = Rice)
summary(Model1)
```

```
## Linear mixed model fit by REML t-tests use Satterthwaite approximations
##   to degrees of freedom [lmerMod]
## Formula: yield ~ nrate * manage * var + (1 | block) + (1 | block:nrate) +
##     (1 | block:nrate:manage)
##    Data: Rice
##
## REML criterion at convergence: 232.1
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.72561 -0.49133 -0.05887  0.60262  1.95006
##
## Random effects:
##  Groups              Name        Variance Std.Dev.
##  block:nrate:manage (Intercept) 0.000000 0.0000
##  block:nrate        (Intercept) 0.009025 0.0950
##  block              (Intercept) 0.000000 0.0000
##  Residual                       0.437110 0.6611
## Number of obs: 135, groups:
## block:nrate:manage, 45; block:nrate, 15; block, 3
##
## Fixed effects:
```

```
##                       Estimate Std. Error        df t value Pr(>|t|)
## (Intercept)           3.897000   0.385632 89.710000  10.105 2.22e-16 ***
## nrate2                0.335000   0.545365 89.710000   0.614 0.540594
## nrate3                1.329000   0.545365 89.710000   2.437 0.016788 *
## nrate4                0.753333   0.545365 89.710000   1.381 0.170607
## nrate5                0.164667   0.545365 89.710000   0.302 0.763398
## manage2               0.420333   0.539821 80.000000   0.779 0.438481
## manage3               1.428000   0.539821 80.000000   2.645 0.009822 **
## var2                  1.449000   0.539821 80.000000   2.684 0.008834 **
## var3                  1.481333   0.539821 80.000000   2.744 0.007488 **
## nrate2:manage2       -0.076000   0.763422 80.000000  -0.100 0.920949
## nrate3:manage2        0.086000   0.763422 80.000000   0.113 0.910590
## nrate4:manage2        0.376667   0.763422 80.000000   0.493 0.623087
## nrate5:manage2        0.718000   0.763422 80.000000   0.941 0.349792
## nrate2:manage3       -0.177333   0.763422 80.000000  -0.232 0.816908
## nrate3:manage3       -0.107667   0.763422 80.000000  -0.141 0.888200
## nrate4:manage3        0.158000   0.763422 80.000000   0.207 0.836565
## nrate5:manage3        0.482000   0.763422 80.000000   0.631 0.529600
## nrate2:var2           0.240667   0.763422 80.000000   0.315 0.753395
## nrate3:var2          -0.695333   0.763422 80.000000  -0.911 0.365131
## nrate4:var2           0.152667   0.763422 80.000000   0.200 0.842006
## nrate5:var2           1.265000   0.763422 80.000000   1.657 0.101434
## nrate2:var3           1.068000   0.763422 80.000000   1.399 0.165689
## nrate3:var3           1.226000   0.763422 80.000000   1.606 0.112230
## nrate4:var3           1.321000   0.763422 80.000000   1.730 0.087421 .
## nrate5:var3           3.075000   0.763422 80.000000   4.028 0.000127 ***
## manage2:var2         -1.054667   0.763422 80.000000  -1.381 0.170972
## manage3:var2         -1.343000   0.763422 80.000000  -1.759 0.082370 .
## manage2:var3          0.697333   0.763422 80.000000   0.913 0.363761
## manage3:var3          0.753667   0.763422 80.000000   0.987 0.326511
## nrate2:manage2:var2   0.603667   1.079642 80.000000   0.559 0.577631
## nrate3:manage2:var2   1.068667   1.079642 80.000000   0.990 0.325240
## nrate4:manage2:var2   1.009667   1.079642 80.000000   0.935 0.352507
## nrate5:manage2:var2   0.225000   1.079642 80.000000   0.208 0.835444
## nrate2:manage3:var2   0.482667   1.079642 80.000000   0.447 0.656039
## nrate3:manage3:var2   1.329000   1.079642 80.000000   1.231 0.221943
## nrate4:manage3:var2   1.022667   1.079642 80.000000   0.947 0.346375
## nrate5:manage3:var2   0.662667   1.079642 80.000000   0.614 0.541100
## nrate2:manage2:var3  -0.006333   1.079642 80.000000  -0.006 0.995334
## nrate3:manage2:var3  -0.569667   1.079642 80.000000  -0.528 0.599207
## nrate4:manage2:var3  -0.322333   1.079642 80.000000  -0.299 0.766053
## nrate5:manage2:var3  -1.054333   1.079642 80.000000  -0.977 0.331732
## nrate2:manage3:var3   0.259667   1.079642 80.000000   0.241 0.810549
## nrate3:manage3:var3  -0.816667   1.079642 80.000000  -0.756 0.451617
## nrate4:manage3:var3  -0.541000   1.079642 80.000000  -0.501 0.617682
## nrate5:manage3:var3  -1.292333   1.079642 80.000000  -1.197 0.234841
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
anova(Model1, ddf="Kenward-Roger")
```

```
## Analysis of Variance Table of type III  with  Kenward-Roger
## approximation for degrees of freedom
##                  Sum Sq Mean Sq NumDF DenDF F.value    Pr(>F)
## nrate            51.982  12.995     4     8  29.730 7.494e-05 ***
```

```
## manage            42.936  21.468     2    20  49.114 1.919e-08 ***
## var              206.013 103.007     2    60 235.654 < 2.2e-16 ***
## nrate:manage       1.103   0.138     8    20   0.315 0.9508797
## nrate:var         14.145   1.768     8    60   4.045 0.0006765 ***
## manage:var         3.852   0.963     4    60   2.203 0.0793657 .
## nrate:manage:var   3.699   0.231    16    60   0.529 0.9210465
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
emmeans(Model1, pairwise ~ manage)
```

```
## $emmeans
##  manage   emmean        SE    df lower.CL upper.CL
##  1      5.900378 0.1015639 11.24 5.677415 6.123341
##  2      6.486156 0.1015639 11.24 6.263193 6.709118
##  3      7.276711 0.1015639 11.24 7.053748 7.499674
##
## Results are averaged over the levels of: nrate, var
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast   estimate        SE df t.ratio p.value
##  1 - 2    -0.5857778 0.1393812 20  -4.203  0.0012
##  1 - 3    -1.3763333 0.1393812 20  -9.875  <.0001
##  2 - 3    -0.7905556 0.1393812 20  -5.672  <.0001
##
## Results are averaged over the levels of: nrate, var
## P value adjustment: tukey method for comparing a family of 3 estimates
```

```
emmeans(Model1, pairwise ~ var|nrate)
```

```
## $emmeans
## nrate = 1:
##  var   emmean        SE    df lower.CL upper.CL
##  1   4.513111 0.2271038 48.96 4.056721 4.969502
##  2   5.162889 0.2271038 48.96 4.706498 5.619279
##  3   6.478111 0.2271038 48.96 6.021721 6.934502
##
## nrate = 2:
##  var   emmean        SE    df lower.CL upper.CL
##  1   4.763667 0.2271038 48.96 4.307276 5.220057
##  2   6.016222 0.2271038 48.96 5.559832 6.472613
##  3   7.881111 0.2271038 48.96 7.424721 8.337502
##
## nrate = 3:
##  var   emmean        SE    df lower.CL upper.CL
##  1   5.834889 0.2271038 48.96 5.378498 6.291279
##  2   6.588556 0.2271038 48.96 6.132165 7.044946
##  3   8.563778 0.2271038 48.96 8.107387 9.020168
##
## nrate = 4:
##  var   emmean        SE    df lower.CL upper.CL
##  1   5.444667 0.2271038 48.96 4.988276 5.901057
##  2   6.924556 0.2271038 48.96 6.468165 7.380946
```

```
##  3   8.442889 0.2271038 48.96 7.986498 8.899279
##
## nrate = 5:
##  var   emmean        SE    df lower.CL upper.CL
##  1   5.077778 0.2271038 48.96 4.621387 5.534168
##  2   7.288444 0.2271038 48.96 6.832054 7.744835
##  3   9.335556 0.2271038 48.96 8.879165 9.791946
##
## Results are averaged over the levels of: manage
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
## nrate = 1:
##  contrast   estimate        SE df t.ratio p.value
##  1 - 2    -0.6497778 0.3116659 60  -2.085  0.1016
##  1 - 3    -1.9650000 0.3116659 60  -6.305  <.0001
##  2 - 3    -1.3152222 0.3116659 60  -4.220  0.0002
##
## nrate = 2:
##  contrast   estimate        SE df t.ratio p.value
##  1 - 2    -1.2525556 0.3116659 60  -4.019  0.0005
##  1 - 3    -3.1174444 0.3116659 60 -10.003  <.0001
##  2 - 3    -1.8648889 0.3116659 60  -5.984  <.0001
##
## nrate = 3:
##  contrast   estimate        SE df t.ratio p.value
##  1 - 2    -0.7536667 0.3116659 60  -2.418  0.0483
##  1 - 3    -2.7288889 0.3116659 60  -8.756  <.0001
##  2 - 3    -1.9752222 0.3116659 60  -6.338  <.0001
##
## nrate = 4:
##  contrast   estimate        SE df t.ratio p.value
##  1 - 2    -1.4798889 0.3116659 60  -4.748  <.0001
##  1 - 3    -2.9982222 0.3116659 60  -9.620  <.0001
##  2 - 3    -1.5183333 0.3116659 60  -4.872  <.0001
##
## nrate = 5:
##  contrast   estimate        SE df t.ratio p.value
##  1 - 2    -2.2106667 0.3116659 60  -7.093  <.0001
##  1 - 3    -4.2577778 0.3116659 60 -13.661  <.0001
##  2 - 3    -2.0471111 0.3116659 60  -6.568  <.0001
##
## Results are averaged over the levels of: manage
## P value adjustment: tukey method for comparing a family of 3 estimates
```