

FNR 15N

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Necessary libraries

```
library(knitr)
library(ggplot2)
theme_set(theme_bw())
library(emmeans)
library(multcomp)
library(PLS205)
library(lme4)
library(lmerTest)
library(multcompView)
library(car)
library(Rmisc)
library(dplyr) #https://r4ds.had.co.nz/ (Chapter 3, Chapter 5, look at filter and select)
# https://bookdown.org/ansellbr/WEHI_tidyR_course_book/
library(stringr)
```

```
library(data.table)
library(GGally)
library(formatR)
library(readxl)
library(mgcv)
```

Data Organisation

Read from excel

```
FNR <- read_excel("soils_15N_maturity.xlsx", sheet = 1)
str(FNR)
```

```
## tibble [24 x 11] (S3: tbl_df/tbl/data.frame)
## $ Field          : chr [1:24] "CR" "CR" "CR" "RF" ...
## $ Blk            : chr [1:24] "1" "2" "3" "1" ...
## $ Topdress       : chr [1:24] "Y" "Y" "Y" "Y" ...
## $ Stage          : chr [1:24] "Maturity" "Maturity" "Maturity" "Maturity" ...
## $ soil_recovery_fert_N : num [1:24] 4.98 4.95 4.01 6.25 6.54 ...
## $ soil_recovery_fert_N_percent: num [1:24] 16.6 16.5 13.4 20.8 21.8 ...
## $ crop_recovery_fert_N : num [1:24] 10.23 8.86 9.14 11.52 11.34 ...
## $ crop_recovery_fert_N_percent: num [1:24] 34.1 29.5 30.5 38.4 37.8 ...
## $ total_fertN_recovery : num [1:24] 15.2 13.8 13.2 17.8 17.9 ...
## $ total_fertN_recovery_percent: num [1:24] 50.7 46 43.8 59.2 59.6 ...
## $ Year           : num [1:24] 2021 2021 2021 2021 2021 ...
```

Clean up variables

```
FNR <- mutate_if(FNR, is.character, as.factor)
FNR$Blk <- as.factor(FNR$Blk)
FNR$Year <- as.factor(FNR$Year)

str(FNR)
```

```
## tibble [24 x 11] (S3: tbl_df/tbl/data.frame)
## $ Field          : Factor w/ 2 levels "CR","RF": 1 1 1 2 2 2 1 1 1 2 ...
## $ Blk            : Factor w/ 6 levels "1","2","3","4",...: 1 2 3 1 2 3 1 2 3 1 ...
## $ Topdress       : Factor w/ 2 levels "N","Y": 2 2 2 2 2 2 1 1 1 1 ...
## $ Stage          : Factor w/ 1 level "Maturity": 1 1 1 1 1 1 1 1 1 1 ...
## $ soil_recovery_fert_N : num [1:24] 4.98 4.95 4.01 6.25 6.54 ...
## $ soil_recovery_fert_N_percent: num [1:24] 16.6 16.5 13.4 20.8 21.8 ...
## $ crop_recovery_fert_N : num [1:24] 10.23 8.86 9.14 11.52 11.34 ...
## $ crop_recovery_fert_N_percent: num [1:24] 34.1 29.5 30.5 38.4 37.8 ...
## $ total_fertN_recovery : num [1:24] 15.2 13.8 13.2 17.8 17.9 ...
## $ total_fertN_recovery_percent: num [1:24] 50.7 46 43.8 59.2 59.6 ...
## $ Year           : Factor w/ 2 levels "2021","2022": 1 1 1 1 1 1 1 1 1 1 ...
```

Sub dataset for “preplant” and “topdress”

```
preplant <- FNR %>% filter(Topdress == "N")
str(preplant)
```

```
## tibble [12 x 11] (S3: tbl_df/tbl/data.frame)
##  $ Field          : Factor w/ 2 levels "CR","RF": 1 1 1 2 2 2 1 1 1 2 ...
##  $ Blk            : Factor w/ 6 levels "1","2","3","4",...: 1 2 3 1 2 3 4 5 6 4 ...
##  $ Topdress       : Factor w/ 2 levels "N","Y": 1 1 1 1 1 1 1 1 1 1 ...
##  $ Stage          : Factor w/ 1 level "Maturity": 1 1 1 1 1 1 1 1 1 1 ...
##  $ soil_recovery_fert_N : num [1:12] 31.2 23.5 24.2 34 39.1 ...
##  $ soil_recovery_fert_N_percent: num [1:12] 20.8 15.7 16.1 22.7 26.1 ...
##  $ crop_recovery_fert_N : num [1:12] 58.1 42.5 49.4 56.1 50.6 ...
##  $ crop_recovery_fert_N_percent: num [1:12] 38.7 28.4 32.9 37.4 33.8 ...
##  $ total_fertN_recovery : num [1:12] 89.3 66 73.5 90.1 89.7 ...
##  $ total_fertN_recovery_percent: num [1:12] 59.5 44 49 60.1 59.8 ...
##  $ Year           : Factor w/ 2 levels "2021","2022": 1 1 1 1 1 1 2 2 2 2 ...
```

```
topdress <- FNR %>% filter(Topdress == "Y")
str(topdress)
```

```
## tibble [12 x 11] (S3: tbl_df/tbl/data.frame)
##  $ Field          : Factor w/ 2 levels "CR","RF": 1 1 1 2 2 2 1 1 1 2 ...
##  $ Blk            : Factor w/ 6 levels "1","2","3","4",...: 1 2 3 1 2 3 4 5 6 4 ...
##  $ Topdress       : Factor w/ 2 levels "N","Y": 2 2 2 2 2 2 2 2 2 2 ...
##  $ Stage          : Factor w/ 1 level "Maturity": 1 1 1 1 1 1 1 1 1 1 ...
##  $ soil_recovery_fert_N : num [1:12] 4.98 4.95 4.01 6.25 6.54 ...
##  $ soil_recovery_fert_N_percent: num [1:12] 16.6 16.5 13.4 20.8 21.8 ...
##  $ crop_recovery_fert_N : num [1:12] 10.23 8.86 9.14 11.52 11.34 ...
##  $ crop_recovery_fert_N_percent: num [1:12] 34.1 29.5 30.5 38.4 37.8 ...
##  $ total_fertN_recovery : num [1:12] 15.2 13.8 13.2 17.8 17.9 ...
##  $ total_fertN_recovery_percent: num [1:12] 50.7 46 43.8 59.2 59.6 ...
##  $ Year           : Factor w/ 2 levels "2021","2022": 1 1 1 1 1 1 2 2 2 2 ...
```

Preplant FNR

Continuous Rice

```
preplant_CR <- preplant %>% filter(Field == "CR")
mean(preplant_CR$crop_recovery_fert_N_percent)
```

```
## [1] 28.9668
```

```
mean(preplant_CR$soil_recovery_fert_N_percent)
```

```
## [1] 22.07258
```

```
mean(preplant_CR$total_fertN_recovery_percent)
```

```
## [1] 51.03938
```

Fallow Rice

```
preplant_RF <- preplant %>% filter(Field == "RF")  
mean(preplant_RF$crop_recovery_fert_N_percent)
```

```
## [1] 30.66233
```

```
mean(preplant_RF$soil_recovery_fert_N_percent)
```

```
## [1] 25.50177
```

```
mean(preplant_RF$total_fertN_recovery_percent)
```

```
## [1] 56.1641
```

Testing for preplant

```
#total FNR  
preplant_total_model <- lmer(total_fertN_recovery_percent~Field*Year+(1|Blk), data = preplant)
```

```
## boundary (singular) fit: see help('isSingular')
```

```
anova(preplant_total_model)
```

```
## Type III Analysis of Variance Table with Satterthwaite's method  
##           Sum Sq Mean Sq NumDF DenDF F value Pr(>F)  
## Field      78.789   78.789     1     8  1.9903 0.1960  
## Year       25.255   25.255     1     8  0.6380 0.4475  
## Field:Year 32.178   32.178     1     8  0.8129 0.3936
```

```
preplant_total_means <- emmeans(preplant_total_model, spec = 'Field')
```

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

```
preplant_total_effects <- contrast(preplant_total_means, method = 'pairwise', adjust = "tukey")  
cld(preplant_total_means)
```

```
## Field emmean SE df lower.CL upper.CL .group
## CR 51.0 2.57 8 45.1 57.0 1
## RF 56.2 2.57 8 50.2 62.1 1
##
```

```
## Results are averaged over the levels of: Year
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
## significance level used: alpha = 0.05
## NOTE: If two or more means share the same grouping symbol,
##       then we cannot show them to be different.
##       But we also did not show them to be the same.
```

```
summary(preplant_total_effects)
```

```
## contrast estimate SE df t.ratio p.value
## CR - RF -5.12 3.63 4 -1.411 0.2311
##
## Results are averaged over the levels of: Year
## Degrees-of-freedom method: kenward-roger
```

```
#crop FNR
```

```
preplant_crop_model <- lmer(crop_recovery_fert_N_percent~Field*Year+(1|Blk), data = preplant)
```

```
anova(preplant_crop_model)
```

```
## Type III Analysis of Variance Table with Satterthwaite's method
## Sum Sq Mean Sq NumDF DenDF F value Pr(>F)
## Field 8.625 8.625 1 4 0.9972 0.37450
## Year 108.810 108.810 1 4 12.5811 0.02386 *
## Field:Year 1.839 1.839 1 4 0.2126 0.66869
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
preplant_crop_means <- emmeans(preplant_crop_model, spec = 'Field')
```

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

```
preplant_crop_effects <- contrast(preplant_crop_means, method = 'pairwise', adjust = "tukey")
cld(preplant_crop_means)
```

```
## Field emmean SE df lower.CL upper.CL .group
## CR 29.0 1.4 7.47 25.7 32.2 1
## RF 30.7 1.4 7.47 27.4 33.9 1
##
```

```
## Results are averaged over the levels of: Year
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
## significance level used: alpha = 0.05
## NOTE: If two or more means share the same grouping symbol,
##       then we cannot show them to be different.
##       But we also did not show them to be the same.
```

```
summary(preplant_crop_effects)
```

```
## contrast estimate SE df t.ratio p.value
## CR - RF          -1.7 1.7  4  -0.999  0.3745
##
## Results are averaged over the levels of: Year
## Degrees-of-freedom method: kenward-roger
```

```
#soil FNR
```

```
preplant_soil_model <- lmer(soil_recovery_fert_N_percent~Field*Year+(1|Blk), data = preplant)
```

```
## boundary (singular) fit: see help('isSingular')
```

```
anova(preplant_soil_model)
```

```
## Type III Analysis of Variance Table with Satterthwaite's method
##           Sum Sq Mean Sq NumDF DenDF F value Pr(>F)
## Field      35.278  35.278     1     8  1.4153 0.2683
## Year       75.547  75.547     1     8  3.0308 0.1199
## Field:Year  49.401  49.401     1     8  1.9819 0.1968
```

```
preplant_soil_means <- emmeans(preplant_soil_model, spec = 'Field')
```

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

```
preplant_soil_effects <- contrast(preplant_soil_means, method = 'pairwise', adjust = "tukey")
cld(preplant_soil_means)
```

```
## Field emmean SE df lower.CL upper.CL .group
## CR      22.1 2.04 8      17.4      26.8 1
## RF      25.5 2.04 8      20.8      30.2 1
##
## Results are averaged over the levels of: Year
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
## significance level used: alpha = 0.05
## NOTE: If two or more means share the same grouping symbol,
##       then we cannot show them to be different.
##       But we also did not show them to be the same.
```

```
summary(preplant_soil_effects)
```

```
## contrast estimate SE df t.ratio p.value
## CR - RF          -3.43 2.88 4  -1.190  0.3000
##
## Results are averaged over the levels of: Year
## Degrees-of-freedom method: kenward-roger
```

Topdress FNR

Continuous Rice

```
topdress_CR <- topdress %>% filter(Field == "CR")
mean(topdress_CR$crop_recovery_fert_N_percent)
```

```
## [1] 28.24514
```

```
mean(topdress_CR$soil_recovery_fert_N_percent)
```

```
## [1] 17.63424
```

```
mean(topdress_CR$total_fertN_recovery_percent)
```

```
## [1] 45.87937
```

Fallow Rice

```
topdress_RF <- topdress %>% filter(Field == "RF")
mean(topdress_RF$crop_recovery_fert_N_percent)
```

```
## [1] 37.62093
```

```
mean(topdress_RF$soil_recovery_fert_N_percent)
```

```
## [1] 20.49374
```

```
mean(topdress_RF$total_fertN_recovery_percent)
```

```
## [1] 58.11467
```

Testing for topdress

```
#total FNR
topdress_total_model <- lmer(total_fertN_recovery_percent~Field*Year+(1|Blk), data = topdress)
anova(topdress_total_model)
```

```
## Type III Analysis of Variance Table with Satterthwaite's method
##           Sum Sq Mean Sq NumDF DenDF F value  Pr(>F)
## Field      449.11   449.11     1     4   9.7585 0.03539 *
## Year        44.61    44.61     1     4   0.9694 0.38058
## Field:Year 176.03   176.03     1     4   3.8249 0.12215
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```

topdress_total_means <- emmeans(topdress_total_model, spec = 'Field')

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

topdress_total_effects <- contrast(topdress_total_means, method = 'pairwise', adjust = "tukey")
cld(topdress_total_means)

## Field emmean SE df lower.CL upper.CL .group
## CR 45.9 3.51 7.01 37.6 54.2 1
## RF 58.1 3.51 7.01 49.8 66.4 2
##
## Results are averaged over the levels of: Year
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
## significance level used: alpha = 0.05
## NOTE: If two or more means share the same grouping symbol,
## then we cannot show them to be different.
## But we also did not show them to be the same.

summary(topdress_total_effects)

## contrast estimate SE df t.ratio p.value
## CR - RF -12.2 3.92 4 -3.124 0.0354
##
## Results are averaged over the levels of: Year
## Degrees-of-freedom method: kenward-roger

#crop FNR
topdress_crop_model <- lmer(crop_recovery_fert_N_percent~Field*Year+(1|Blk), data = topdress)

## boundary (singular) fit: see help('isSingular')

anova(topdress_crop_model)

## Type III Analysis of Variance Table with Satterthwaite's method
## Sum Sq Mean Sq NumDF DenDF F value Pr(>F)
## Field 263.717 263.717 1 8 8.0294 0.02203 *
## Year 1.226 1.226 1 8 0.0373 0.85159
## Field:Year 141.353 141.353 1 8 4.3038 0.07172 .
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

topdress_crop_means <- emmeans(topdress_crop_model, spec = 'Field')

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

topdress_crop_effects <- contrast(topdress_crop_means, method = 'pairwise', adjust = "tukey")
cld(topdress_crop_means)

```



```
## Field emmean SE df lower.CL upper.CL .group
## CR 28.2 2.34 8 22.8 33.6 1
## RF 37.6 2.34 8 32.2 43.0 2
##
## Results are averaged over the levels of: Year
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
## significance level used: alpha = 0.05
## NOTE: If two or more means share the same grouping symbol,
## then we cannot show them to be different.
## But we also did not show them to be the same.
```

```
summary(topdress_crop_effects)
```

```
## contrast estimate SE df t.ratio p.value
## CR - RF -9.38 3.31 4 -2.834 0.0472
##
## Results are averaged over the levels of: Year
## Degrees-of-freedom method: kenward-roger
```

```
#soil FNR
```

```
topdress_soil_model <- lmer(soil_recovery_fert_N_percent~Field*Year+(1|Blk), data = topdress)
```

```
anova(topdress_soil_model)
```

```
## Type III Analysis of Variance Table with Satterthwaite's method
## Sum Sq Mean Sq NumDF DenDF F value Pr(>F)
## Field 24.530 24.530 1 4 1.7558 0.2558
## Year 39.223 39.223 1 4 2.8074 0.1691
## Field:Year 1.900 1.900 1 4 0.1360 0.7310
```

```
topdress_soil_means <- emmeans(topdress_soil_model, spec = 'Field')
```

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

```
topdress_soil_effects <- contrast(topdress_soil_means, method = 'pairwise', adjust = "tukey")
cld(topdress_soil_means)
```

```
## Field emmean SE df lower.CL upper.CL .group
## CR 17.6 1.86 7.22 13.3 22.0 1
## RF 20.5 1.86 7.22 16.1 24.9 1
##
## Results are averaged over the levels of: Year
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
## significance level used: alpha = 0.05
## NOTE: If two or more means share the same grouping symbol,
## then we cannot show them to be different.
## But we also did not show them to be the same.
```

```
summary(topdress_soil_effects)
```

```
## contrast estimate    SE df t.ratio p.value
## CR - RF           -2.86 2.16  4  -1.325  0.2558
##
## Results are averaged over the levels of: Year
## Degrees-of-freedom method: kenward-roger
```