N Rate Trial

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Contents

Necessary libraries

Data Organisation

Read from excel

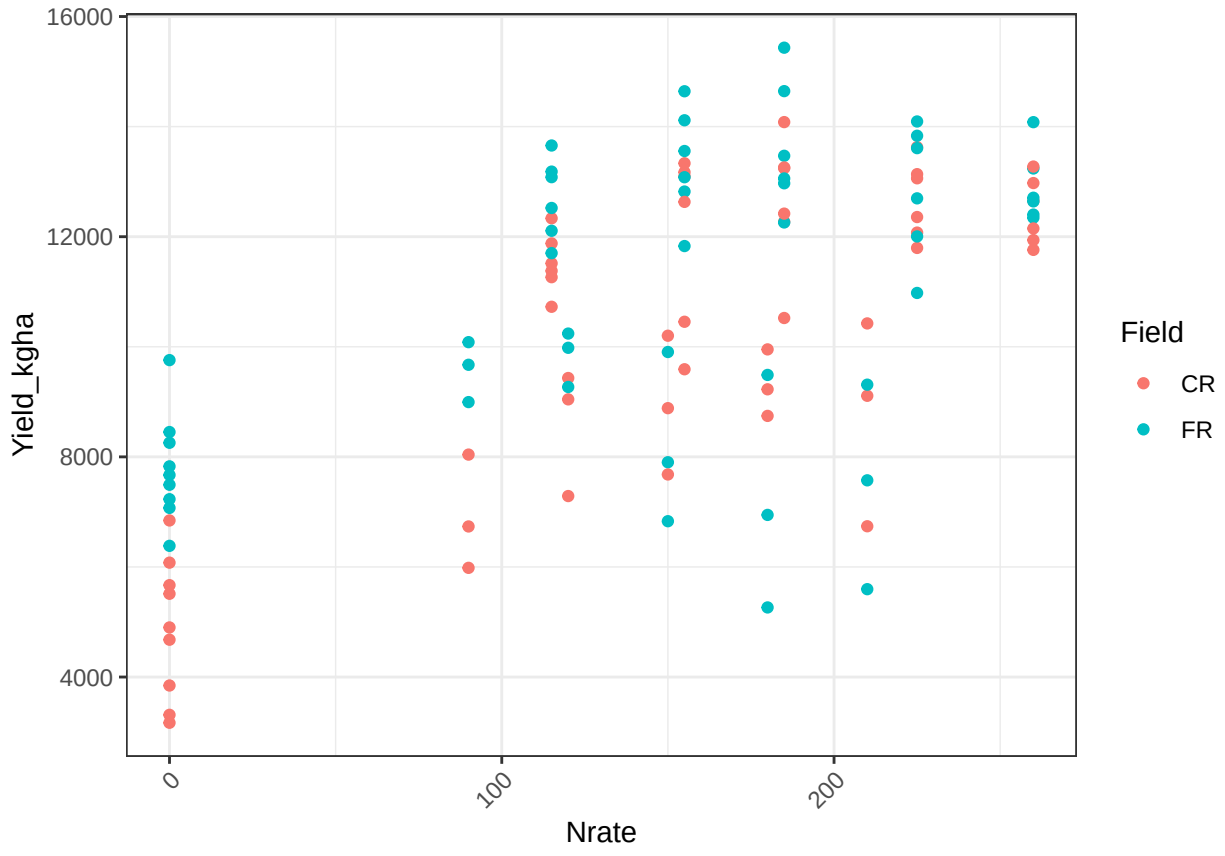
```
master <- read_excel("Grain yield for Dustin.xlsx", sheet = 1)
master <- mutate_if(master, is.character, as.factor)
master$NrateF <- as.factor(master$Nrate)
master$Year <- as.factor(master$Year)

str(master)
```

```
## tibble [108 x 7] (S3: tbl_df/tbl/data.frame)
##  $ Plot      : Factor w/ 108 levels "101","102","103",..: 1 2 3 4 5 6 7 8 9 10 ...
##  $ Field     : Factor w/ 2 levels "CR","FR": 2 2 2 2 2 2 1 1 1 1 ...
##  $ Blk       : num [1:108] 1 1 1 1 1 1 1 1 1 1 ...
##  $ Nrate     : num [1:108] 260 115 155 0 185 225 225 115 185 155 ...
##  $ Yield_kgha: num [1:108] 14081 13082 14642 7073 15434 ...
##  $ Year      : Factor w/ 3 levels "2021","2022",..: 1 1 1 1 1 1 1 1 1 1 ...
##  $ NrateF    : Factor w/ 11 levels "0","90","115",..: 11 3 6 1 8 10 10 3 8 6 ...
```

Initial visualisation

```
ggplot(master, aes(y=Yield_kgha, x=Nrate, color=Field))+
  geom_point()+
  theme(axis.text.x = element_text(angle = 45, hjust = 1, size= 9))
```



Check for most important variables

Year effect very significant. So analyse data by 3 different years.

```
all_factors_model <- lm(Yield_kgha~Year*NrateF*Field, data = master)

anova(all_factors_model)
```

```
## Analysis of Variance Table
##
## Response: Yield_kgha
##                    Df    Sum Sq   Mean Sq  F value    Pr(>F)
## Year                2 319434692 159717346 153.3683 < 2.2e-16 ***
## NrateF             10 427844149  42784415  41.0837 < 2.2e-16 ***
## Field               1  23605054  23605054  22.6667 9.683e-06 ***
## Year:NrateF         5  10080982   2016196   1.9360   0.09883 .
## Year:Field          2   1328601    664300   0.6379   0.53136
## NrateF:Field       10  51181407   5118141   4.9147 2.136e-05 ***
## Year:NrateF:Field   5   2037827    407565   0.3914   0.85321
## Residuals          72  74980592   1041397
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Subset data from the 3 years

```
yield_2021 <- master %>% filter (Year == "2021")

yield_2022 <- master %>% filter (Year == "2022")

yield_2023 <- master %>% filter (Year == "2023")

#checked datasets, all looks good.
```

statistical testing

2021

```
model_2021 <- lmer(Yield_kgha ~ NrateF+Field:NrateF+(1|Field:Blk)+(1|NrateF:Blk), data=yield_2021)
```

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

```
field_means_2021 = emmeans(model_2021,spec = 'Field',by = 'NrateF')
```

```
## NOTE: A nesting structure was detected in the fitted model:
##     Field %in% NrateF
```

```
field_effects_2021 = contrast(field_means_2021, method = 'pairwise', adjust = "Tukey")

summary(field_effects_2021)
```

```
## NrateF = 0:
##  contrast estimate  SE df t.ratio p.value
##  CR - FR     -2246 413 12  -5.435  0.0002
##
## NrateF = 115:
##  contrast estimate  SE df t.ratio p.value
##  CR - FR     -1177 413 12  -2.850  0.0146
##
## NrateF = 155:
##  contrast estimate  SE df t.ratio p.value
##  CR - FR      -904 413 12  -2.189  0.0491
##
## NrateF = 185:
##  contrast estimate  SE df t.ratio p.value
##  CR - FR      -988 413 12  -2.391  0.0341
##
## NrateF = 225:
##  contrast estimate  SE df t.ratio p.value
##  CR - FR      -806 413 12  -1.950  0.0750
##
## NrateF = 260:
##  contrast estimate  SE df t.ratio p.value
##  CR - FR      -858 413 12  -2.077  0.0600
##
## Degrees-of-freedom method: kenward-roger
```

```
cld(field_means_2021)
```

```
## NrateF = 0:
##  Field emmean  SE   df lower.CL upper.CL .group
##  CR      5219 338 22.6     4520     5918  1
##  FR      7465 338 22.6     6766     8164   2
##
## NrateF = 115:
##  Field emmean  SE   df lower.CL upper.CL .group
##  CR     11910 338 22.6    11211    12609  1
##  FR     13087 338 22.6    12388    13786   2
##
## NrateF = 155:
##  Field emmean  SE   df lower.CL upper.CL .group
##  CR     13200 338 22.6    12501    13899  1
##  FR     14105 338 22.6    13406    14804   2
##
## NrateF = 185:
##  Field emmean  SE   df lower.CL upper.CL .group
##  CR     13528 338 22.6    12829    14227  1
##  FR     14516 338 22.6    13817    15215   2
##
```

```
## NrateF = 225:
##  Field emmean  SE   df lower.CL upper.CL .group
##  CR     13040 338 22.6    12341    13739  1
##  FR     13845 338 22.6    13146    14544  1
##
## NrateF = 260:
##  Field emmean  SE   df lower.CL upper.CL .group
##  CR     12462 338 22.6    11763    13161  1
##  FR     13321 338 22.6    12621    14020  1
##
## 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.
```

2022

```
model_2022 <- lmer(Yield_kgha ~ NrateF+Field:NrateF+(1|Field:Blk)+(1|NrateF:Blk), data=yield_2022)
```

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

```
field_means_2022 = emmeans(model_2022,spec = 'Field',by = 'NrateF')
```

```
## NOTE: A nesting structure was detected in the fitted model:
##     Field %in% NrateF
```

```
field_effects_2022 = contrast(field_means_2022, method = 'pairwise', adjust = "Tukey")

summary(field_effects_2022)
```

```
## NrateF = 0:
##  contrast estimate  SE   df t.ratio p.value
##  CR - FR   -2515.1 849 12.2  -2.964  0.0116
##
## NrateF = 115:
##  contrast estimate  SE   df t.ratio p.value
##  CR - FR   -1207.3 849 12.2  -1.423  0.1799
##
## NrateF = 155:
##  contrast estimate  SE   df t.ratio p.value
##  CR - FR   -1684.1 849 12.2  -1.985  0.0701
##
## NrateF = 185:
##  contrast estimate  SE   df t.ratio p.value
##  CR - FR   -1024.7 849 12.2  -1.208  0.2501
##
## NrateF = 225:
##  contrast estimate  SE   df t.ratio p.value
```

```
##  CR - FR     417.4 849 12.2   0.492  0.6316
##
## NrateF = 260:
##  contrast estimate  SE   df t.ratio p.value
##  CR - FR     -30.8 849 12.2  -0.036  0.9716
##
## Degrees-of-freedom method: kenward-roger
```

```
cld(field_means_2022)
```

```
## NrateF = 0:
##  Field emmean  SE   df lower.CL upper.CL .group
##  CR      5276 600 18.6     4018     6533  1
##  FR      7791 600 18.6     6533     9048   2
##
## NrateF = 115:
##  Field emmean  SE   df lower.CL upper.CL .group
##  CR     11123 600 18.6     9866    12381  1
##  FR     12331 600 18.6    11073    13588  1
##
## NrateF = 155:
##  Field emmean  SE   df lower.CL upper.CL .group
##  CR     10893 600 18.6     9635    12150  1
##  FR     12577 600 18.6    11319    13834  1
##
## NrateF = 185:
##  Field emmean  SE   df lower.CL upper.CL .group
##  CR     11738 600 18.6    10480    12995  1
##  FR     12762 600 18.6    11505    14020  1
##
## NrateF = 225:
##  Field emmean  SE   df lower.CL upper.CL .group
##  FR     11893 600 18.6    10636    13151  1
##  CR     12311 600 18.6    11053    13568  1
##
## NrateF = 260:
##  Field emmean  SE   df lower.CL upper.CL .group
##  CR     12454 600 18.6    11197    13712  1
##  FR     12485 600 18.6    11227    13743  1
##
## 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.
```

2023

```
model_2023 <- lmer(Yield_kgha ~ NrateF+Field:NrateF+(1|Field:Blk)+(1|NrateF:Blk), data=yield_2023)

field_means_2023 = emmeans(model_2023,spec = 'Field',by = 'NrateF')
```

```
## NOTE: A nesting structure was detected in the fitted model:
##     Field %in% NrateF
```

```
field_effects_2023 = contrast(field_means_2023, method = 'pairwise', adjust = "Tukey")

summary(field_effects_2023)
```

```
## NrateF = 0:
##  contrast estimate  SE   df t.ratio p.value
##  CR - FR     -3950 740 8.91  -5.337  0.0005
##
## NrateF = 120:
##  contrast estimate  SE   df t.ratio p.value
##  CR - FR     -1242 740 8.91  -1.678  0.1280
##
## NrateF = 150:
##  contrast estimate  SE   df t.ratio p.value
##  CR - FR       709 740 8.91   0.959  0.3631
##
## NrateF = 180:
##  contrast estimate  SE   df t.ratio p.value
##  CR - FR      2076 740 8.91   2.804  0.0208
##
## NrateF = 210:
##  contrast estimate  SE   df t.ratio p.value
##  CR - FR      1264 740 8.91   1.708  0.1222
##
## NrateF = 90:
##  contrast estimate  SE   df t.ratio p.value
##  CR - FR     -2664 740 8.91  -3.599  0.0059
##
## Degrees-of-freedom method: kenward-roger
```

```
cld(field_means_2023)
```

```
## NrateF = 0:
##  Field emmean  SE   df lower.CL upper.CL .group
##  CR      4176 770 17.6     2556     5796  1
##  FR      8126 770 17.6     6506     9746   2
##
## NrateF = 90:
##  Field emmean  SE   df lower.CL upper.CL .group
##  CR      6920 770 17.6     5300     8540  1
##  FR      9584 770 17.6     7964    11204   2
##
## NrateF = 120:
##  Field emmean  SE   df lower.CL upper.CL .group
##  CR      8588 770 17.6     6969    10208  1
##  FR      9830 770 17.6     8211    11450  1
##
## NrateF = 150:
##  Field emmean  SE   df lower.CL upper.CL .group
##  FR      8213 770 17.6     6593     9832  1
```

```
##  CR      8922 770 17.6     7302    10542  1
##
## NrateF = 180:
##  Field emmean  SE   df lower.CL upper.CL .group
##  FR      7233 770 17.6     5613     8852  1
##  CR      9308 770 17.6     7688    10928   2
##
## NrateF = 210:
##  Field emmean  SE   df lower.CL upper.CL .group
##  FR      7494 770 17.6     5874     9114  1
##  CR      8758 770 17.6     7138    10378  1
##
## 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.
```

Graphing dataframes

```
# 2021 dataframe

yield_2021_dataframe <- yield_2021 %>%
    group_by(Field, Nrate) %>%
   mutate(Yield_kgha_sd = sd(Yield_kgha)) %>%
  summarise(Yield_kgha = mean(Yield_kgha),
            Yield_kgha_sd = mean(Yield_kgha_sd)) %>%
  mutate(Year = 2021)
```

```
## `summarise()` has grouped output by 'Field'. You can override using the
## `.groups` argument.
```

```
# 2022 dataframe

yield_2022_dataframe <- yield_2022 %>%
    group_by(Field, Nrate) %>%
   mutate(Yield_kgha_sd = sd(Yield_kgha)) %>%
  summarise(Yield_kgha = mean(Yield_kgha),
            Yield_kgha_sd = mean(Yield_kgha_sd)) %>%
  mutate(Year = 2022)
```

```
## `summarise()` has grouped output by 'Field'. You can override using the
## `.groups` argument.
```

```
# 2023 dataframe

yield_2023_dataframe <- yield_2023 %>%
    group_by(Field, Nrate) %>%
   mutate(Yield_kgha_sd = sd(Yield_kgha)) %>%
```

```
  summarise(Yield_kgha = mean(Yield_kgha),
            Yield_kgha_sd = mean(Yield_kgha_sd)) %>%
  mutate(Year = 2023)
```

```
## `summarise()` has grouped output by 'Field'. You can override using the
## `.groups` argument.
```

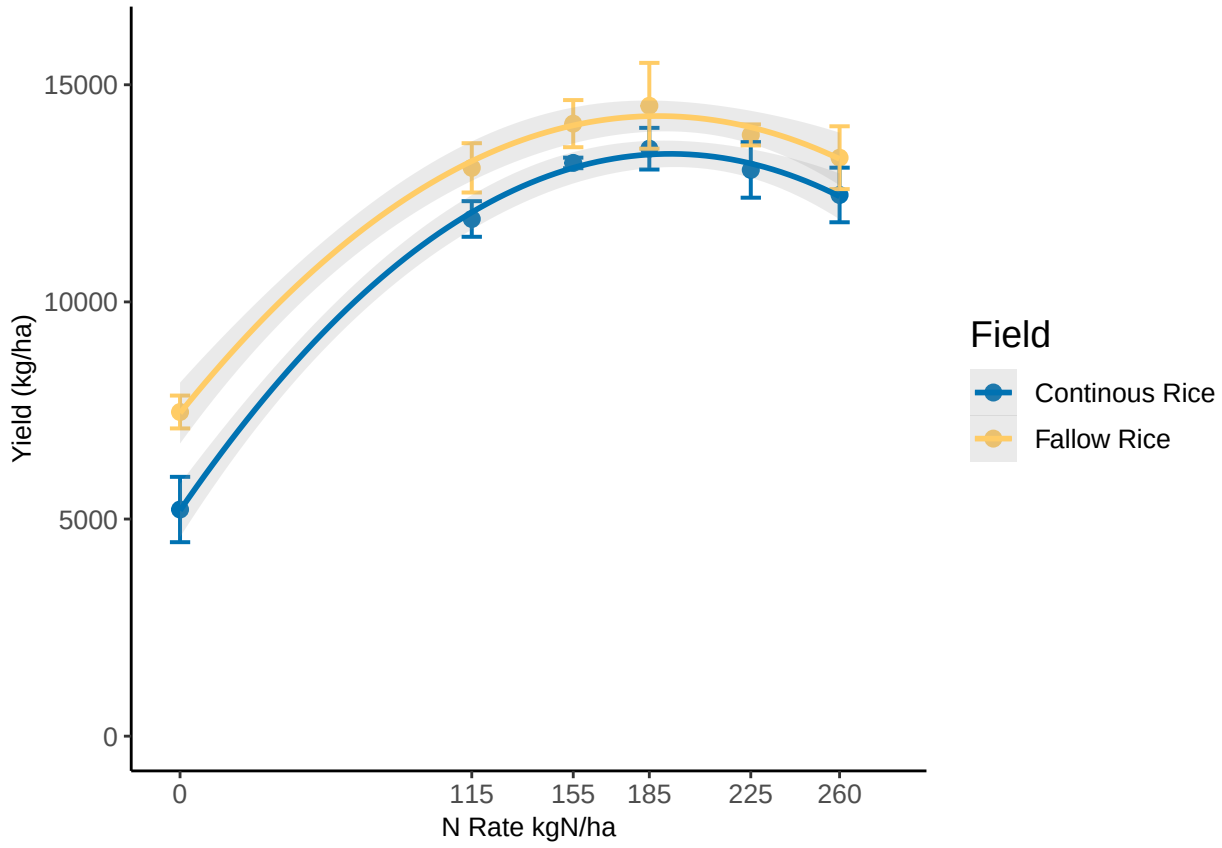
Graphs

2021 graph

```
N_response_curve_2021 <-
ggplot(yield_2021_dataframe, aes(x=Nrate, y=Yield_kgha, color=Field))+
  geom_point(data=yield_2021_dataframe, size=2.5)+
  scale_color_manual(values=c("#0072B2","#FFCC66"), name = "Field", labels = c('Continous Rice','Fallow
  scale_x_continuous(name="N Rate kgN/ha", limits = c(-5, 280), breaks = c(0, 115, 155, 185, 225, 260))+
  scale_y_continuous(name= "Yield (kg/ha)", limits = c(0, 16000))+ #, limits = c(0, 16000), expand = c(
  geom_errorbar(data=yield_2021_dataframe, aes(ymin=Yield_kgha-Yield_kgha_sd, ymax=Yield_kgha+Yield_kgha
  theme_classic()+theme(axis.text = element_text(size = 10), axis.title = element_text(size=10))+
  geom_smooth(data = yield_2021, method = "lm", formula = y ~ poly(x, 2), se = TRUE, alpha=0.2)+
  #geom_vline(xintercept = c(0, 115, 155, 185, 225, 260), linetype = "dashed", color = "black") +
  theme(legend.text = element_text(size = 10),legend.title = element_text(size = 14))
```

```
## Warning: Using `size` aesthetic for lines was deprecated in ggplot2 3.4.0.
## i Please use `linewidth` instead.
## This warning is displayed once every 8 hours.
## Call `lifecycle::last_lifecycle_warnings()` to see where this warning was
## generated.
```

```
N_response_curve_2021
```

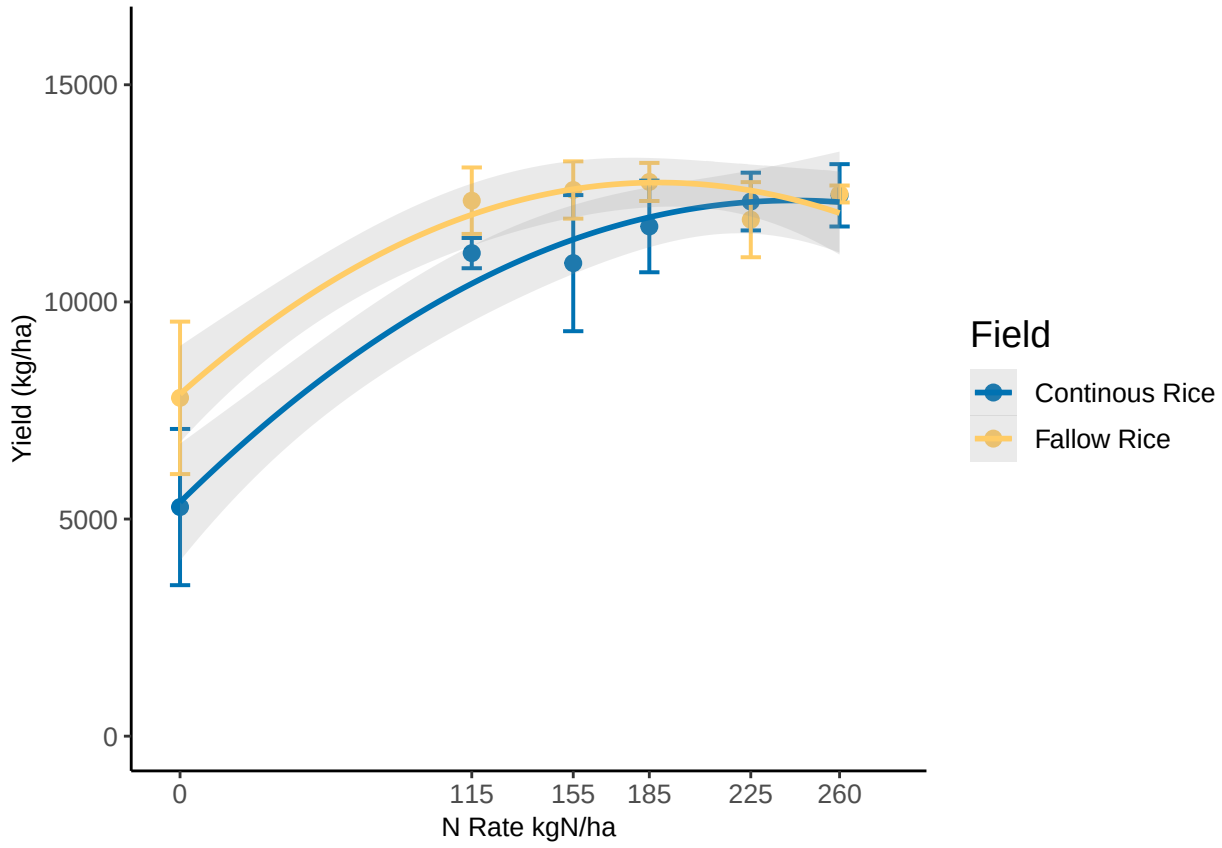



```
ggsave(N_response_curve_2021, filename = "N_response_curve_2021.png", height = 15, width = 20, units =
```

2022 graph

```
N_response_curve_2022 <-
ggplot(yield_2022_dataframe, aes(x=Nrate, y=Yield_kgha, color=Field))+
  geom_point(data=yield_2022_dataframe, size=2.5)+
  scale_color_manual(values=c("#0072B2","#FFCC66"), name = "Field", labels = c('Continous Rice','Fallow
  scale_x_continuous(name="N Rate kgN/ha", limits = c(-5, 280), breaks = c(0, 115, 155, 185, 225, 260))+
  scale_y_continuous(name= "Yield (kg/ha)", limits = c(0, 16000))+ #, limits = c(0, 16000), expand = c(
  geom_errorbar(data=yield_2022_dataframe, aes(ymin=Yield_kgha-Yield_kgha_sd, ymax=Yield_kgha+Yield_kgha
  theme_classic()+theme(axis.text = element_text(size = 10), axis.title = element_text(size=10))+
  geom_smooth(data = yield_2022, method = "lm", formula = y ~ poly(x, 2), se = TRUE, alpha=0.2)+
  #geom_vline(xintercept = c(0, 115, 155, 185, 225, 260), linetype = "dashed", color = "black") +
  theme(legend.text = element_text(size = 10),legend.title = element_text(size = 14))

N_response_curve_2022
```

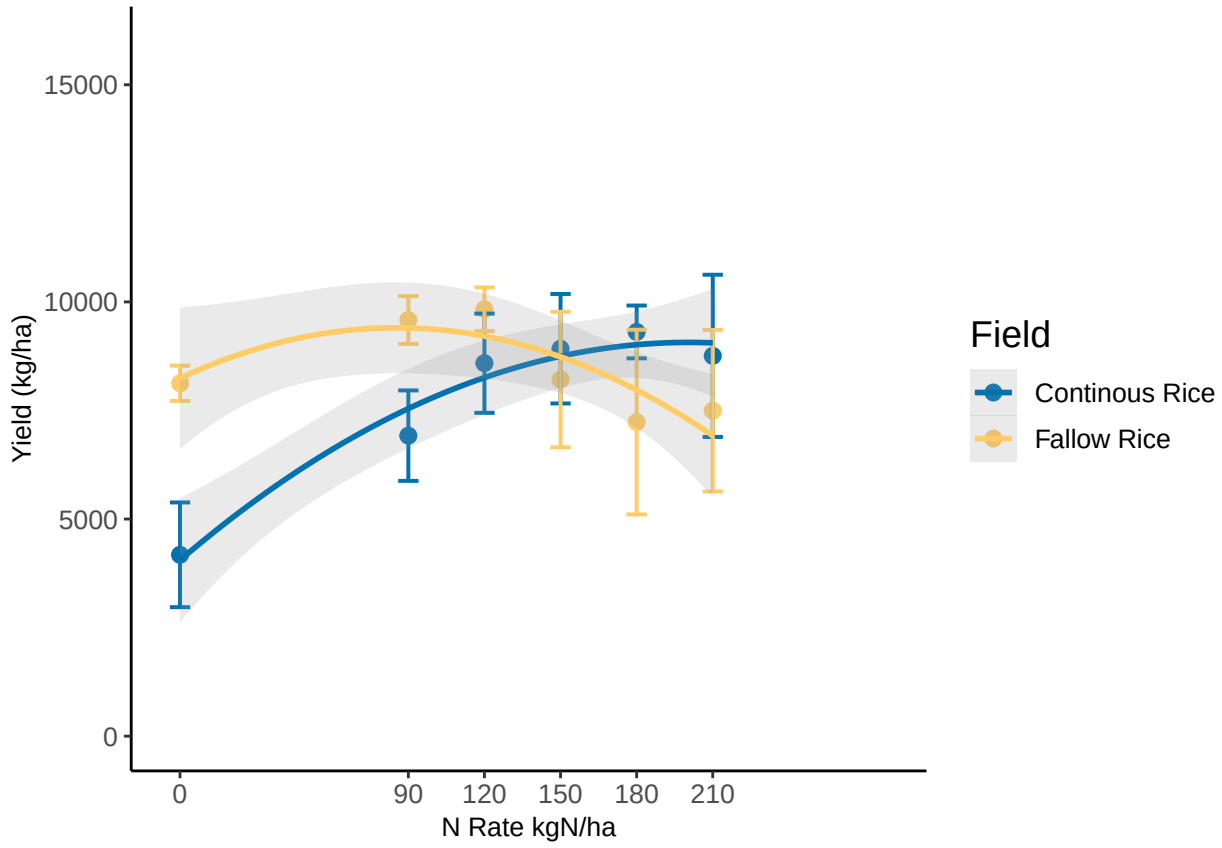



```
ggsave(N_response_curve_2022, filename = "N_response_curve_2022.png", height = 15, width = 20, units =
```

2023 graph

```
N_response_curve_2023 <-
ggplot(yield_2023_dataframe, aes(x=Nrate, y=Yield_kgha, color=Field))+
  geom_point(data=yield_2023_dataframe, size=2.5)+
  scale_color_manual(values=c("#0072B2","#FFCC66"), name = "Field", labels = c('Continous Rice','Fallow
  scale_x_continuous(name="N Rate kgN/ha", limits = c(-5, 280), breaks = c(0, 90, 120, 150, 180, 210))+
  scale_y_continuous(name= "Yield (kg/ha)", limits = c(0, 16000))+ #, limits = c(0, 16000), expand = c(
  geom_errorbar(data=yield_2023_dataframe, aes(ymin=Yield_kgha-Yield_kgha_sd, ymax=Yield_kgha+Yield_kgha
  theme_classic()+theme(axis.text = element_text(size = 10), axis.title = element_text(size=10))+
  geom_smooth(data = yield_2023, method = "lm", formula = y ~ poly(x, 2), se = TRUE, alpha=0.2)+
  #geom_vline(xintercept = c(0, 90, 120, 150, 180, 210), linetype = "dashed", color = "black") +
  theme(legend.text = element_text(size = 10),legend.title = element_text(size = 14))

N_response_curve_2023
```




```
ggsave(N_response_curve_2023, filename = "N_response_curve_2023.png", height = 15, width = 20, units =
```