Genetic differentiation on flowering time in Cerastium fontanum using a reciprocal transplant experiment

Analyses with FFD

Alicia Valdés

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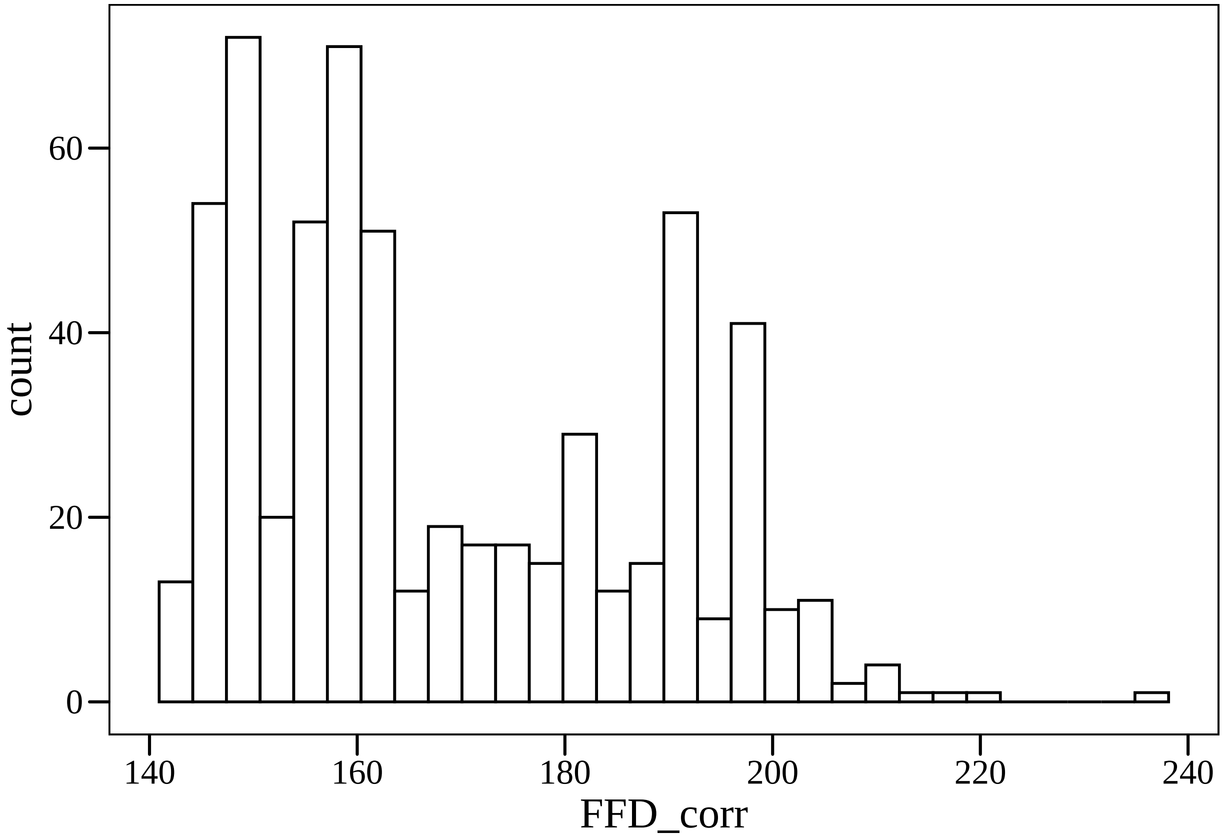
Read clean data from .csv files

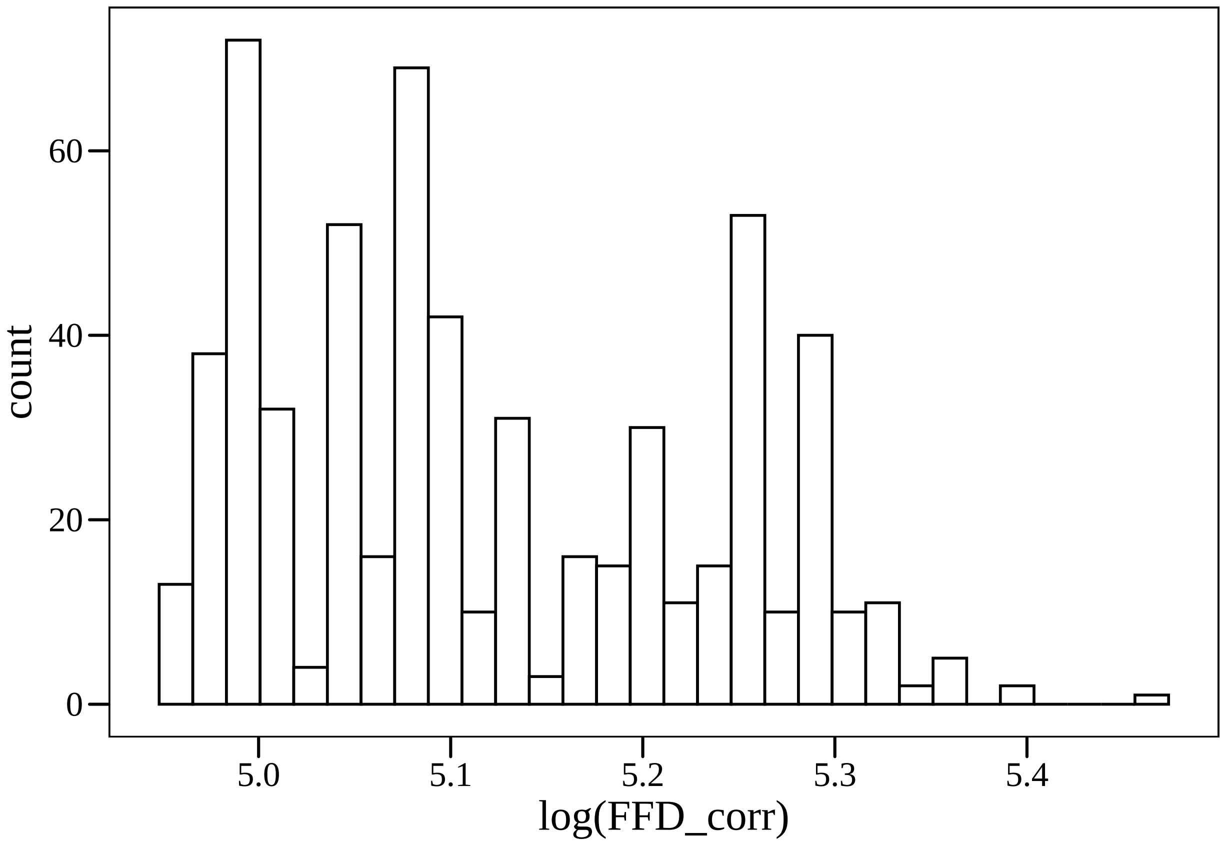
```
data_transplants <- read_csv("data/clean/data_transplants.csv")
```

Distributions

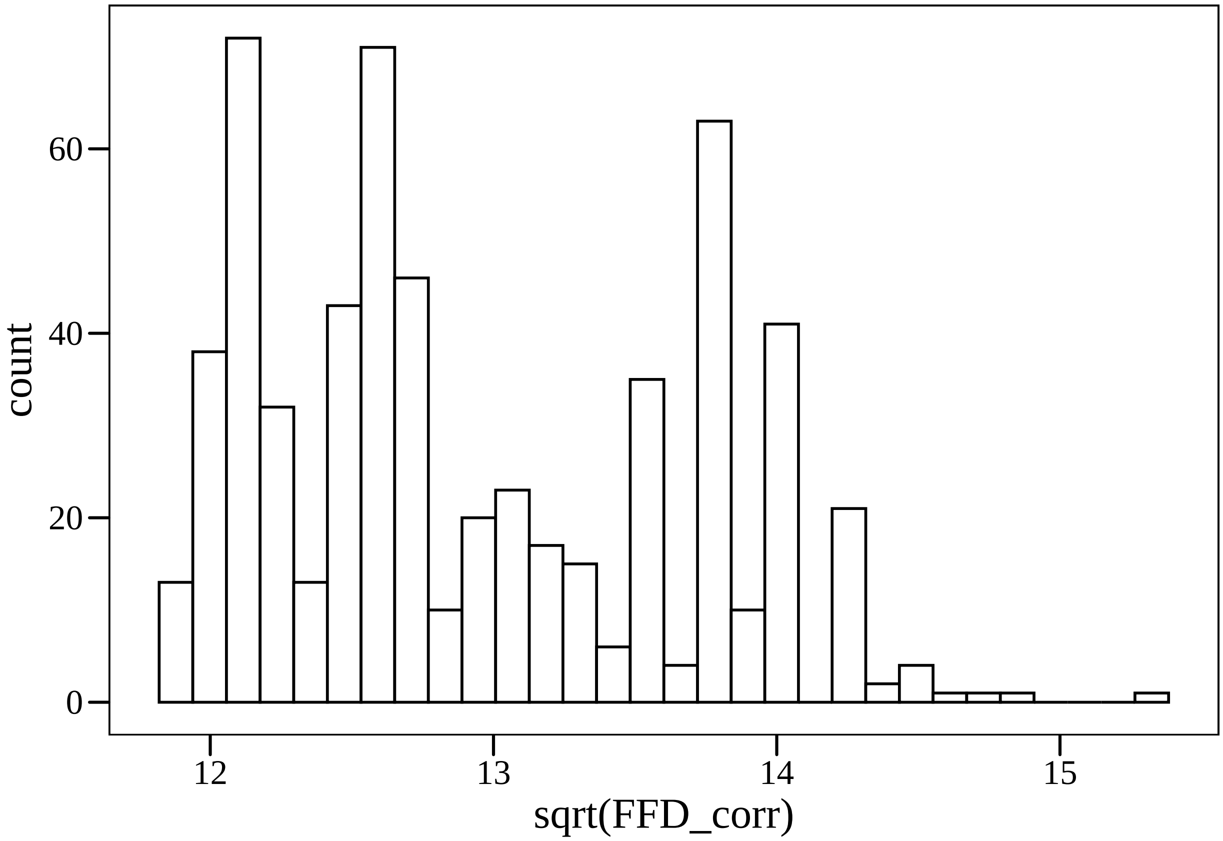
```
ggplot(data_transplants,aes(x=FFD_corr))+
  geom_histogram(color="black",fill="white")+
  my_theme()
```



```
ggplot(data_transplants,aes(x=log(FFD_corr)))+
  geom_histogram(color="black",fill="white")+
  my_theme()
```



```
ggplot(data_transplants,aes(x=sqrt(FFD_corr)))+
  geom_histogram(color="black",fill="white")+
  my_theme()
```



Models FFD

Temp mother + Temp father

```
data_transplants$heat_zone <- factor(data_transplants$heat_zone,
                                     levels=c("Cold", "Intermediate", "Hot"))
```

```
model_FFD1<-lmer(FFD_corr~(temp_mother+temp_father)*heat_zone+
                   (1|mother)+(1|father)+(1|crossing)+(1|plot),data_transplants)
model_FFD2<-lmer(FFD_corr~(temp_mother+temp_father)*temp+
                   (1|mother)+(1|father)+(1|crossing)+(1|plot),data_transplants)
```

```
tab_model(model_FFD1,model_FFD2,
          transform=NULL,show.ci=F,show.se=T,show.stat=T,digits=3,
          dv.labels=c("heat_zone","temp"),
          title="Models FFD")
```

Models FFD

heat_zone

temp

Predictors	Estimates	std. Error	Statistic	p	Estimates	std. Error	Statistic	p
(Intercept)	194.764	3.623	53.760	<0.001	188.803	4.881	38.685	<0.001
temp mother	-0.011	0.075	-0.146	0.884	-0.007	0.082	-0.086	0.932
temp father	-0.086	0.054	-1.602	0.110	-0.176	0.064	-2.753	0.006

heat zone [Intermediate]

-26.792

4.469

-5.995

<0.001

heat zone [Hot]

-44.012

4.531

-9.714

<0.001

temp mother × heat zone[Intermediate]

0.086

0.077

1.118

0.264

temp mother × heat zone[Hot]

0.085

0.081

1.050

0.294

temp father × heat zone[Intermediate]

-0.042

0.070

-0.606

0.545

temp father × heat zone[Hot]

0.145

0.076

1.902

0.058

temp

-0.932

0.092

-10.081

<0.001

temp mother × temp

0.003

0.003

0.869

0.385

temp father × temp

0.006

0.003

2.176

0.030

Random Effects

2

54.30

51.16

00

0.00 crossing

0.00 crossing

0.00 father

0.16 father

10.76 mother

9.82 mother

29.88 plot

155.98 plot

ICC

0.76

N

63 mother

63 mother

64 father

64 father

131 crossing

131 crossing

8 plot

8 plot

Observations

603

603

Marginal R2 / Conditional R2

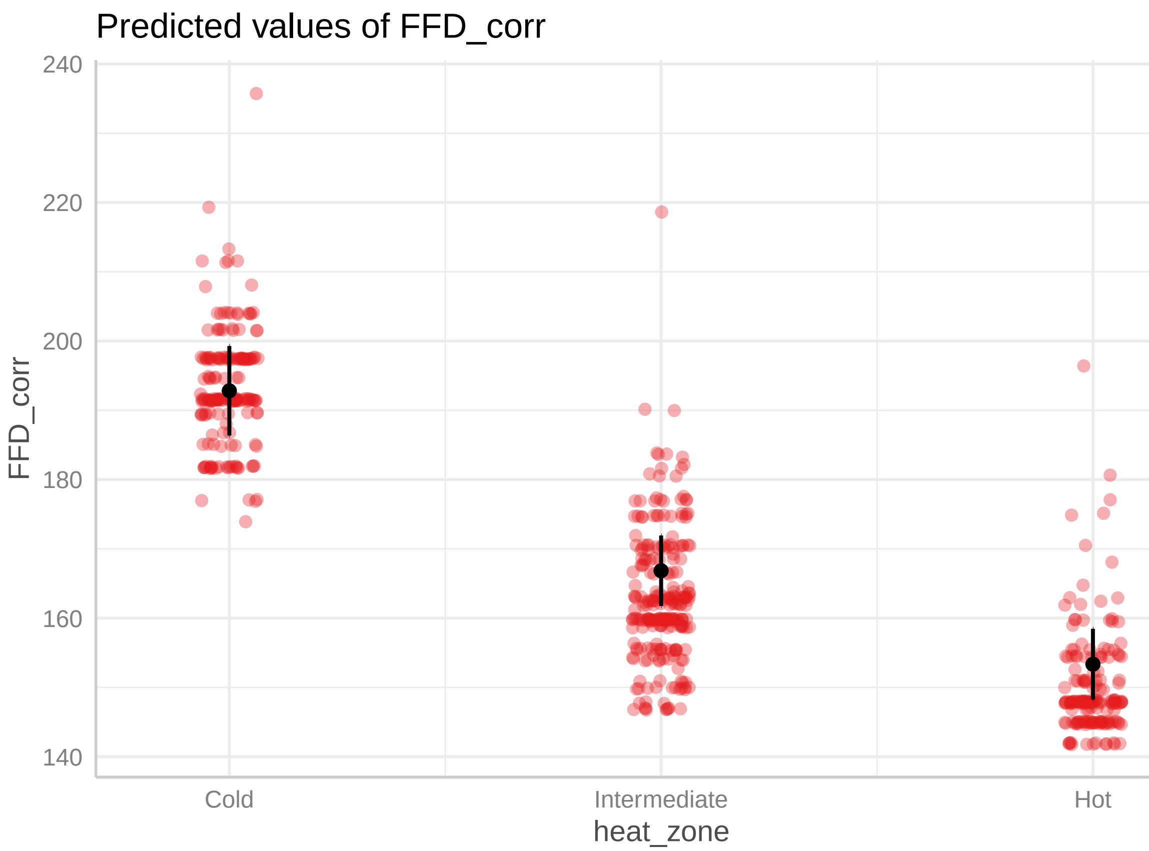
0.815 / NA

0.181 / 0.807

Save models as HTML table

Plots predicted effects

```
plot(ggpredict(model_FFD1,terms=c("heat_zone")),add.data=T)
```



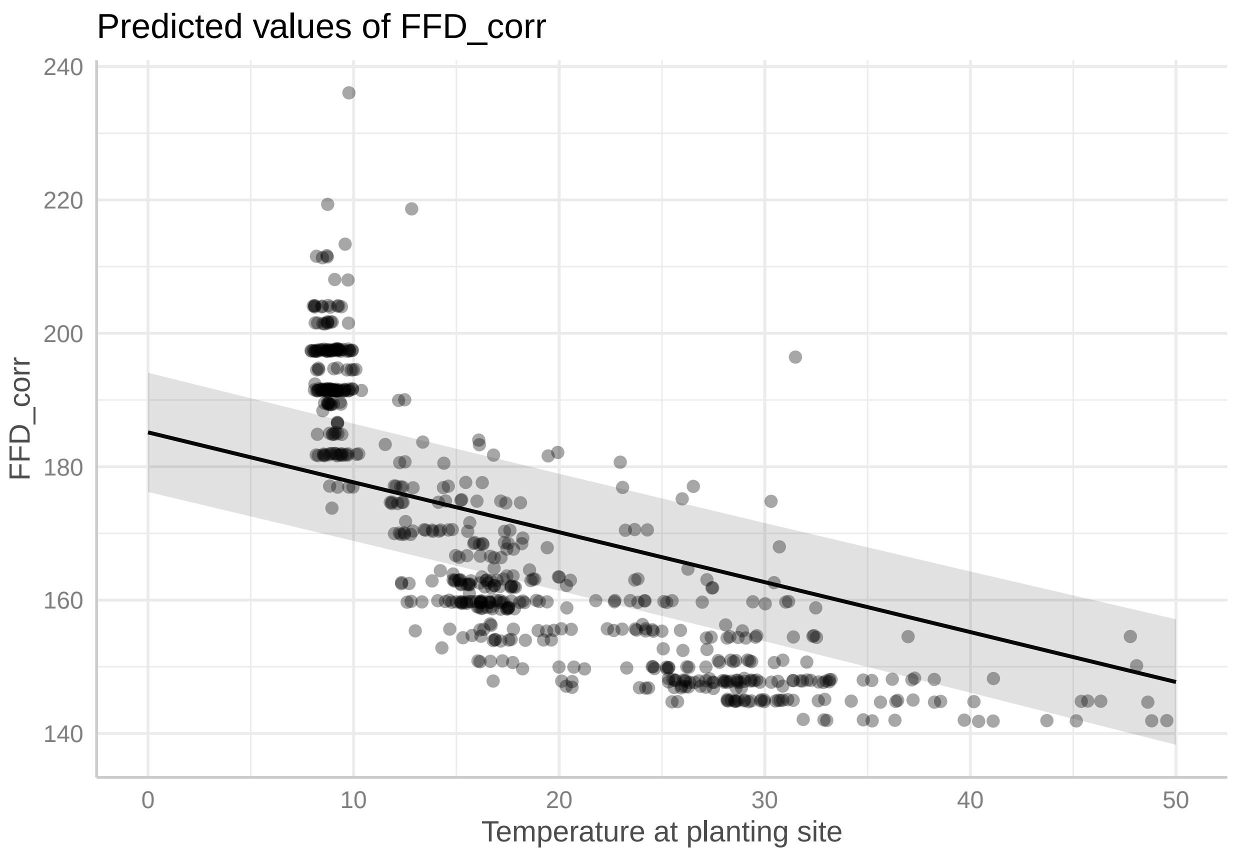
Heat zone (model1)

There is plasticity in flowering time: individuals planted in warmer areas flower earlier.

Temp at planting site (model2)

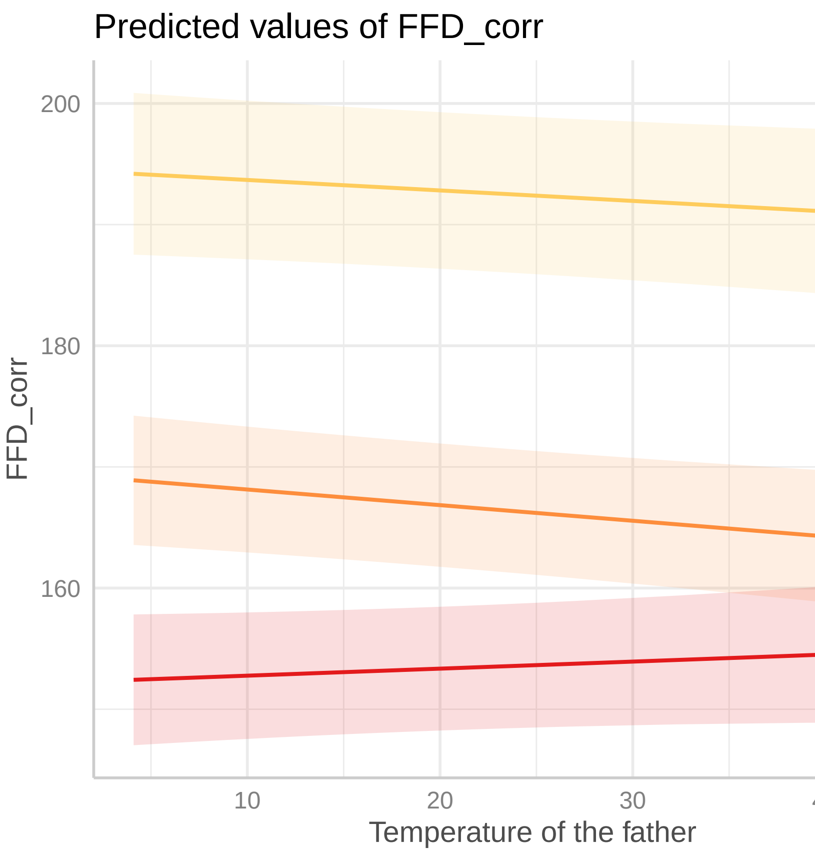
Non-linear effect?

```
plot(ggpredict(model_FFD2,terms=c("temp")),add.data=T)+
  xlab("Temperature at planting site")
```



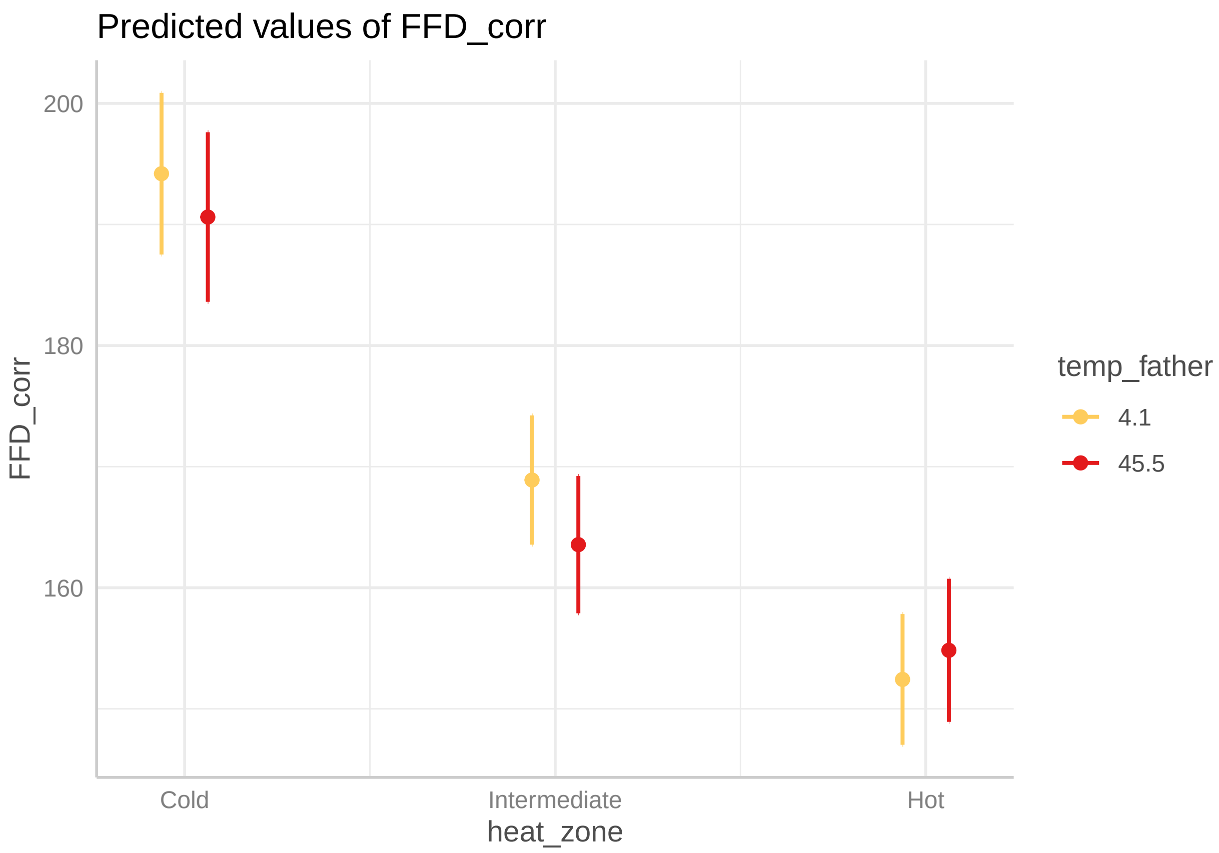
There is plasticity in flowering time: individuals planted in warmer areas flower earlier.

```
plot(ggpredict(model_FFD1,terms=c("temp_father[all]","heat_zone")),add.data=F)+
  scale_color_manual(values = c("#fecc5c", "#fd8d3c", "#e31a1c"))+
  scale_fill_manual(values = c("#fecc5c", "#fd8d3c", "#e31a1c"))+
  xlab("Temperature of the father")
```

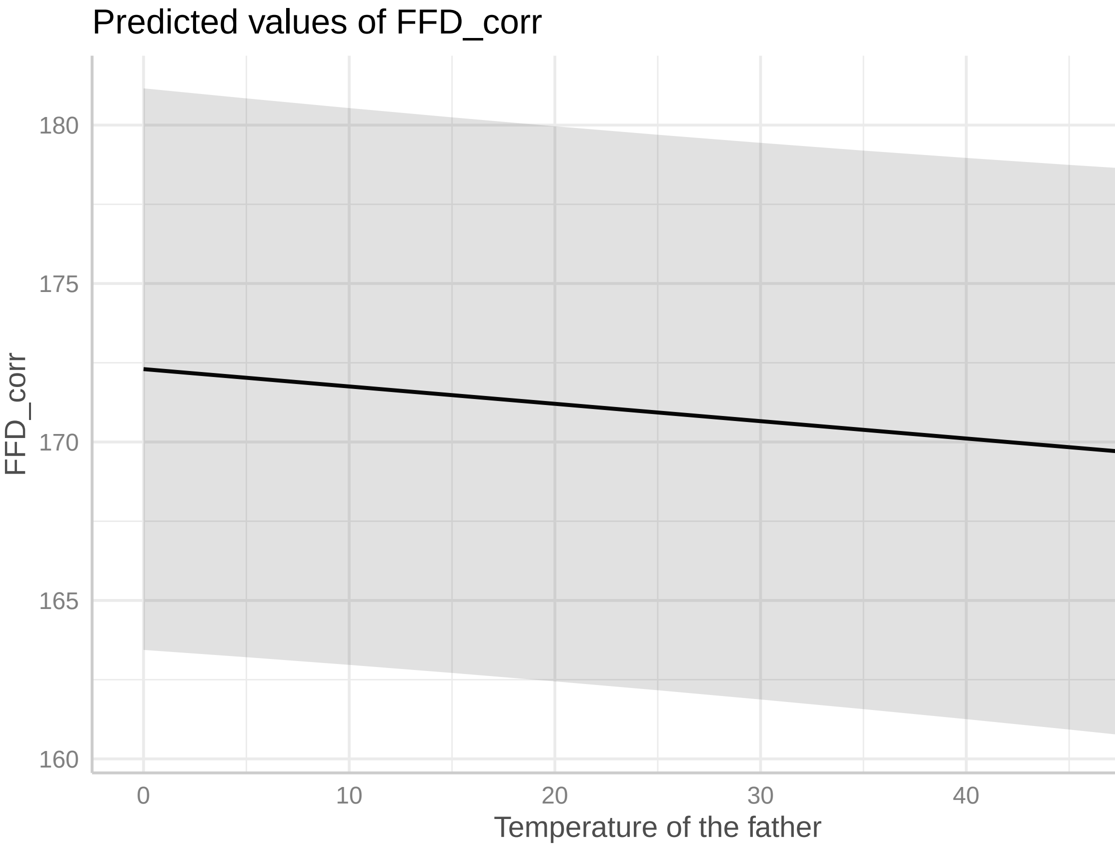


Interaction heat zone x temp father (model1)

```
plot(ggpredict(model_FFD1,terms=c("heat_zone","temp_father[minmax]")),add.data=F)+
  scale_color_manual(values = c("#fecc5c", "#e31a1c"))
```



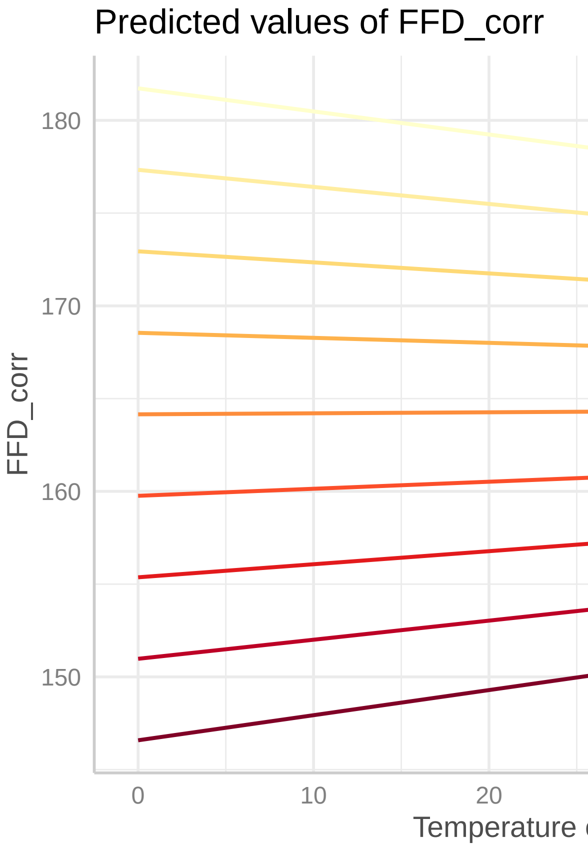
```
plot(ggpredict(model_FFD2,terms=c("temp_father")),add.data=F)+
  xlab("Temperature of the father")
```



Temp father (model2)

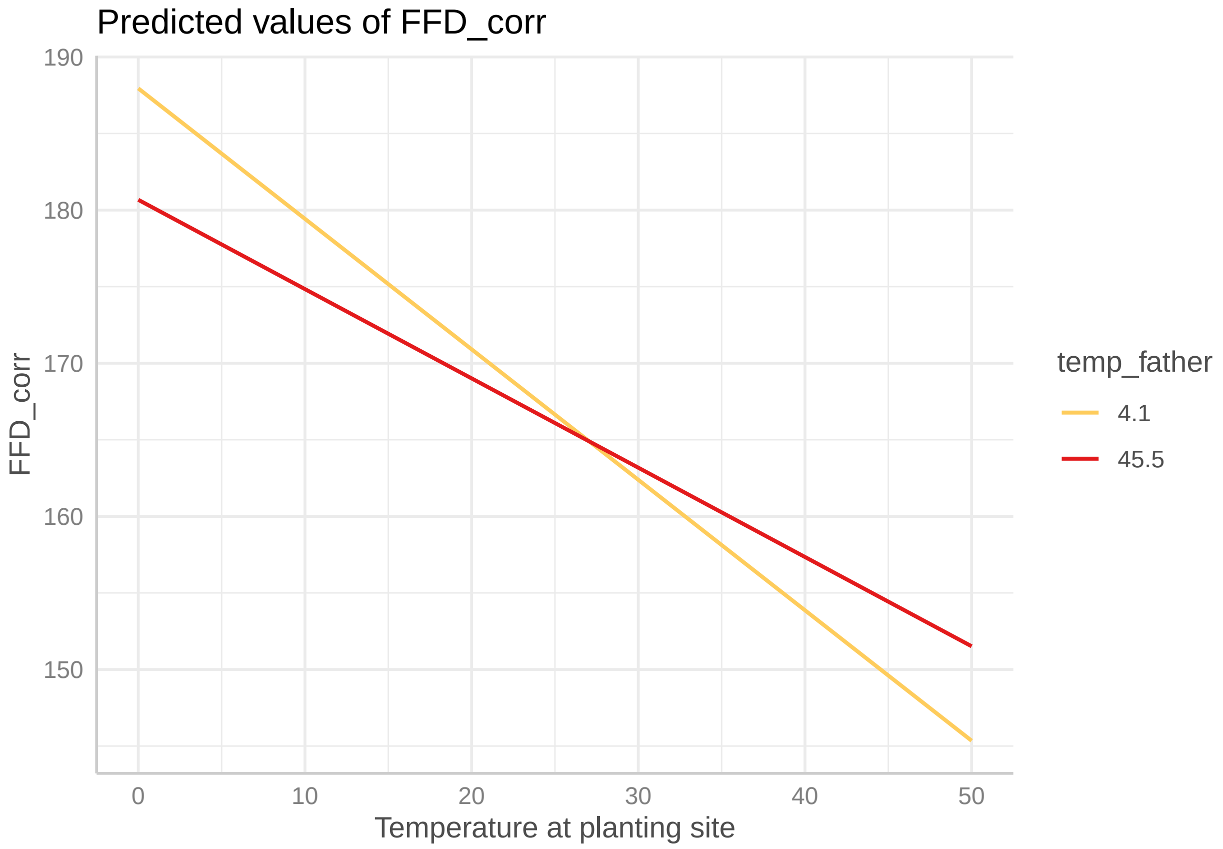
I was expecting that this effect would go in the opposite direction, and that plants with fathers from colder origins would flower on average earlier. But maybe we should not really interpret this main effect, because the interaction with temperature at planting site is significant?

```
plot(ggpredict(model_FFD2,terms=c("temp_father","temp[7.9:49.7 by=5]")),add.data=F,ci=F)+
  scale_color_brewer(palette="YlOrRd")+
  xlab("Temperature of the father")
```



Interaction temp at planting site x temp of the father (model2)

```
plot(ggpredict(model_FFD2,terms=c("temp","temp_father[minmax]")),add.data=F,ci=F)+
  scale_color_manual(values = c("#fecc5c", "#e31a1c"))+
  xlab("Temperature at planting site")
```



Plants with fathers from colder origins flower on average earlier when planted on warmer areas, and on average later when planted on colder areas. Plasticity varies between temperatures of origin of the father: the differences in FFD between planting sites are larger for plants with fathers from colder origin than for plants with fathers from warmer origin.

Mean temp parents

```
data_transplants<-data_transplants%>%
  mutate(mean_temp_parents=(temp_mother+temp_father)/2)
```

```
model_FFD1_mean<-lmer(FFD_corr~mean_temp_parents*heat_zone+
                   (1|mother)+(1|father)+(1|crossing)+(1|plot),data_transplants)
model_FFD2_mean<-lmer(FFD_corr~mean_temp_parents*temp+
                   (1|mother)+(1|father)+(1|crossing)+(1|plot),data_transplants)
```

```
tab_model(model_FFD1_mean,model_FFD2_mean,
          transform=NULL,show.ci=F,show.se=T,show.stat=T,digits=3,
          dv.labels=c("heat_zone","temp"),
          title="Models FFD mean temp parents")
```

Models FFD mean temp parents

heat_zone

temp

Predictors

Estimates

std. Error

Statistic

p

Estimates

std. Error

Statistic

p

(Intercept)

195.507

3.528

55.411

<0.001

189.605

4.841

39.170

<0.001

mean temp parents

-0.137

0.071

-1.930

0.054

-0.226

0.084

-2.696

0.007

heat zone [Intermediate]

-26.728

4.410

-6.061

<0.001

heat zone [Hot]

-44.167

4.473

-9.875

<0.001

mean temp parents × heatzone [Intermediate]

0.037

0.087

0.431

0.667

mean temp parents × heatzone [Hot]

0.233

0.095

2.464

0.014

temp

-0.940

0.092

-10.170

<0.001

mean temp parents × temp

0.010

0.004

2.553

0.011

Random Effects

2

54.55

51.25

00

0.00 crossing

0.00 crossing

0.00 father

0.24 father

10.57 mother

9.48 mother

28.89 plot

155.50 plot

ICC

0.42

0.76

N

63 mother

63 mother

64 father

64 father

131 crossing

131 crossing

8 plot

8 plot

Observations

603

603

Marginal R2 / Conditional R2

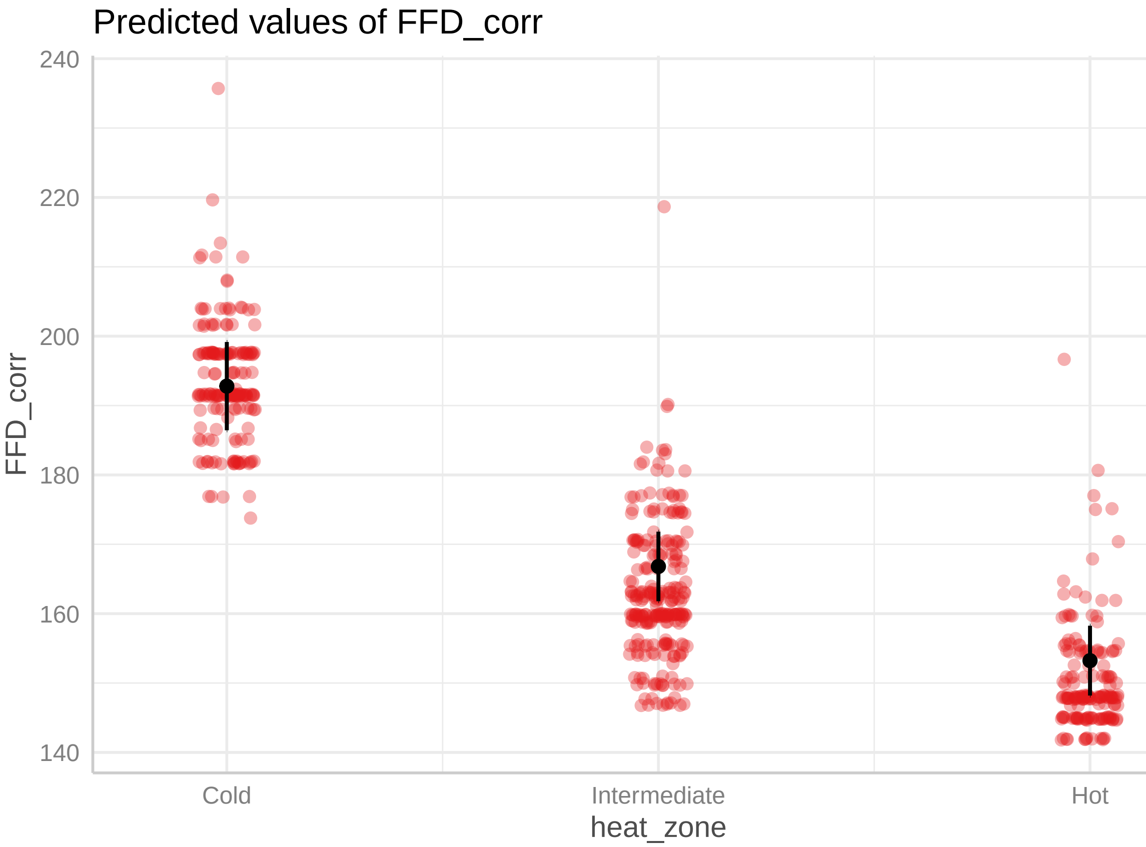
0.719 / 0.837

0.182 / 0.806

Save models as HTML table

Plots predicted effects

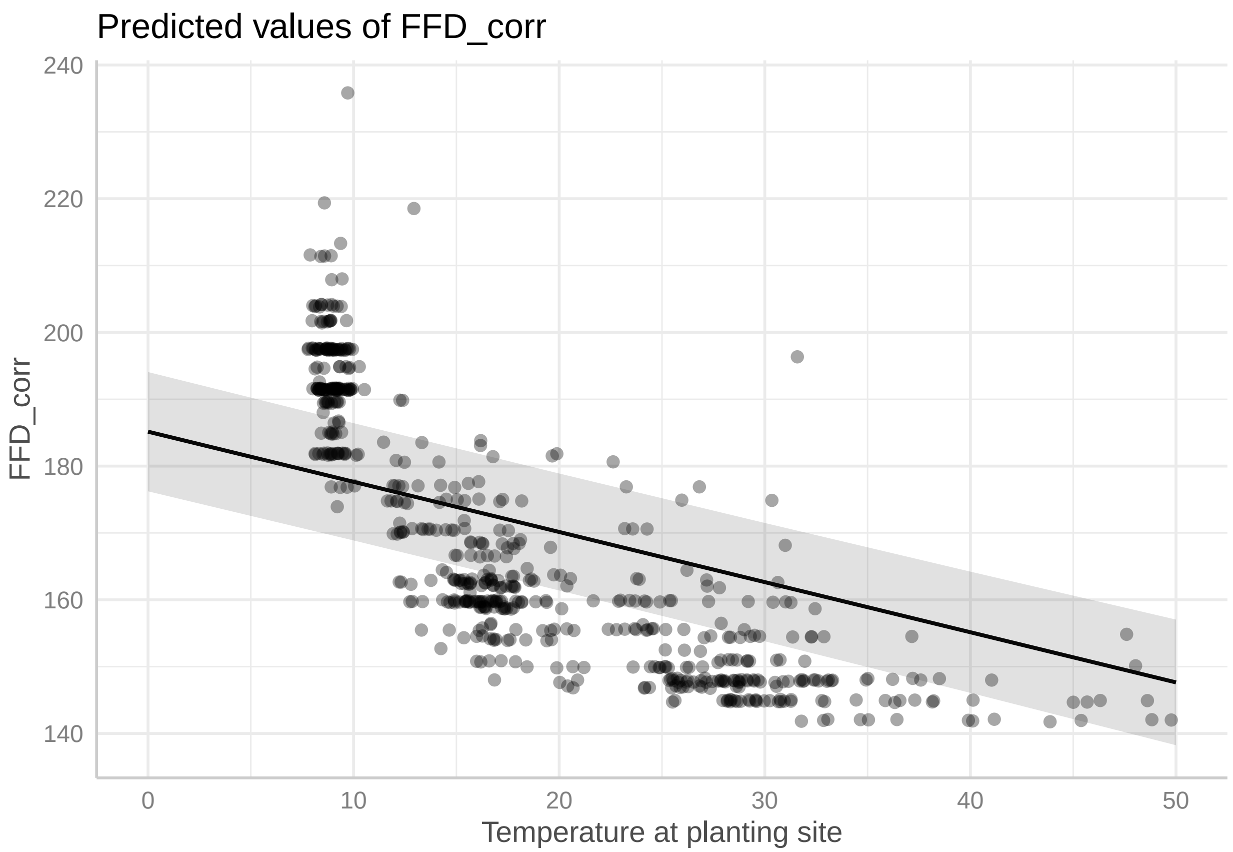
```
plot(ggpredict(model_FFD1_mean,terms=c("heat_zone")),add.data=T)
```



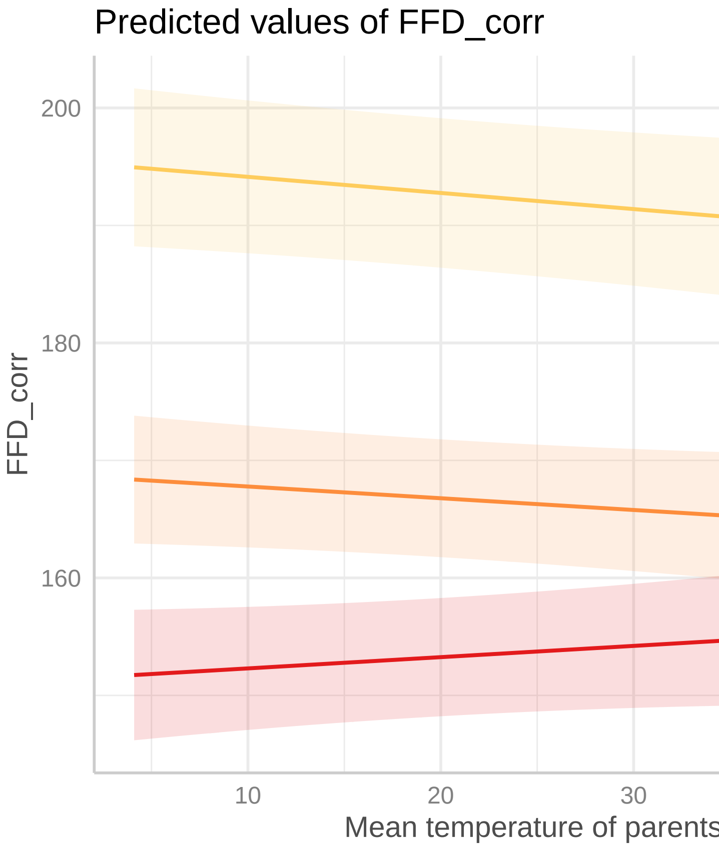
Heat zone (model1)

Temp at planting site (model2) Non-linear effect?

```
plot(ggpredict(model_FFD2_mean,terms=c("temp")),add.data=T)+
  xlab("Temperature at planting site")
```

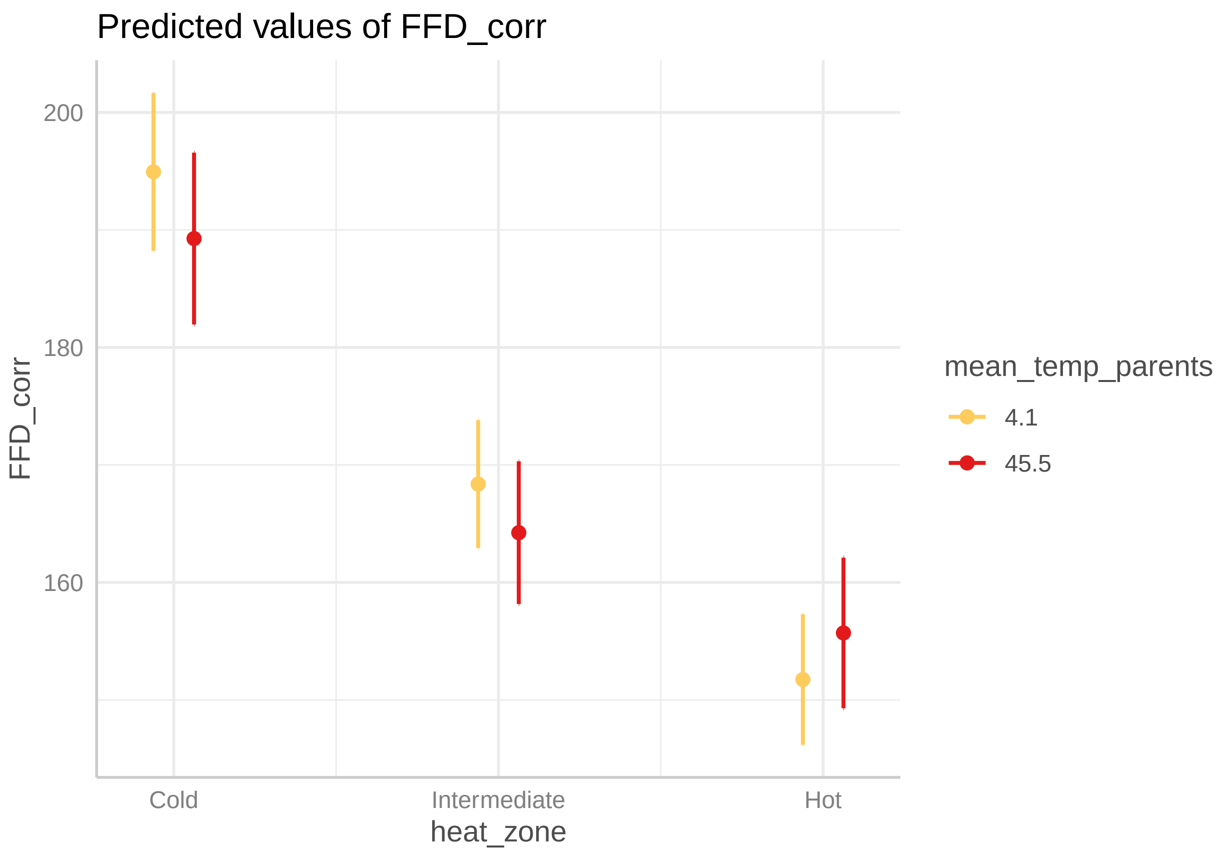


```
plot(ggpredict(model_FFD1_mean,terms=c("mean_temp_parents[all]","heat_zone")),add.data=F)+
  scale_color_manual(values = c("#fecc5c", "#fd8d3c", "#e31a1c"))+
  scale_fill_manual(values = c("#fecc5c", "#fd8d3c", "#e31a1c"))+
  xlab("Mean temperature of parents")
```

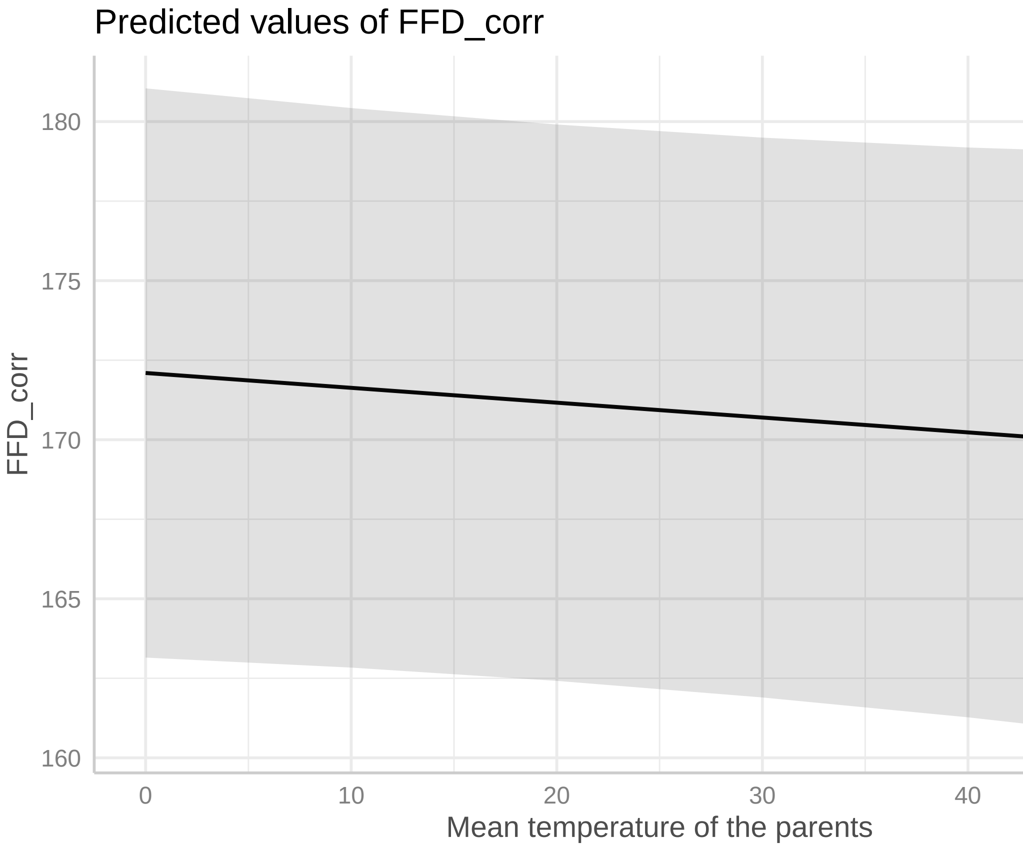


Interaction heat zone x mean temp parents (model1)

```
plot(ggpredict(model_FFD1_mean,terms=c("heat_zone","mean_temp_parents[minmax]")),add.data=F)+
  scale_color_manual(values = c("#fecc5c", "#e31a1c"))
```

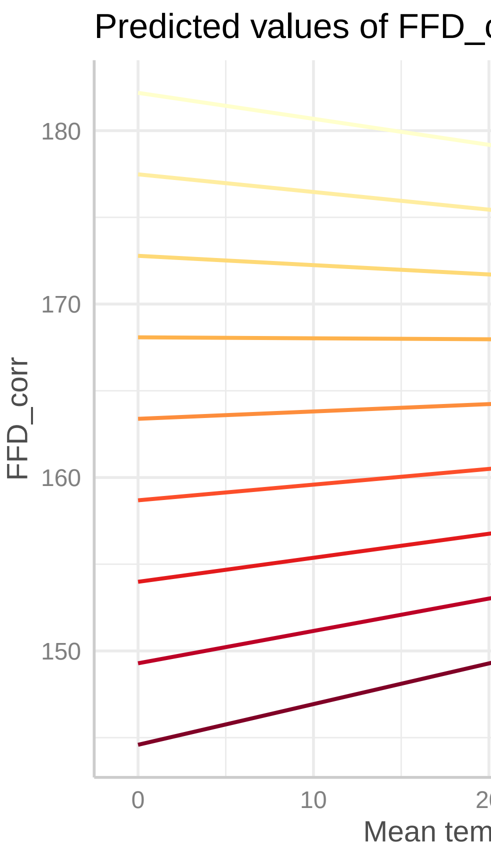


```
plot(ggpredict(model_FFD2_mean,terms=c("mean_temp_parents")),add.data=F)+
  xlab("Mean temperature of the parents")
```



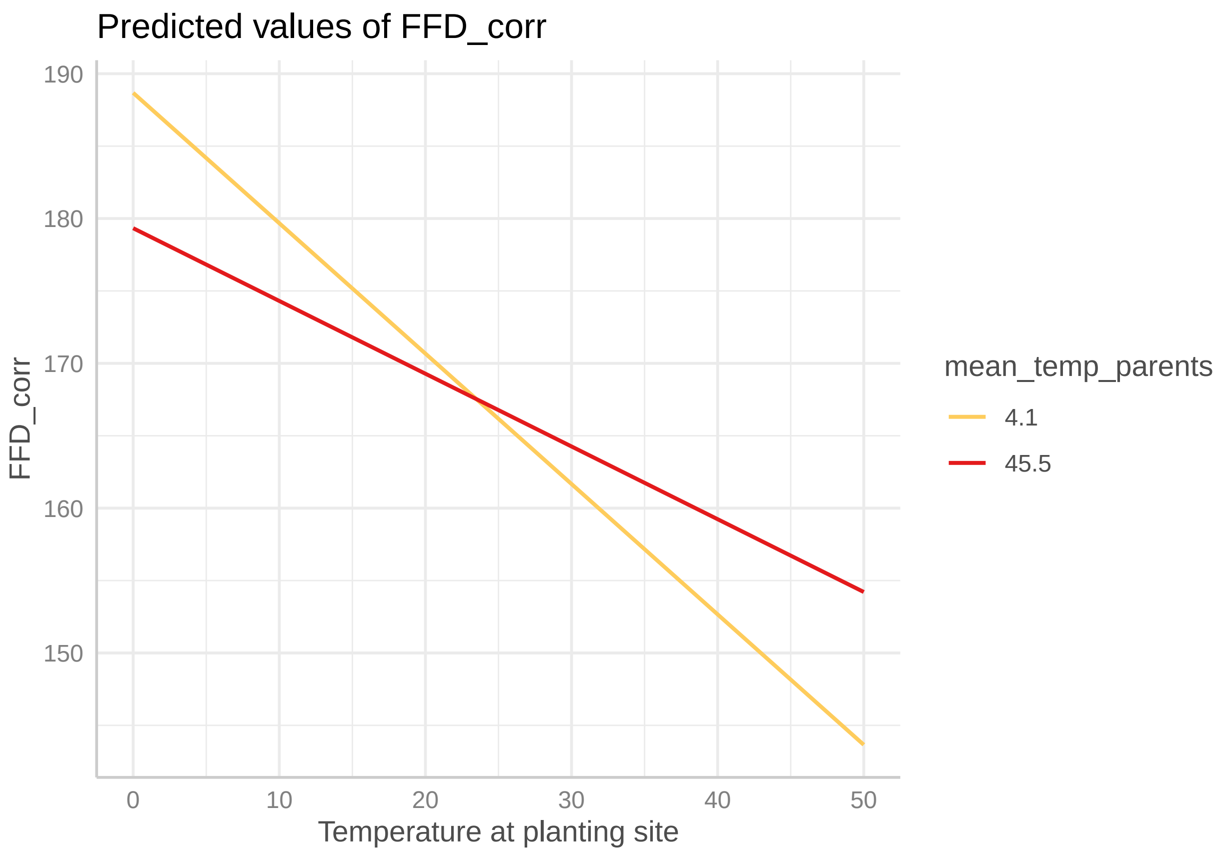
Mean temp parents (model2)

```
plot(ggpredict(model_FFD2_mean,terms=c("mean_temp_parents","temp[7.9:49.7 by=5]")),
     add.data=F,ci=F)+
  scale_color_brewer(palette="YlOrRd")+
  xlab("Mean temperature of the parents")
```



Interaction temp at planting site x mean temp of the parents (model2)

```
plot(ggpredict(model_FFD2_mean,terms=c("temp","mean_temp_parents[minmax]")),add.data=F,ci=F)+
  scale_color_manual(values = c("#fecc5c", "#e31a1c"))+
  xlab("Temperature at planting site")
```



Session info

```
sessionInfo()
```

```
## R version 4.2.2 (2022-10-31 ucrt)
## Platform: x86_64-w64-mingw32/x64 (64-bit)
## Running under: Windows 10 x64 (build 19045)
##
## Matrix products: default
##
## locale:
## [1] LC_COLLATE=Swedish_Sweden.utf8  LC_CTYPE=Swedish_Sweden.utf8
## [3] LC_MONETARY=Swedish_Sweden.utf8 LC_NUMERIC=C
## [5] LC_TIME=Swedish_Sweden.utf8
##
## attached base packages:
## [1] stats     graphics  grDevices utils     datasets  methods   base
##
## other attached packages:
##  [1] ggeffects_1.2.0    sjPlot_2.8.12      car_3.1-1          carData_3.0-5
##  [5] lmerTest_3.1-3     lme4_1.1-31        Matrix_1.5-1       glmmTMB_1.1.5
##  [9] ggthemes_4.2.4     knitr_1.42         RColorBrewer_1.1-3 readxl_1.4.2
## [13] lubridate_1.9.2    forcats_1.0.0      stringr_1.5.0      dplyr_1.1.0
## [17] purrr_1.0.1        readr_2.1.4        tidyr_1.3.0        tibble_3.1.8
## [21] ggplot2_3.4.1      tidyverse_2.0.0
##
## loaded via a namespace (and not attached):
##  [1] nlme_3.1-160        bit64_4.0.5         insight_0.19.0
##  [4] numDeriv_2016.8-1.1 tools_4.2.2         TMB_1.9.2
##  [7] backports_1.4.1     utf8_1.2.3          R6_2.5.1
## [10] sjlabelled_1.2.0    colorspace_2.1-0    withr_2.5.0
## [13] tidyselect_1.2.0    emmeans_1.8.4-1     bit_4.0.5
## [16] compiler_4.2.2      performance_0.10.2  cli_3.6.0
## [19] labeling_0.4.2      bayestestR_0.13.0   scales_1.2.1
## [22] mvtnorm_1.1-3       digest_0.6.31       minqa_1.2.5
## [25] rmarkdown_2.20      pkgconfig_2.0.3     htmltools_0.5.4
## [28] fastmap_1.1.1       highr_0.10          rlang_1.0.6
## [31] rstudioapi_0.14     generics_0.1.3      farver_2.1.1
## [34] vroom_1.6.1         magrittr_2.0.3      parameters_0.20.2
## [37] Rcpp_1.0.10         munsell_0.5.0       fansi_1.0.4
## [40] abind_1.4-5         lifecycle_1.0.3     stringi_1.7.12
## [43] yaml_2.3.7          MASS_7.3-58.1       grid_4.2.2
## [46] parallel_4.2.2      sjmisc_2.8.9        crayon_1.5.2
## [49] lattice_0.20-45     haven_2.5.2         splines_4.2.2
## [52] sjstats_0.18.2      hms_1.1.2           pillar_1.8.1
## [55] boot_1.3-28         estimability_1.4.1  effectsize_0.8.3
## [58] glue_1.6.2          evaluate_0.20       modelr_0.1.10
## [61] vctrs_0.5.2         nloptr_2.0.3        tzdb_0.3.0
## [64] cellranger_1.1.0    gtable_0.3.1        datawizard_0.6.5
## [67] xfun_0.37           xtable_1.8-4        broom_1.0.3
## [70] coda_0.19-4         timechange_0.2.0    ellipsis_0.3.2
```