

Response to Selection based on Genomic Prediction Based on a Simulation (Pollen Pool GCA2-Cycle 4)

This is the code to simulate response to selection based on genomic prediction and to generate the plot. The dataset used here is the pollen pool GCA2 Cycle 4 data.

Load the R packages

```
library(parallel)
library(foreach)
library(doParallel)
library(tictoc)
library(plyr)
library(doSNOW)
library(progress)
library(reshape2)

rm(list = ls())
options(scipen = 999, digits = 5)
```

Reload Gamma Matrix

```
Gamma.mat <- readRDS("Gamma_Mat_GCA2_Cycle_4.RDS")
```

Entries

```
##### Number of Entries #####
row.gamma <- nrow(Gamma.mat)
n.geno <- row.gamma/2

# Take n (proportion selection)
n.1 <- round(n.geno*0.01,0)
n.5 <- round(n.geno*0.05,0)
n.10 <- round(n.geno*0.10,0)
n.15 <- round(n.geno*0.15,0)
n.20 <- round(n.geno*0.20,0)
n.30 <- round(n.geno*0.30,0)
n.50 <- round(n.geno*0.50,0)
```

Parallelisation setup

```
##### Parallelisation setup #####
n.cores <- detectCores() - 1
```

```

my.cluster <- parallel::makeCluster(n.cores, type = "PSOCK")
print(my.cluster)

## Socketcluster mit 7 Knoten auf System 'localhost'
registerDoSNOW(my.cluster)

iterations <- 100000

##### Function for separate the results in the simulation #####
comb <- function(x, ...) {
  lapply(seq_along(x),
    function(i) c(x[[i]], lapply(list(...), function(y) y[[i]])))
}

##### Progress Time #####
pb <- progress_bar$new(format = ":percent | Elapsed time: :elapsed eta: :eta",
  total = iterations, clear = FALSE)

progress <- function(n){
  pb$tick()
}

opts <- list(progress = progress)

```

Start Simulation

```

##### Start Simulation #####
tic()
simu.list <- foreach(i = 1:iterations,
  .combine = comb, .multicombine = TRUE,
  .options.snow = opts,
  .init = list(list(), list(), list(), list(),
    list(), list(), list(), list())) %dopar% {

  z <- matrix(rnorm(n = row.gamma), nrow = row.gamma)

  w <- Gamma.mat %*% z # W matrix

  sim.ghat <- w[(row.gamma/2) + 1:row.gamma,] # Take the Ghat
  sim.gtrue <- w[1:(row.gamma/2),] # Take the true genotype values

  # Make a data frame for Ghat and true genotype values
  v <- data.frame(sim.ghat = sim.ghat, sim.gtrue = sim.gtrue,
    rank.ghat = rank(-sim.ghat), rank.gtrue = rank(-sim.gtrue), nsim = i)

  # Subset the data from the simulation for each n
  sel.1 <- v[v$rank.ghat <= n.1, ]
  sel.5 <- v[v$rank.ghat <= n.5, ]
  sel.10 <- v[v$rank.ghat <= n.10, ]
  sel.15 <- v[v$rank.ghat <= n.15, ]
  sel.20 <- v[v$rank.ghat <= n.20, ]
  sel.30 <- v[v$rank.ghat <= n.30, ]
  sel.50 <- v[v$rank.ghat <= n.50, ]
}

```

```

sel.1$n <- n.1
sel.5$n <- n.5
sel.10$n <- n.10
sel.15$n <- n.15
sel.20$n <- n.20
sel.30$n <- n.30
sel.50$n <- n.50

# Count the best entries
# Sel 1%
top1.sel1 <- ifelse(length(which(sel.1$rank.gtrue %in% 1 == TRUE)) == 1, 1, 0)
top3.sel1 <- ifelse(length(which(sel.1$rank.gtrue %in% c(1:3) == TRUE)) == 3, 1, 0)
top5.sel1 <- ifelse(length(which(sel.1$rank.gtrue %in% c(1:5) == TRUE)) == 5, 1, 0)
top10.sel1 <- ifelse(length(which(sel.1$rank.gtrue %in% c(1:10) == TRUE)) == 10, 1, 0)
top15.sel1 <- ifelse(length(which(sel.1$rank.gtrue %in% c(1:15) == TRUE)) == 15, 1, 0)

# Sel 5%
top1.sel5 <- ifelse(length(which(sel.5$rank.gtrue %in% 1 == TRUE)) == 1, 1, 0)
top3.sel5 <- ifelse(length(which(sel.5$rank.gtrue %in% c(1:3) == TRUE)) == 3, 1, 0)
top5.sel5 <- ifelse(length(which(sel.5$rank.gtrue %in% c(1:5) == TRUE)) == 5, 1, 0)
top10.sel5 <- ifelse(length(which(sel.5$rank.gtrue %in% c(1:10) == TRUE)) == 10, 1, 0)
top15.sel5 <- ifelse(length(which(sel.5$rank.gtrue %in% c(1:15) == TRUE)) == 15, 1, 0)

top1.sel10 <- ifelse(length(which(sel.10$rank.gtrue %in% 1 == TRUE)) == 1, 1, 0)
top3.sel10 <- ifelse(length(which(sel.10$rank.gtrue %in% c(1:3) == TRUE)) == 3, 1, 0)
top5.sel10 <- ifelse(length(which(sel.10$rank.gtrue %in% c(1:5) == TRUE)) == 5, 1, 0)
top10.sel10 <- ifelse(length(which(sel.10$rank.gtrue %in% c(1:10) == TRUE)) == 10, 1, 0)
top15.sel10 <- ifelse(length(which(sel.10$rank.gtrue %in% c(1:15) == TRUE)) == 15, 1, 0)

# Sel 15%
top1.sel15 <- ifelse(length(which(sel.15$rank.gtrue %in% 1 == TRUE)) == 1, 1, 0)
top3.sel15 <- ifelse(length(which(sel.15$rank.gtrue %in% c(1:3) == TRUE)) == 3, 1, 0)
top5.sel15 <- ifelse(length(which(sel.15$rank.gtrue %in% c(1:5) == TRUE)) == 5, 1, 0)
top10.sel15 <- ifelse(length(which(sel.15$rank.gtrue %in% c(1:10) == TRUE)) == 10, 1, 0)
top15.sel15 <- ifelse(length(which(sel.15$rank.gtrue %in% c(1:15) == TRUE)) == 15, 1, 0)

# Sel 20%
top1.sel20 <- ifelse(length(which(sel.20$rank.gtrue %in% 1 == TRUE)) == 1, 1, 0)
top3.sel20 <- ifelse(length(which(sel.20$rank.gtrue %in% c(1:3) == TRUE)) == 3, 1, 0)
top5.sel20 <- ifelse(length(which(sel.20$rank.gtrue %in% c(1:5) == TRUE)) == 5, 1, 0)
top10.sel20 <- ifelse(length(which(sel.20$rank.gtrue %in% c(1:10) == TRUE)) == 10, 1, 0)
top15.sel20 <- ifelse(length(which(sel.20$rank.gtrue %in% c(1:15) == TRUE)) == 15, 1, 0)

# Sel 30%
top1.sel30 <- ifelse(length(which(sel.30$rank.gtrue %in% 1 == TRUE)) == 1, 1, 0)
top3.sel30 <- ifelse(length(which(sel.30$rank.gtrue %in% c(1:3) == TRUE)) == 3, 1, 0)
top5.sel30 <- ifelse(length(which(sel.30$rank.gtrue %in% c(1:5) == TRUE)) == 5, 1, 0)
top10.sel30 <- ifelse(length(which(sel.30$rank.gtrue %in% c(1:10) == TRUE)) == 10, 1, 0)
top15.sel30 <- ifelse(length(which(sel.30$rank.gtrue %in% c(1:15) == TRUE)) == 15, 1, 0)

# Sel 50%
top1.sel50 <- ifelse(length(which(sel.50$rank.gtrue %in% 1 == TRUE)) == 1, 1, 0)
top3.sel50 <- ifelse(length(which(sel.50$rank.gtrue %in% c(1:3) == TRUE)) == 3, 1, 0)
top5.sel50 <- ifelse(length(which(sel.50$rank.gtrue %in% c(1:5) == TRUE)) == 5, 1, 0)
top10.sel50 <- ifelse(length(which(sel.50$rank.gtrue %in% c(1:10) == TRUE)) == 10, 1, 0)

```

```

top15.sel50 <- ifelse(length(which(sel.50$rank.gtrue %in% c(1:15) == TRUE)) == 15, 1, 0)

# sel 1% results
best.sel1 <- data.frame(nsim = i, sel = n.1, n.top1 = top1.sel1,
                        n.top3 = top3.sel1, n.top5 = top5.sel1,
                        n.top10 = top10.sel1, n.top15 = top15.sel1)

# sel 5% results
best.sel5 <- data.frame(nsim = i, sel = n.5, n.top1 = top1.sel5,
                        n.top3 = top3.sel5, n.top5 = top5.sel5,
                        n.top10 = top10.sel5, n.top15 = top15.sel5)

# sel 10% results
best.sel10 <- data.frame(nsim = i, sel = n.10, n.top1 = top1.sel10,
                        n.top3 = top3.sel10, n.top5 = top5.sel10,
                        n.top10 = top10.sel10, n.top15 = top15.sel10)

# sel 15% results
best.sel15 <- data.frame(nsim = i, sel = n.15, n.top1 = top1.sel15,
                        n.top3 = top3.sel15, n.top5 = top5.sel15,
                        n.top10 = top10.sel15, n.top15 = top15.sel15)

# sel 20% results
best.sel20 <- data.frame(nsim = i, sel = n.20, n.top1 = top1.sel20,
                        n.top3 = top3.sel20, n.top5 = top5.sel20,
                        n.top10 = top10.sel20, n.top15 = top15.sel20)

# sel 30% results
best.sel30 <- data.frame(nsim = i, sel = n.30, n.top1 = top1.sel30,
                        n.top3 = top3.sel30, n.top5 = top5.sel30,
                        n.top10 = top10.sel30, n.top15 = top15.sel30)

# sel 50% results
best.sel50 <- data.frame(nsim = i, sel = n.50, n.top1 = top1.sel50,
                        n.top3 = top3.sel50, n.top5 = top5.sel50,
                        n.top10 = top10.sel50, n.top15 = top15.sel50)

list(v, best.sel1, best.sel5, best.sel10,
     best.sel15, best.sel20, best.sel30, best.sel50)
}
toc()

```

128.49 sec elapsed

Data wrangling the results

```

##### Extract imulated data #####
tic()
df <- simu.list[[1]]
df <- dplyr::bind_rows(df, .id = "nsim")
toc()

```

4.28 sec elapsed

```

##### Correlations from the simulated data #####
cor(df$sim.ghat, df$sim.gtrue) # Correlation GBLUPs with the true values

```

```
## [1] 0.67323
cor(df$rank.gtrue, df$rank.ghat) # Correlation GBLUPs ranking with the true values ranking

## [1] 0.64479
##### Extract the data for each selection proportion #####
sel1 <- simu.list[[2]]
sel5 <- simu.list[[3]]
sel10 <- simu.list[[4]]
sel15 <- simu.list[[5]]
sel20 <- simu.list[[6]]
sel30 <- simu.list[[7]]
sel50 <- simu.list[[8]]

sel1 <- dplyr::bind_rows(sel1, .id = "nsim")
sel5 <- dplyr::bind_rows(sel5, .id = "nsim")
sel10 <- dplyr::bind_rows(sel10, .id = "nsim")
sel15 <- dplyr::bind_rows(sel15, .id = "nsim")
sel20 <- dplyr::bind_rows(sel20, .id = "nsim")
sel30 <- dplyr::bind_rows(sel30, .id = "nsim")
sel50 <- dplyr::bind_rows(sel50, .id = "nsim")

##### Stack into one data frame #####
sel_dat <- rbind(sel1, sel5, sel10, sel15,
                 sel20, sel30, sel50)

##### Stop cluster for parallel #####
stopCluster(my.cluster)
```

Compute Probability

```
prob.best <- data.frame(dummy = 1)
tic()
for (i in 1:5) {

  f <- as.formula((paste(names(sel_dat[i + 2]), "~ sel")))
  pro <- aggregate(f, sel_dat, FUN = "mean")

  if (i > 1) {
    pro <- pro[-1]
  }
  prob.best <- cbind(prob.best, pro)

  if (i == 1) {
    prob.best <- prob.best[-1]
  }
}
toc()

## 4.85 sec elapsed
```

Data preparation for plot

```
## Transpose the dataset by n
final.dat <- melt(prob.best, id = "sel")
```

```

names(final.dat)[names(final.dat) == 'sel'] <- 'n'
final.dat$n <- as.numeric(final.dat$n)

## Change the second column name
names(final.dat)[2] <- "m"

## Make a column for genotype numbers
final.dat$n.geno <- n.geno

## Make a column for the x axis of the plot (selection proportion)
final.dat$n.pct <- round(final.dat$n/final.dat$n.geno,3)*100

final.dat$m <- as.character(final.dat$m)

## Rename the rows in column m
final.dat$m <- ifelse(final.dat$m == "n.top1" , "Best 1",
                     ifelse(final.dat$m == "n.top3" , "Best 3",
                             ifelse(final.dat$m == "n.top5" , "Best 5",
                                     ifelse(final.dat$m == "n.top10" , "Best 10", "Best 15"))))

final.dat$m <- as.factor(final.dat$m)

## Arrange the level for making the plot
final.dat$m <- factor(final.dat$m,
                     levels = c("Best 1", "Best 3", "Best 5", "Best 10", "Best 15"))

# Make column for identifier of the pool and the cycles
# It is not necessary if only one plot to be made
final.dat$Pool <- "Pollen pool"
final.dat$Cycle <- "GCA1-MY"

knitr::kable(final.dat)

```

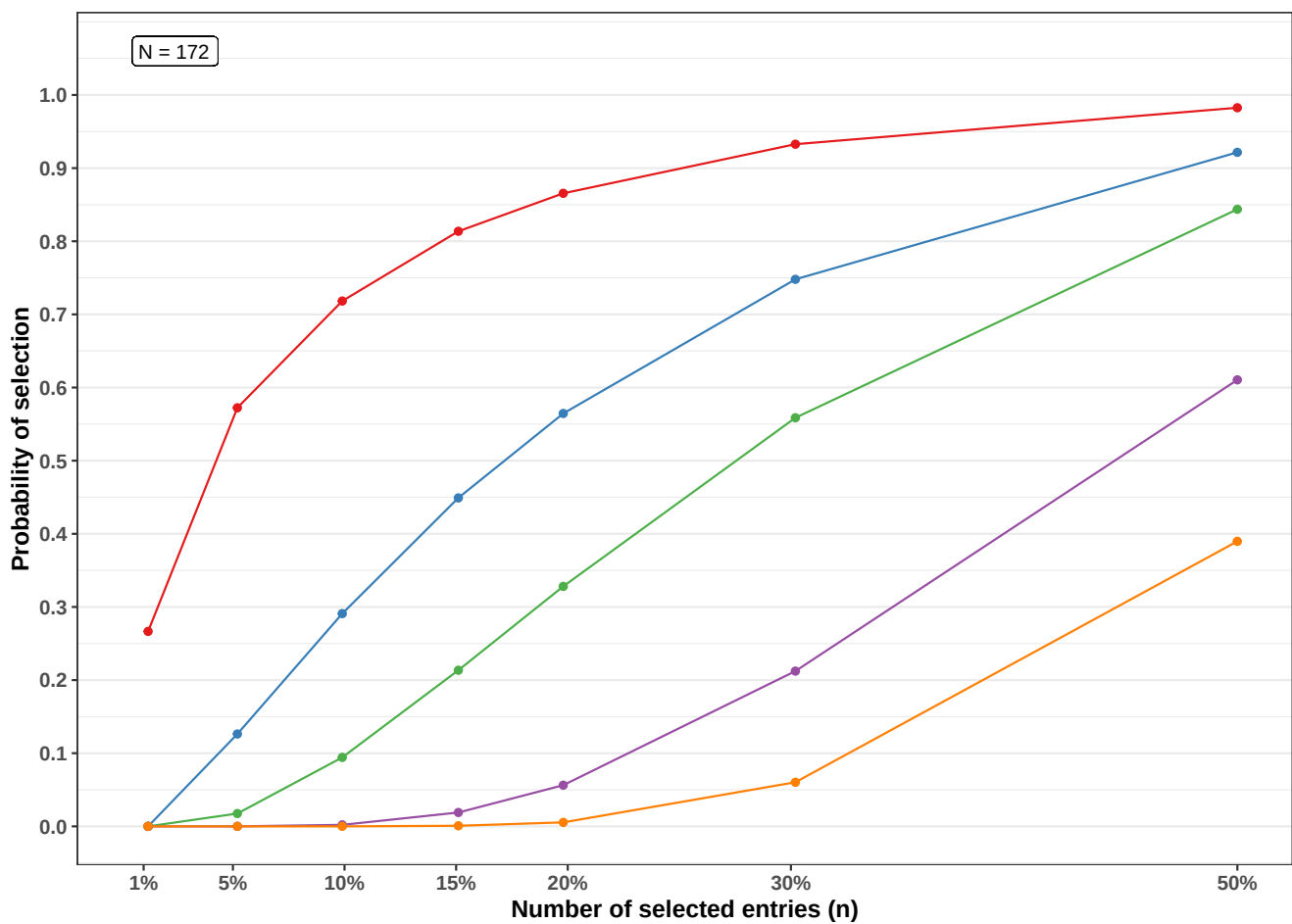
n	m	value	n.geno	n.pct	Pool	Cycle
2	Best 1	0.26657	172	1.2	Pollen pool	GCA1-MY
9	Best 1	0.57232	172	5.2	Pollen pool	GCA1-MY
17	Best 1	0.71830	172	9.9	Pollen pool	GCA1-MY
26	Best 1	0.81363	172	15.1	Pollen pool	GCA1-MY
34	Best 1	0.86556	172	19.8	Pollen pool	GCA1-MY
52	Best 1	0.93271	172	30.2	Pollen pool	GCA1-MY
86	Best 1	0.98254	172	50.0	Pollen pool	GCA1-MY
2	Best 3	0.00000	172	1.2	Pollen pool	GCA1-MY
9	Best 3	0.12631	172	5.2	Pollen pool	GCA1-MY
17	Best 3	0.29090	172	9.9	Pollen pool	GCA1-MY
26	Best 3	0.44911	172	15.1	Pollen pool	GCA1-MY
34	Best 3	0.56453	172	19.8	Pollen pool	GCA1-MY
52	Best 3	0.74794	172	30.2	Pollen pool	GCA1-MY
86	Best 3	0.92159	172	50.0	Pollen pool	GCA1-MY
2	Best 5	0.00000	172	1.2	Pollen pool	GCA1-MY
9	Best 5	0.01754	172	5.2	Pollen pool	GCA1-MY
17	Best 5	0.09430	172	9.9	Pollen pool	GCA1-MY
26	Best 5	0.21347	172	15.1	Pollen pool	GCA1-MY
34	Best 5	0.32812	172	19.8	Pollen pool	GCA1-MY
52	Best 5	0.55866	172	30.2	Pollen pool	GCA1-MY
86	Best 5	0.84374	172	50.0	Pollen pool	GCA1-MY

n	m	value	n.geno	n.pct	Pool	Cycle
2	Best 10	0.00000	172	1.2	Pollen pool	GCA1-MY
9	Best 10	0.00000	172	5.2	Pollen pool	GCA1-MY
17	Best 10	0.00207	172	9.9	Pollen pool	GCA1-MY
26	Best 10	0.01895	172	15.1	Pollen pool	GCA1-MY
34	Best 10	0.05631	172	19.8	Pollen pool	GCA1-MY
52	Best 10	0.21228	172	30.2	Pollen pool	GCA1-MY
86	Best 10	0.61051	172	50.0	Pollen pool	GCA1-MY
2	Best 15	0.00000	172	1.2	Pollen pool	GCA1-MY
9	Best 15	0.00000	172	5.2	Pollen pool	GCA1-MY
17	Best 15	0.00000	172	9.9	Pollen pool	GCA1-MY
26	Best 15	0.00080	172	15.1	Pollen pool	GCA1-MY
34	Best 15	0.00544	172	19.8	Pollen pool	GCA1-MY
52	Best 15	0.06031	172	30.2	Pollen pool	GCA1-MY
86	Best 15	0.38974	172	50.0	Pollen pool	GCA1-MY

Make the plot

```
library(ggplot2)
p <- ggplot(final.dat, aes(x = n.pct, y = value)) +
  geom_line(aes(x = n.pct, y = value, color = m, group = m)) +
  geom_point(aes(color = m, group = m)) +
  geom_label(aes(x = 0.5, y = 1.06, label = paste("N =", n.geno)),
    size = 3.5,
    data = final.dat,
    hjust = 0,
    vjust = 0.5
  ) +
  labs(caption = "Number of simulations = S = 100K") +
  scale_y_continuous(name = "Probability of selection", breaks = seq(0, 1, 0.10)) +
  scale_x_continuous(name = "Number of selected entries (n)",
    breaks = c(1, 5, 10, 15, 20, 30, 50),
    labels = scales::percent_format(scale = 1, accuracy = 1)) +
  scale_colour_brewer(palette = "Set1", name = "Number of truly best entries (m)") +
  theme_bw() +
  theme(
    panel.grid.minor.x = element_blank(),
    panel.grid.major.x = element_blank(),
    panel.background = element_blank(),
    plot.caption = element_text(size = 11),
    axis.title.y = element_text(face = "bold", size = 12),
    strip.text.x = element_text(size = 12, face = "bold"),
    strip.text.y = element_text(size = 12, face = "bold"),
    axis.title.x = element_text(face = "bold", size = 12, lineheight = 1),
    axis.text = element_text(angle = 0, hjust = 0.5, face = "bold", size = 10),
    legend.text = element_text(size = 11, face = "bold"),
    title = element_text(face = "bold", size = 11), legend.position = "bottom")
```

p



Number of truly best entries (m) — Best 1 — Best 3 — Best 5 — Best 10 — Best 15

Number of simulations = S = 100K