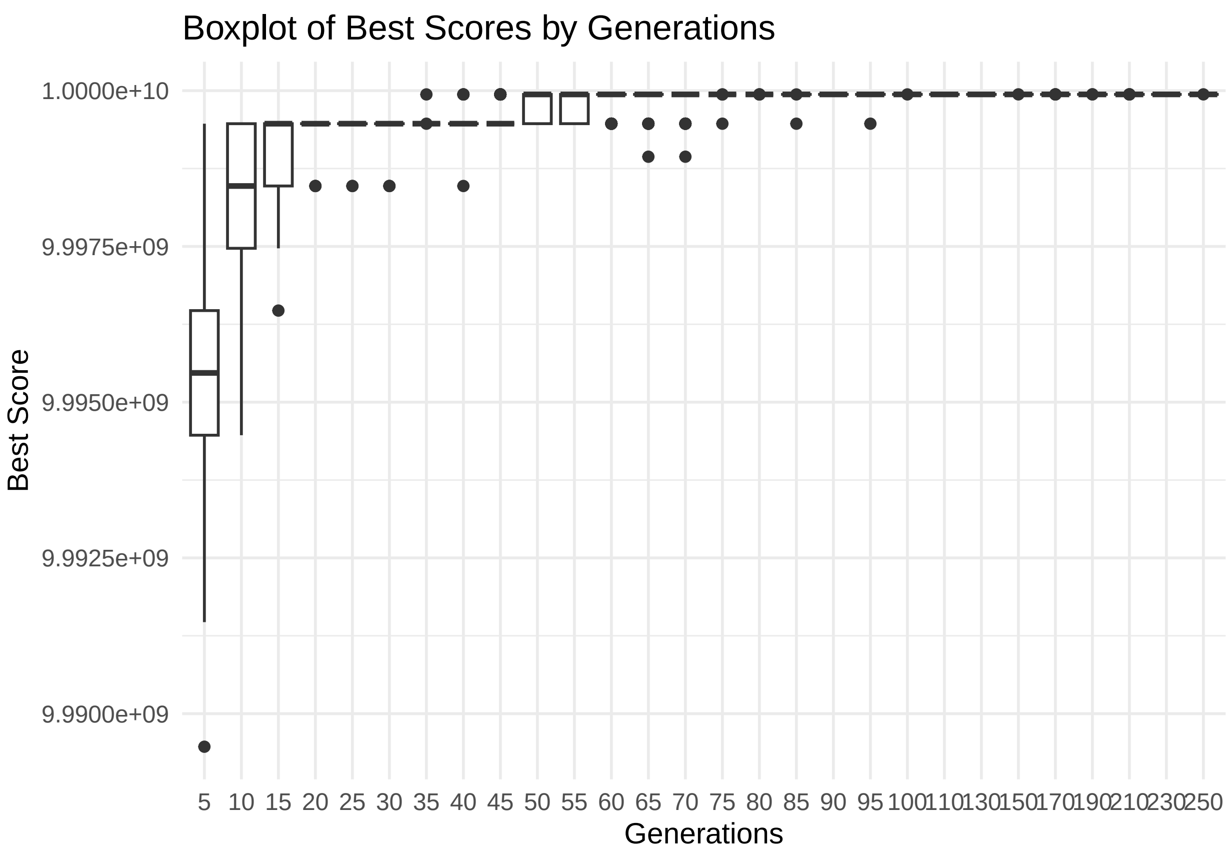
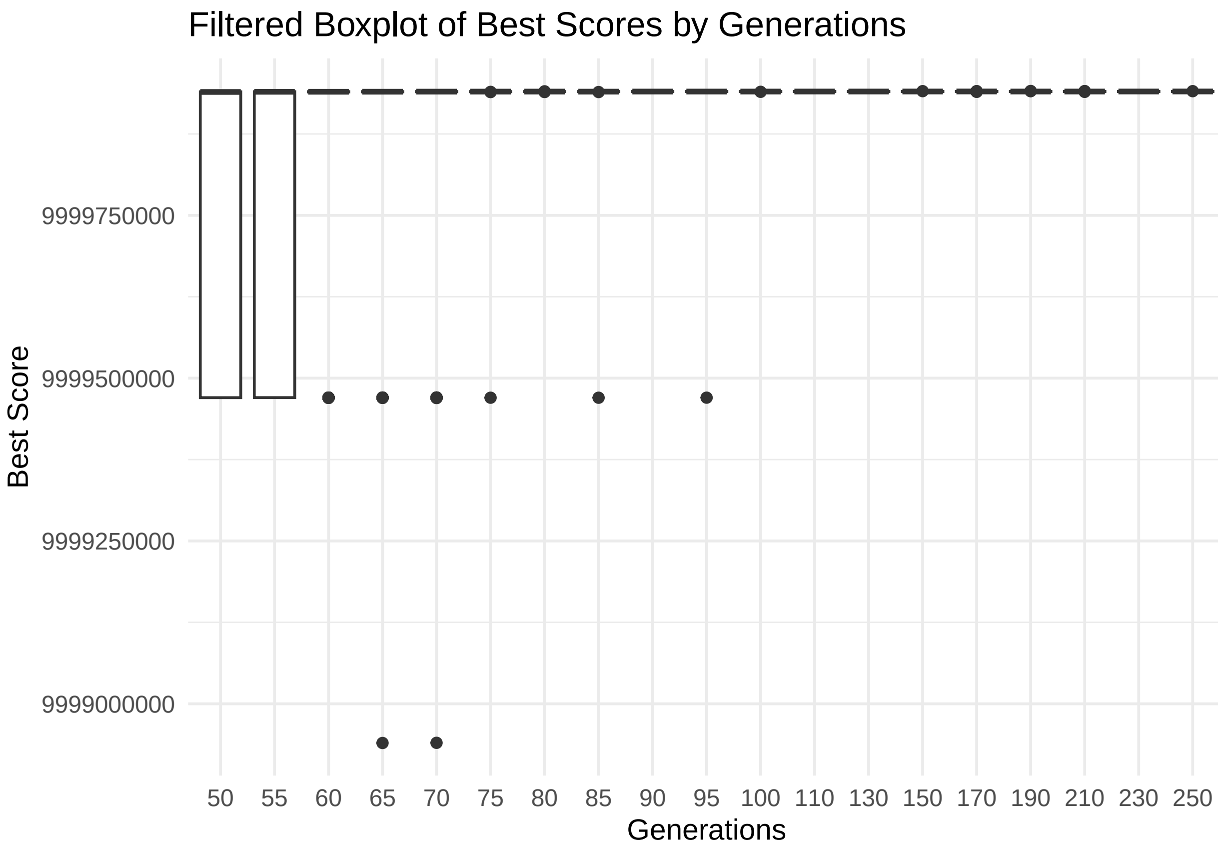
```r
library(ggplot2)
library(reshape2)


data <- read.csv("knapsack_results_250base_inc20.csv")
filtered_data <- subset(data, !(generations %in% c(5,10,15,20,25,30,35,40,45)))

# boxplot
ggplot(data, aes(x = as.factor(generations), y = best_score)) +
  geom_boxplot() +
  labs(title = "Boxplot of Best Scores by Generations",
       x = "Generations",
       y = "Best Score") +
  theme_minimal()
```




```r
ggplot(filtered_data, aes(x = as.factor(generations), y = best_score)) +
  geom_boxplot() +
  labs(title = "Filtered Boxplot of Best Scores by Generations",
       x = "Generations",
       y = "Best Score") +
  theme_minimal()
```




```r
# p values

wilcox_results <- pairwise.wilcox.test(data$best_score,
                                        as.factor(data$generations),
                                        p.adjust.method = "bonferroni")
print("Pairwise Wilcoxon Test Results (All Data):")
```

```
## [1] "Pairwise Wilcoxon Test Results (All Data):"
```

```r
print(wilcox_results)
```

```
##
##  Pairwise comparisons using Wilcoxon rank sum test with continuity correction
##
## data:  data$best_score and as.factor(data$generations)
##
##     5       10      15      20      25      30      35      40      45
## 10  7.8e-13 -       -       -       -       -       -       -       -
## 15  1.7e-13 5.3e-05 -       -       -       -       -       -       -
## 20  4.9e-15 2.9e-12 1.00000 -       -       -       -       -       -
## 25  3.4e-15 5.2e-14 0.18610 1.00000 -       -       -       -       -
## 30  < 2e-16 < 2e-16 1.5e-06 0.74207 1.00000 -       -       -       -
## 35  2.7e-15 < 2e-16 5.9e-05 1.00000 1.00000 1.00000 -       -       -
## 40  3.0e-15 < 2e-16 0.00012 1.00000 1.00000 1.00000 1.00000 -       -
## 45  3.0e-15 < 2e-16 8.0e-08 0.00295 0.03038 1.00000 1.00000 1.00000 -
## 50  < 2e-16 < 2e-16 1.6e-15 1.6e-11 7.2e-11 3.2e-12 7.5e-09 9.0e-06 0.06135
## 55  2.7e-15 < 2e-16 1.4e-12 3.2e-10 1.9e-09 1.4e-10 2.9e-08 2.5e-06 0.00121
## 60  2.7e-15 < 2e-16 3.9e-12 2.0e-10 7.5e-10 8.8e-12 7.3e-09 3.9e-07 4.3e-05
```

```
## 65  3.0e-15 < 2e-16 1.7e-12 3.7e-11 4.9e-11 4.7e-14 4.6e-10 2.1e-09 3.9e-07
## 70  < 2e-16 < 2e-16 < 2e-16 < 2e-16 < 2e-16 < 2e-16 < 2e-16 5.4e-16 7.3e-14
## 75  2.7e-15 < 2e-16 3.8e-15 7.4e-15 9.3e-15 < 2e-16 1.3e-14 4.5e-14 2.1e-12
## 80  2.7e-15 < 2e-16 2.7e-15 2.7e-15 2.7e-15 < 2e-16 2.8e-15 5.5e-15 7.9e-14
## 85  2.7e-15 < 2e-16 3.8e-15 7.8e-15 9.3e-15 < 2e-16 1.2e-14 2.9e-14 5.5e-13
## 90  < 2e-16 < 2e-16 < 2e-16 < 2e-16 < 2e-16 < 2e-16 < 2e-16 < 2e-16 < 2e-16
## 95  2.7e-15 < 2e-16 3.4e-15 4.1e-15 5.5e-15 < 2e-16 5.8e-15 1.5e-14 8.3e-14
## 100 < 2e-16 < 2e-16 < 2e-16 < 2e-16 < 2e-16 < 2e-16 < 2e-16 < 2e-16 < 2e-16
## 110 2.7e-15 < 2e-16 2.7e-15 2.7e-15 2.7e-15 < 2e-16 2.7e-15 3.0e-15 1.2e-14
## 130 2.7e-15 < 2e-16 2.7e-15 2.7e-15 2.7e-15 < 2e-16 2.7e-15 2.7e-15 1.2e-14
## 150 2.7e-15 < 2e-16 2.7e-15 2.7e-15 2.7e-15 < 2e-16 2.7e-15 3.0e-15 1.0e-14
## 170 2.7e-15 < 2e-16 2.7e-15 2.7e-15 2.7e-15 < 2e-16 2.7e-15 3.6e-15 7.8e-15
## 190 2.7e-15 < 2e-16 2.7e-15 2.7e-15 2.7e-15 < 2e-16 2.7e-15 2.8e-15 9.6e-15
## 210 2.7e-15 < 2e-16 2.7e-15 2.7e-15 2.7e-15 < 2e-16 2.8e-15 3.4e-15 1.5e-14
## 230 2.7e-15 < 2e-16 2.7e-15 2.7e-15 2.7e-15 < 2e-16 2.7e-15 3.4e-15 1.4e-14
## 250 2.7e-15 < 2e-16 2.7e-15 2.7e-15 2.7e-15 < 2e-16 2.7e-15 2.7e-15 6.6e-15
##     50      55      60      65      70      75      80      85      90
## 10  -       -       -       -       -       -       -       -       -
## 15  -       -       -       -       -       -       -       -       -
## 20  -       -       -       -       -       -       -       -       -
## 25  -       -       -       -       -       -       -       -       -
## 30  -       -       -       -       -       -       -       -       -
## 35  -       -       -       -       -       -       -       -       -
## 40  -       -       -       -       -       -       -       -       -
## 45  -       -       -       -       -       -       -       -       -
## 50  -       -       -       -       -       -       -       -       -
## 55  1.00000 -       -       -       -       -       -       -       -
## 60  0.40205 1.00000 -       -       -       -       -       -       -
## 65  0.00081 1.00000 1.00000 -       -       -       -       -       -
## 70  3.6e-13 0.00022 0.02157 1.00000 -       -       -       -       -
## 75  2.8e-11 4.1e-05 0.00548 0.95686 1.00000 -       -       -       -
## 80  5.2e-14 1.1e-07 2.3e-05 0.01878 1.00000 1.00000 -       -       -
## 85  6.5e-12 1.3e-05 0.00169 0.67674 1.00000 1.00000 1.00000 -       -
## 90  < 2e-16 1.7e-11 3.3e-09 1.8e-05 0.09525 1.00000 1.00000 1.00000 -
## 95  4.6e-15 2.0e-08 3.4e-07 0.00071 0.68908 1.00000 1.00000 1.00000 1.00000
## 100 < 2e-16 7.0e-14 1.6e-11 1.3e-07 0.00105 0.31562 1.00000 0.37992 1.00000
## 110 < 2e-16 1.2e-10 1.3e-09 1.9e-06 0.00915 0.33676 1.00000 0.38079 1.00000
## 130 < 2e-16 2.7e-10 8.4e-09 1.2e-05 0.02511 0.66085 1.00000 1.00000 1.00000
## 150 < 2e-16 1.4e-10 1.7e-09 3.2e-06 0.00210 0.07974 1.00000 0.26911 1.00000
## 170 < 2e-16 3.0e-11 3.3e-11 2.7e-08 4.0e-06 0.00021 0.00146 0.00247 0.31112
## 190 < 2e-16 4.9e-11 6.5e-10 1.4e-06 0.00128 0.03764 0.95692 0.21704 1.00000
## 210 < 2e-16 1.8e-10 1.2e-09 3.0e-06 0.00191 0.06863 0.70086 0.25589 1.00000
## 230 < 2e-16 4.2e-10 1.2e-08 1.5e-05 0.00535 0.22837 1.00000 0.50321 1.00000
## 250 < 2e-16 6.5e-12 5.7e-11 3.1e-08 1.1e-05 0.00103 0.01130 0.00239 0.76229
##     95      100     110     130     150     170     190     210     230
## 10  -       -       -       -       -       -       -       -       -
## 15  -       -       -       -       -       -       -       -       -
## 20  -       -       -       -       -       -       -       -       -
## 25  -       -       -       -       -       -       -       -       -
## 30  -       -       -       -       -       -       -       -       -
## 35  -       -       -       -       -       -       -       -       -
## 40  -       -       -       -       -       -       -       -       -
## 45  -       -       -       -       -       -       -       -       -
## 50  -       -       -       -       -       -       -       -       -
```

```
## 55  -       -       -       -       -       -       -       -       -
## 60  -       -       -       -       -       -       -       -       -
## 65  -       -       -       -       -       -       -       -       -
## 70  -       -       -       -       -       -       -       -       -
## 75  -       -       -       -       -       -       -       -       -
## 80  -       -       -       -       -       -       -       -       -
## 85  -       -       -       -       -       -       -       -       -
## 90  -       -       -       -       -       -       -       -       -
## 95  -       -       -       -       -       -       -       -       -
## 100 1.00000 -       -       -       -       -       -       -       -
## 110 1.00000 1.00000 -       -       -       -       -       -       -
## 130 1.00000 1.00000 1.00000 -       -       -       -       -       -
## 150 1.00000 1.00000 1.00000 1.00000 -       -       -       -       -
## 170 0.34096 1.00000 1.00000 1.00000 1.00000 -       -       -       -
## 190 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 -       -       -
## 210 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 -       -
## 230 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 -
## 250 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000 1.00000
##
## P value adjustment method: bonferroni
```

```r
matrix_results <- wilcox_results$p.value

# Convert to a data frame for better visualization
library(tibble)
library(knitr)

# Replace NA values with "-" for better readability
matrix_results[is.na(matrix_results)] <- "-"

# Print the complete triangular table neatly
kable(matrix_results, format = "markdown")
```

	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	110	130	150	170	190	210	230
10	7.78956528255321e-13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
55	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	110	130	150	170	190	210	230
60	2.669[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-
	15	19	12	10	10	12	09	07	05																		
65	3.010[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-
	15	19	12	11	11	14	10	09	07																		
70	9.636[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	-	-
	21	30	18	17	17	26	17	16	14	13																	
75	2.669[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	-
	15	21	15	15	15	20	14	14	12	11	05																
80	2.669[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	-
	15	21	15	15	15	21	15	15	14	14	07	05															
85	2.668[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	-
	15	21	15	15	15	20	14	14	13	12	05																
90	8.203[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-	-	-	-
	21	32	21	21	21	32	21	20	19	23	11	09	05														
95	2.669[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-	-	-	-
	15	21	15	15	15	20	15	14	14	15	08	07															
100	8.205[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-
	21	32	21	21	21	32	21	20	20	25	14	11	07														
110	2.669[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-
	15	21	15	15	15	21	15	15	14	17	10	09	06														
130	2.666[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1	-	-	-	-	-	-
	15	21	15	15	15	21	15	15	14	17	10	09	05														
150	2.669[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	-	-	-	-	-
	15	21	15	15	15	21	15	15	14	17	10	09	06														
170	2.669[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-
	15	21	15	15	15	21	15	15	15	19	11	11	08	06													
190	2.669[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1	-	-	-
	15	21	15	15	15	21	15	15	15	18	11	10	06														
210	2.669[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1	1	-	-
	15	21	15	15	15	21	15	15	14	17	10	09	06														
230	2.669[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1	1	1	-
	15	21	15	15	15	21	15	15	14	17	10	08	05														
250	2.670[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1	1	1
	15	21	15	15	15	21	15	15	15	18	12	11	08	05													

```r
# Convert Wilcoxon test results into a data frame
wilcox_matrix <- as.data.frame(as.table(wilcox_results$p.value))

# Rename columns for clarity
colnames(wilcox_matrix) <- c("Gen1", "Gen2", "P_Value")

# Remove NA values
wilcox_matrix <- na.omit(wilcox_matrix)

# Convert generations to numeric
wilcox_matrix$Gen1 <- as.numeric(as.character(wilcox_matrix$Gen1))
wilcox_matrix$Gen2 <- as.numeric(as.character(wilcox_matrix$Gen2))

# Create the heatmap
ggplot(wilcox_matrix, aes(x = factor(Gen1, levels = unique(wilcox_matrix$Gen1)),
                          y = factor(Gen2, levels = unique(wilcox_matrix$Gen2)),
                          fill = -log10(P_Value))) +
```

```
geom_tile(color = "white") +
scale_fill_gradient(low = "blue", high = "red", name = "-log10(p-value)") +
labs(title = "Pairwise Wilcoxon Test Heatmap",
     x = "Generations",
     y = "Generations") +
theme_minimal() +
theme(axis.text.x = element_text(angle = 90, vjust = 0.5))
```