

Pseudomonas Epiphytic Growth and Virulence Analysis

2024 Summer

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Load Libraries

```
pacman::p_load(ggplot2, readxl, BiocManager, RColorBrewer, paletteer, aplot, ggbeeswarm,
  dplyr, tidyverse, devtools, emmeans, cowplot, phangorn, knitr, survival, here,
  tibble, survminer, lubridate, formatR, gridExtra, ggsurvfit, ggtree, treeio,
  gtsummary, phytools, tidycmprsk, install = FALSE)
```

Load Data

```
# Define the desired order of the treatments
strains_order <- c("194", "200", "204", "205", "215", "216", "220", "221", "227",
  "228", "B728a", "Cit7", "pisi", "Control")

strains_df <- read_excel("data/strains_R.xlsx")

epi_growth_data <- read_excel("data/pseud_epi_growth_2024summer_R.xlsx")

# Convert the strain variable to a factor with the specified order
epi_growth_data$treatment <- factor(epi_growth_data$treatment, levels = strains_order)

# Join the strains dataframe to epi growth
epi_growth_data <- left_join(epi_growth_data, strains_df, by = "treatment")

# Load virulence data
aphid_virulence_data <- read_csv("data/virulence_new_all.csv")

## Rows: 4973 Columns: 6
## -- Column specification -----
## Delimiter: ","
## chr (3): date, treatment, replicate
## dbl (3): individual, censored, time
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.

# Convert the treatment variable to a factor with the specified order
aphid_virulence_data$treatment <- factor(aphid_virulence_data$treatment, levels = strains_order)

# Join the strains dataframe to virulence
aphid_virulence_data <- left_join(aphid_virulence_data, strains_df, by = "treatment")

# Set a seed for this analysis
set.seed(3132001)
```

Load colors

```
# Extract the default ggplot colors
default_colors <- (scales::hue_pal())(length(strains_order) - 1)

# Create a named vector for strain colors, ensuring 'Control' is black
strain_colors <- setNames(c(default_colors, "black"), strains_order)

# Load species colors
species_colors <- c(`P. fluorescens` = "dodgerblue2", `P. syringae` = "springgreen3",
  `P. putida` = "sienna4", Control = "black")
```

```
species_colors_manual <- c(`194` = "sienna4", `200` = "dodgerblue2", `204` = "dodgerblue2",
  `205` = "dodgerblue2", `215` = "springgreen3", `216` = "dodgerblue2", `220` = "sienna4",
  `221` = "dodgerblue2", `227` = "dodgerblue2", `228` = "dodgerblue2", B728a = "springgreen3",
  Cit7 = "springgreen3", pisi = "springgreen3", Control = "black")
```

Goals

- Create Kaplan-Meier curve for Pseud. virulence data
- Use stats (Wilcox?) to determine statistical significance of each strain
- Compare virulence data with epiphytic growth ability

Virulence Analysis

Note: *In order to help me with this analysis, I am using the following sites - Survival Analysis in R and Hazard Ratio: Interpretation & Definition.*

Calculate survival probabilities for each strain and create dataframe

Survival model

```
# Fit the survival model
km_fit <- survfit(Surv(time, censored) ~ treatment, data = aphid_virulence_data)
```

Extract survival probability

```
# Fit the survival model
km_fit <- survfit(Surv(time, censored) ~ treatment, data = aphid_virulence_data)

# Extract survival probabilities at specific time points
time_points <- c(72)
km_summary <- summary(km_fit, times = time_points)

# Calculate standard error (assuming fit includes the necessary information)
std_error <- summary(km_fit, times = time_points)$std.err

# Initialize empty lists to store the results
times_list <- list()
treatment_list <- list()
surv_prob_list <- list()
std_error_list <- list()

# Loop over each treatment group and extract survival probabilities at
# specified time points
for (i in 1:length(km_fit$strata)) {
  treatment_name <- names(km_fit$strata)[i]
  for (t in time_points) {
```

```

idx <- which(km_summary$time == t & km_summary$strata == treatment_name)
if (length(idx) > 0) {
  times_list <- c(times_list, t)
  treatment_list <- c(treatment_list, treatment_name)
  surv_prob_list <- c(surv_prob_list, km_summary$surv[idx])
  std_error_list <- c(std_error_list, km_summary$std.err[idx])
} else {
  times_list <- c(times_list, t)
  treatment_list <- c(treatment_list, treatment_name)
  surv_prob_list <- c(surv_prob_list, NA)
  std_error_list <- c(std_error_list, NA)
}
}
}

# Create the data frame
surv_probs <- data.frame(time = unlist(times_list), treatment = unlist(treatment_list),
  surv_prob = unlist(surv_prob_list), std_error_data = unlist(std_error_list))

# Replace 'treatment=' with an empty string
surv_probs$treatment <- gsub("treatment=", "", surv_probs$treatment)

# Convert the treatment variable to a factor with the specified order
surv_probs$treatment <- factor(surv_probs$treatment, levels = strains_order)

# Join the survival dataframe to strains
surv_probs <- left_join(surv_probs, strains_df, by = "treatment")

# Print the data frame
print(surv_probs)

```

```

##      time treatment  surv_prob std_error_data      strain      -80
## 1    72      194 0.12244898   0.019117897 field sample #8    194
## 2    72      200 0.02230483   0.009003784 field sample #14   200
## 3    72      204 0.05281690   0.013272241 field sample #17   204
## 4    72      205 0.07118644   0.014971038 field sample #18-1  205
## 5    72      215 0.22222222   0.024497697 field sample #26-1  215
## 6    72      216 0.15625000   0.021395412 field sample #26-2  216
## 7    72      220 0.17229730   0.021949800 field sample #29-2  220
## 8    72      221 0.09363296   0.017828335 field sample #29-3  221
## 9    72      227 0.16949153   0.021844143 field sample #35    227
## 10   72      228 0.10447761   0.018684542 field sample #36    228
## 11   72      B728a 0.10996564   0.018339411      B728a  B728a
## 12   72      Cit7 0.17073171   0.022210773      Cit7      14
## 13   72      Control 0.81678082   0.011319228      Control Control
## 14   72      pisi 0.74151436   0.022370650      1704B      6
##      previous_work species_complex      species_match
## 1      new P. fluorescens      P. paralactis
## 2      new P. fluorescens      P. fluorescens
## 3      new P. fluorescens      P. rhodesiae
## 4      new P. fluorescens      P. orientalis
## 5      new P. syringae      P. syringae
## 6      new P. putida      P. putida

```

## 7	new	P. fluorescens	P. pergaminensis
## 8	new	P. fluorescens	P. fluorescens
## 9	new	P. fluorescens	P. pergaminensis
## 10	new	P. syringae	P. lijiangensis
## 11	old	P. syringae	P. syringae pv. Syringae
## 12	old	P. syringae	P. syringae
## 13	old	Control	Control
## 14	old	P. syringae	P. syringae
##		collector	source ANI
## 1		Kathryn L Herr	Pisum sativum 98.44
## 2		Kathryn L Herr	Pisum sativum <NA>
## 3		Kathryn L Herr	Pisum sativum 98.92
## 4		Kathryn L Herr	Pisum sativum 95.78
## 5		Kathryn L Herr	Pisum sativum 95.57
## 6		Kathryn L Herr	Pisum sativum 95.42
## 7		Kathryn L Herr	Pisum sativum 98.64
## 8		Kathryn L Herr	Pisum sativum <NA>
## 9		Kathryn L Herr	Pisum sativum 98.22
## 10		Kathryn L Herr	Pisum sativum 96.6
## 11	Alan Collmer/J. Lindemann?	Phaseolus vulgaris	<NA>
## 12		<NA>	Pisum sativum <NA>
## 13		Control	Control Control
## 14		David Baltrus	Citrus leaf surface <NA>
##		genome_match	Reseq/Genbank
## 1	Pseudomonas paralactis DSM 29164	GCA_001439735.1	
## 2		<NA>	<NA>
## 3	Pseudomonas rhodesiae CIP104664	GCF_024169765.1	
## 4	Pseudomonas orientalis DSM 17489	GCF_001439815.1	
## 5	Pseudomonas syringae DSM 10604	GCA_000597765.1	
## 6	Pseudomonas putida S13.1.2	GCF_000498395.2	
## 7	Pseudomonas pergaminensis 1008	GCF_024112395.1	
## 8		<NA>	<NA>
## 9	Pseudomonas pergaminensis 1008	GCF_024112395.1	
## 10	Pseudomonas lijiangensis LJ2	GCF_018968705.1	
## 11		<NA>	CP000075
## 12		<NA>	AEAJ 00000000
## 13		Control	Control
## 14		<NA>	AEAI 00000000
##			
## 1			
## 2			
## 3			
## 4			
## 5			
## 6			
## 7			
## 8			
## 9			
## 10			
## 11			
177.	https://doi.org/10.1146/annurev.py.28.090190.001103		
## 12			
177.	https://doi.org/10.1146/annurev.py.28.090190.001103		
## 13			

```
## 14 Baltrus, D. A., Nishimura, M. T., Romanchuk, A., Chang, J. H., Mukhtar, M. S., Cherkis, K., Roach
```

Post-hoc test for survival

```
# Perform pairwise log-rank tests between treatment groups and the control
# group
pairwise_tests_treatment <- pairwise_survdif(Surv(time, censored) ~ treatment, data = aphid_virulence_

# Print the pairwise tests
print(pairwise_tests_treatment)
```

```
##
## Pairwise comparisons using Log-Rank test
##
## data: aphid_virulence_data and treatment
##
##      194      200      204      205      215      216      220      221      227
## 200    2.3e-12 -          -          -          -          -          -          -
## 204    1.6e-08 0.26489 -          -          -          -          -          -
## 205    3.7e-06 0.04009 0.38289 -          -          -          -          -
## 215    4.6e-05 < 2e-16 < 2e-16 7.8e-16 -          -          -          -
## 216    0.20589 3.0e-06 0.00054 0.00915 1.3e-05 -          -          -
## 220    1.2e-05 0.34987 0.95899 0.61067 7.5e-10 0.04787 -          -
## 221    0.06597 1.7e-06 0.00063 0.01560 3.0e-08 0.57084 0.05899 -          -
## 227    0.00048 0.05275 0.34910 0.75895 1.7e-08 0.14997 0.65606 0.23547 -
## 228    0.02457 2.3e-05 0.00265 0.03730 5.6e-09 0.52684 0.02668 0.75895 0.15756
## B728a  0.30241 3.8e-15 2.0e-10 1.5e-07 0.00193 0.15635 0.00089 0.00913 0.00558
## Cit7   0.97833 6.8e-10 1.0e-06 8.4e-05 0.00044 0.38289 0.00217 0.11439 0.01459
## Control < 2e-16 < 2e-16 < 2e-16 < 2e-16 < 2e-16 < 2e-16 < 2e-16 < 2e-16
## pisi   < 2e-16 < 2e-16 < 2e-16 < 2e-16 < 2e-16 < 2e-16 < 2e-16 < 2e-16
##      228      B728a      Cit7      Control
## 200    -          -          -          -
## 204    -          -          -          -
## 205    -          -          -          -
## 215    -          -          -          -
## 216    -          -          -          -
## 220    -          -          -          -
## 221    -          -          -          -
## 227    -          -          -          -
## 228    -          -          -          -
## B728a  0.00265 -          -          -
## Cit7   0.05646 0.46912 -          -
## Control < 2e-16 < 2e-16 < 2e-16 -
## pisi   < 2e-16 < 2e-16 < 2e-16 0.00042
##
## P value adjustment method: BH
```

```
# Perform pairwise log-rank tests between species_complex groups and the
# control group
pairwise_tests_species <- pairwise_survdif(Surv(time, censored) ~ species_complex,
      data = aphid_virulence_data)
```

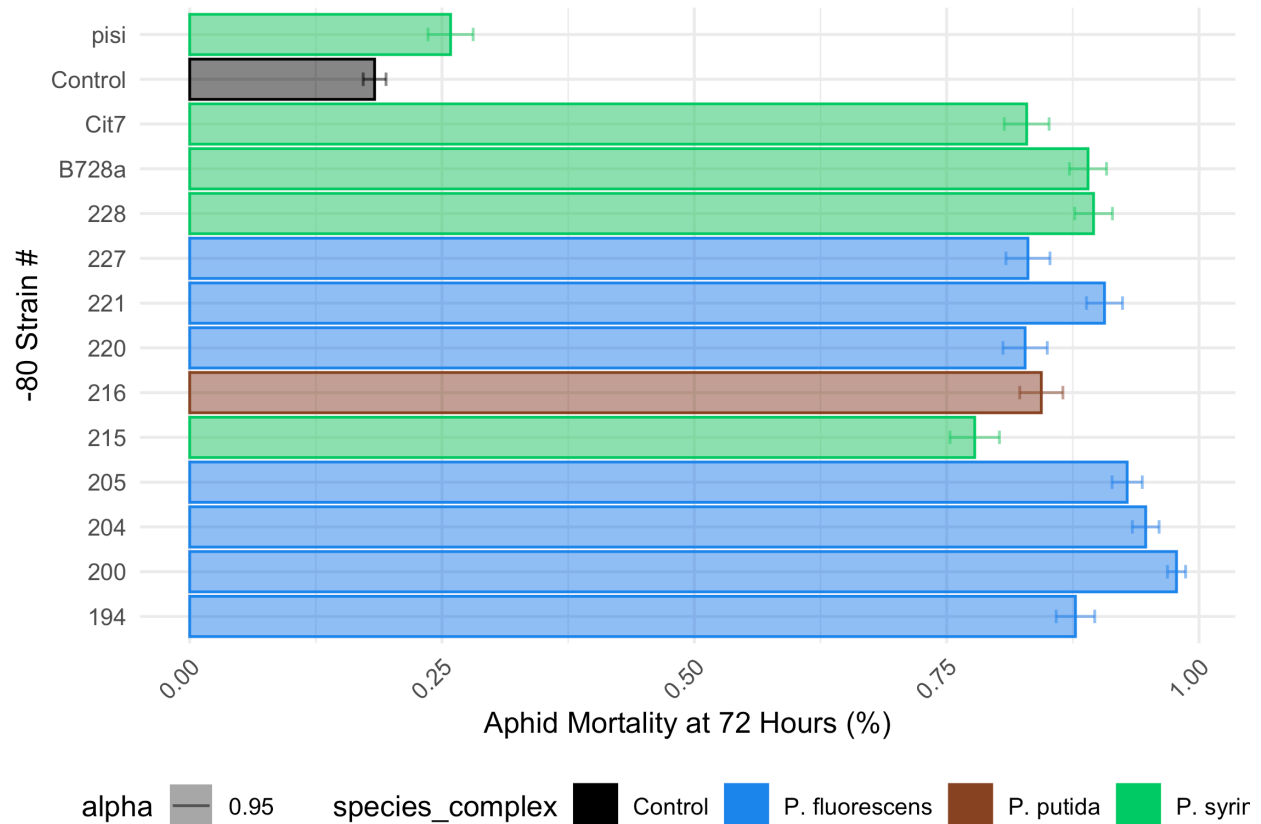
```
# Print the pairwise tests
print(pairwise_tests_species)
```

```
##
## Pairwise comparisons using Log-Rank test
##
## data: aphid_virulence_data and species_complex
##
##           Control P. fluorescens P. putida
## P. fluorescens < 2e-16 - -
## P. putida      < 2e-16 0.0084 -
## P. syringae    < 2e-16 < 2e-16 2.6e-10
##
## P value adjustment method: BH
```

Plot Survival Dataframe at different times

```
surv_plot <- ggplot(data = surv_probs, aes(x = treatment, y = (1-surv_prob), color = species_complex, fill = species_complex)) +
  geom_col() +
  geom_errorbar(aes(ymin = (1-surv_prob) - std_error_data, ymax = (1-surv_prob) + std_error_data),
    width = 0.3, # Width of error bars
    position = position_dodge(width = 0.9)) + # Dodge bars slightly
  labs(x = "-80 Strain #",
    y = "Aphid Mortality at 72 Hours (%)") +
  theme_minimal() +
  coord_flip() +
  scale_fill_manual(values = species_colors) +
  scale_color_manual(values = species_colors) +
  theme(plot.title = element_text(hjust = 0.5),
    axis.text.x = element_text(angle = 45, hjust = 1), legend.position = "bottom")

surv_plot
```



Make Kaplan-Meier Plot

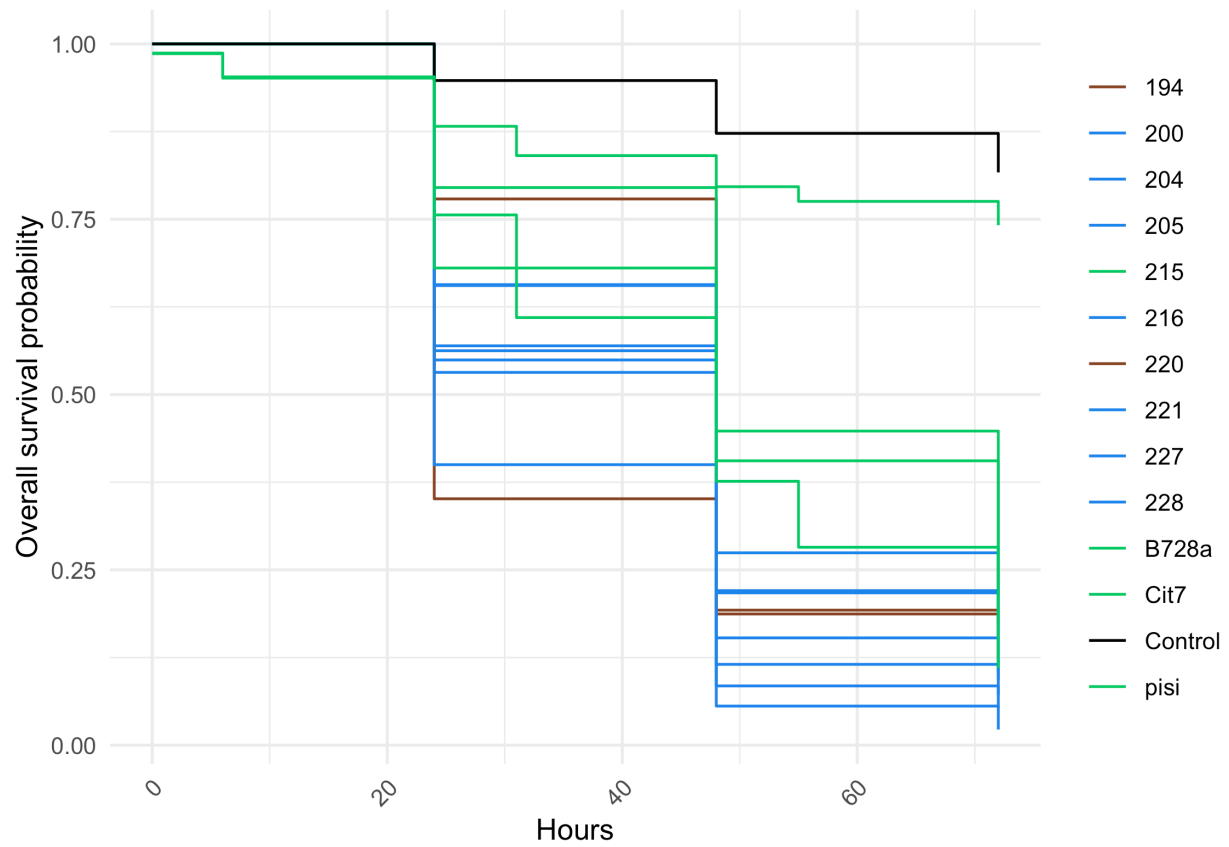
Cohort Survival Curve

```
# Plot the Kaplan-Meier survival curves by treatment
surv_curv_treatment <- survfit2(Surv(time, censored) ~ treatment, data = aphid_virulence_data) %>%
  ggsvfit(type = "survival") + labs(x = "Hours", y = "Overall survival probability") +
  theme_minimal() + scale_fill_manual(values = species_colors_manual) + scale_color_manual(values = species_colors_manual) +
  theme(plot.title = element_text(hjust = 0.5), axis.text.x = element_text(angle = 45, hjust = 1), legend.position = "right")

# Plot the Kaplan-Meier survival curves by species complex
surv_curv_species <- survfit2(Surv(time, censored) ~ species_complex, data = aphid_virulence_data) %>%
  ggsvfit(type = "survival") + labs(x = "Hours", y = "Overall survival probability") +
  theme_minimal() + scale_fill_manual(values = species_colors) + scale_color_manual(values = species_colors) +
  theme(plot.title = element_text(hjust = 0.5), axis.text.x = element_text(angle = 45, hjust = 1), legend.position = "right")

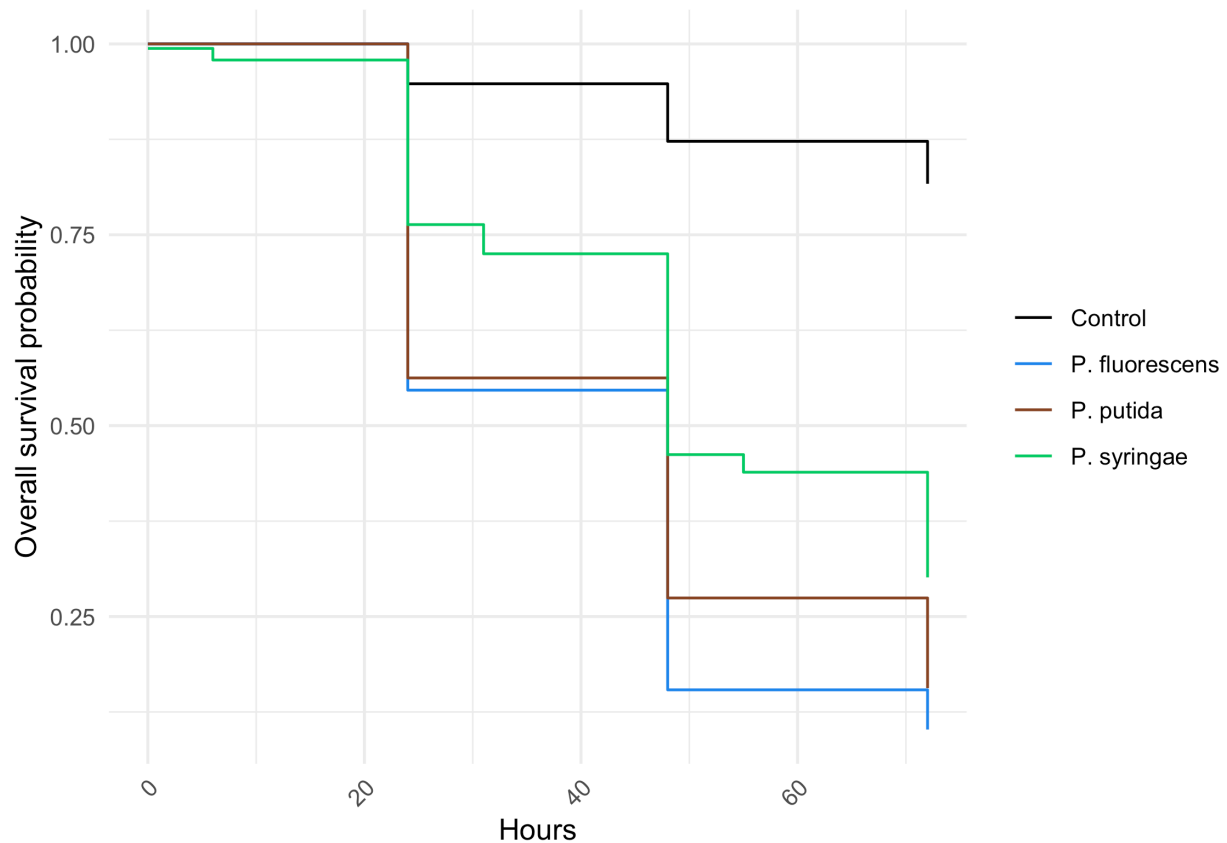
# show plots
surv_curv_treatment
```

```
## Warning: No shared levels found between `names(values)` of the manual scale and the
## data's fill values.
```

```
surv_curv_species
```

```
## Warning: No shared levels found between `names(values)` of the manual scale and the
## data's fill values.
```



Epiphytic Growth Analysis

Calculate mean/variance epiphytic growth ability

```
# Replace NA with a lower value or remove them for visualization Remove rows
# with NA in CFU_per_10_leafdiscs_log_10
epi_growth_clean <- epi_growth_data %>%
  filter(!is.na(CFU_per_10_leafdiscs_log_10))

# Convert CFU_per_10_leafdiscs_log_10 to numeric, handling scientific notation
epi_growth_clean$CFU_per_10_leafdiscs_log_10 <- as.numeric(gsub("<", "", epi_growth_clean$CFU_per_10_lea

## Warning: NAs introduced by coercion

# Subset data to remove unfinished strains and extract the letter part from the
# 'plant_rep' column
epi_growth_clean <- epi_growth_clean %>%
  mutate(plant_rep_letter = substr(plant_rep, 1, 1))

# Calculate the mean and SD CFU per strain for each plant rep letter and retain
# the specified columns
epi_growth_mean_per_rep <- epi_growth_clean %>%
```

```

group_by(treatment, plant_rep_letter) %>%
summarise(CFU_per_10_leafdiscs_log_10 = mean(CFU_per_10_leafdiscs_log_10, na.rm = TRUE),
  sd_CFU = sd(CFU_per_10_leafdiscs_log_10, na.rm = TRUE), sample = first(sample),
  person = first(person), species_complex = first(species_complex), block = first(block),
  treatment = first(treatment), plant_rep = first(plant_rep), .groups = "drop")

# Calculate the mean and SD CFU per strain for each plant rep letter and retain
# the specified columns
epi_growth_mean_per_strain <- epi_growth_clean %>%
  group_by(treatment) %>%
  summarise(CFU_per_10_leafdiscs_log_10 = mean(CFU_per_10_leafdiscs_log_10, na.rm = TRUE),
    sd_CFU = sd(CFU_per_10_leafdiscs_log_10, na.rm = TRUE), sample = first(sample),
    person = first(person), species_complex = first(species_complex), block = first(block),
    treatment = first(treatment), plant_rep = first(plant_rep), .groups = "drop")

epi_growth_mean_per_strain

```

```

## # A tibble: 13 x 8
##   treatment CFU_per_10_leafdiscs_l~1 sd_CFU sample person species_complex block
##   <chr>          <dbl>    <dbl> <chr>  <chr>  <chr>      <chr>
## 1 194          5.07      NA 194-A1 Havi   P. fluorescens 2-1
## 2 200          5.26      NA 200-A1 Havi   P. fluorescens 2-6
## 3 204          4.93      NA 204-A1 Havi   P. fluorescens 2-3
## 4 205          4.87      NA 205-A1 Sara  P. fluorescens 3
## 5 215          3         NA 215-A1 Sara  P. syringae    3
## 6 216          3.59      NA 216-A1 Sara  P. putida      3
## 7 220          4.82      NA 220-A1 Sara  P. fluorescens 5
## 8 221          5.25      NA 221-A1 Havi   P. fluorescens 2-7
## 9 227          4.16      NA 227-A1 Sara  P. fluorescens 5
## 10 228          3.83      NA 228-A1 Sara  P. syringae    5
## 11 B728a        3.72      NA B728a~ Sara  P. syringae    4
## 12 Cit7         4.28      NA Cit7-- Havi   P. syringae    2-3
## 13 pisi         3.32      NA pisi-- Havi   P. syringae    2-4
## # i abbreviated name: 1: CFU_per_10_leafdiscs_log_10
## # i 1 more variable: plant_rep <chr>

```

Plot Epiphytic Growth

```

# plot by treatment
epi_growth_treatment <- ggplot(data = epi_growth_mean_per_rep, aes(x = treatment,
  y = CFU_per_10_leafdiscs_log_10, color = species_complex, fill = species_complex)) +
  geom_boxplot(outlier.shape = NA, alpha = 0.3) + geom_beeswarm(stroke = 0.5, size = 0.8,
  alpha = 0.8) + theme_minimal() + coord_flip() + scale_fill_manual(values = species_colors) +
  scale_color_manual(values = species_colors) + scale_y_continuous(limits = c(2.5,
  5.5)) + theme(plot.title = element_text(hjust = 0.5), axis.text.x = element_text(angle = 45,
  hjust = 1), legend.position = "bottom")

# plot by species complex
epi_growth_species <- ggplot(data = epi_growth_mean_per_rep, aes(x = species_complex,
  y = CFU_per_10_leafdiscs_log_10, color = species_complex, fill = species_complex)) +
  geom_boxplot(outlier.shape = NA, alpha = 0.3) + geom_beeswarm(stroke = 0.5, size = 0.8,

```

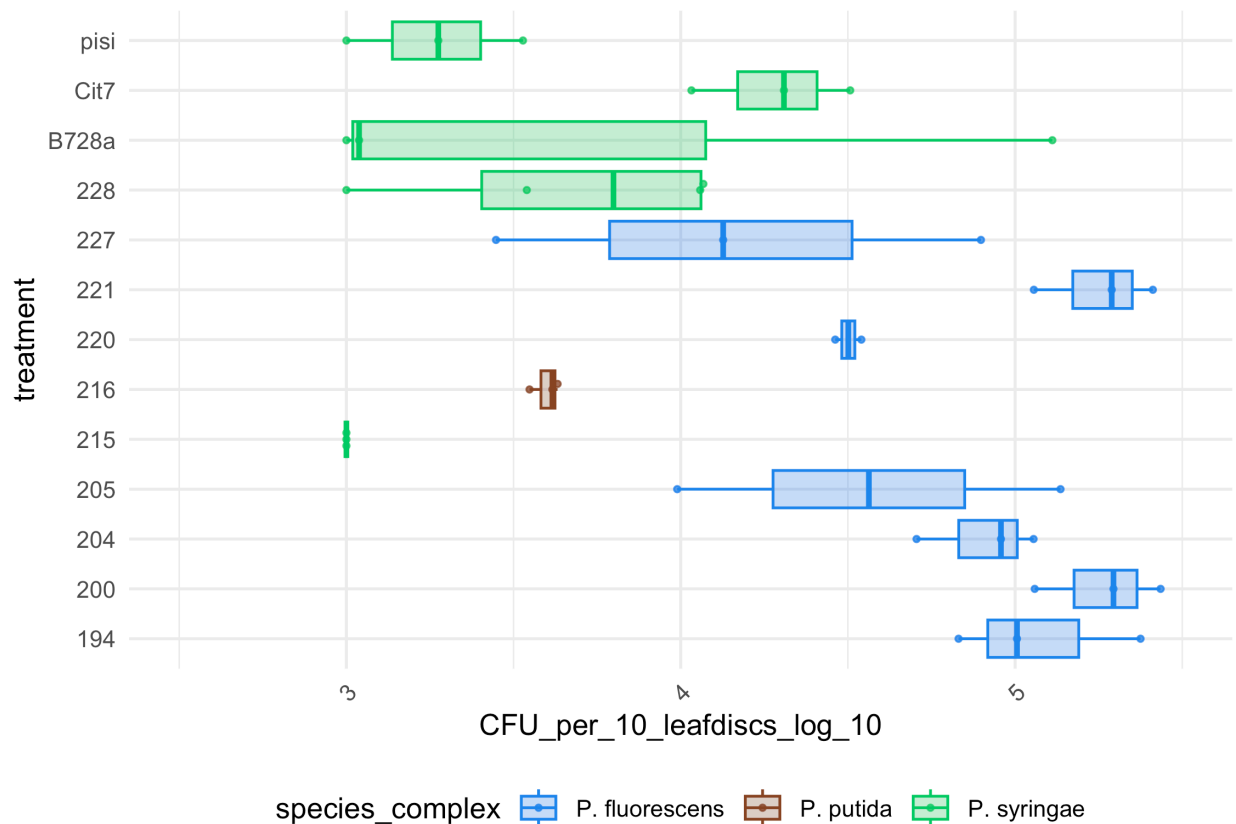
```
alpha = 0.8) + theme_minimal() + scale_fill_manual(values = species_colors) +
scale_color_manual(values = species_colors) + scale_y_continuous(limits = c(2.5,
5.5)) + theme(plot.title = element_text(hjust = 0.5), axis.text.x = element_text(angle = 45,
hjust = 1), legend.position = "bottom")
```

```
# show plots
```

```
epi_growth_treatment
```

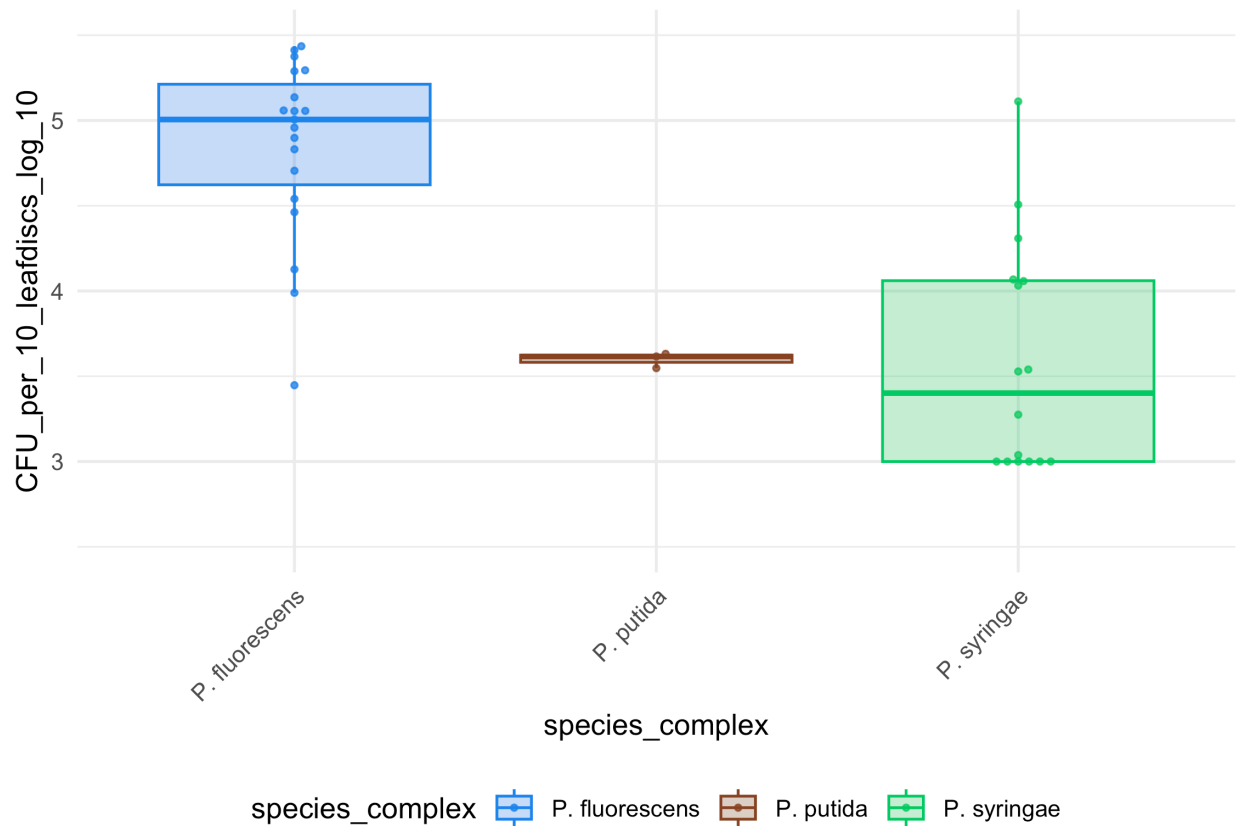
```
## Warning: Removed 2 rows containing non-finite outside the scale range
## (`stat_boxplot()`).
```

```
## Warning: Removed 2 rows containing missing values or values outside the scale range
## (`geom_point()`).
```



```
epi_growth_species
```

```
## Warning: Removed 2 rows containing non-finite outside the scale range
## (`stat_boxplot()`).
## Removed 2 rows containing missing values or values outside the scale range
## (`geom_point()`).
```



Epiphytic growth stats

```
# stats per treatment
epi_growth_mod_treatment = lm(CFU_per_10_leafdiscs_log_10 ~ treatment, data = epi_growth_mean_per_rep)

emmeans(epi_growth_mod_treatment, pairwise ~ treatment)
```

```
## $emmeans
## treatment emmean SE df lower.CL upper.CL
## 194 5.07 0.305 27 4.45 5.70
## 200 5.26 0.305 27 4.64 5.89
## 204 4.91 0.305 27 4.28 5.53
## 205 4.90 0.305 27 4.28 5.53
## 215 3.00 0.305 27 2.37 3.63
## 216 3.60 0.305 27 2.97 4.22
## 220 4.87 0.305 27 4.24 5.49
## 221 5.25 0.305 27 4.63 5.88
## 227 4.16 0.305 27 3.53 4.78
## 228 3.67 0.264 27 3.13 4.21
## B728a 3.72 0.305 27 3.09 4.34
## Cit7 4.28 0.305 27 3.66 4.91
## pisi 3.27 0.305 27 2.64 3.89
##
```

```

## Confidence level used: 0.95
##
## $contrasts
## contrast      estimate      SE df t.ratio p.value
## 194 - 200      -0.19212 0.431 27  -0.446  1.0000
## 194 - 204       0.16452 0.431 27   0.382  1.0000
## 194 - 205       0.16752 0.431 27   0.389  1.0000
## 194 - 215       2.07066 0.431 27   4.807  0.0028
## 194 - 216       1.47217 0.431 27   3.417  0.0782
## 194 - 220       0.20476 0.431 27   0.475  1.0000
## 194 - 221      -0.18180 0.431 27  -0.422  1.0000
## 194 - 227       0.91321 0.431 27   2.120  0.6504
## 194 - 228       1.40429 0.403 27   3.485  0.0676
## 194 - B728a     1.35417 0.431 27   3.143  0.1373
## 194 - Cit7      0.78812 0.431 27   1.829  0.8188
## 194 - pisi      1.80298 0.431 27   4.185  0.0134
## 200 - 204       0.35664 0.431 27   0.828  0.9996
## 200 - 205       0.35964 0.431 27   0.835  0.9996
## 200 - 215       2.26278 0.431 27   5.253  0.0009
## 200 - 216       1.66429 0.431 27   3.863  0.0288
## 200 - 220       0.39688 0.431 27   0.921  0.9990
## 200 - 221       0.01032 0.431 27   0.024  1.0000
## 200 - 227       1.10533 0.431 27   2.566  0.3752
## 200 - 228       1.59641 0.403 27   3.962  0.0228
## 200 - B728a     1.54629 0.431 27   3.589  0.0537
## 200 - Cit7      0.98024 0.431 27   2.275  0.5509
## 200 - pisi      1.99510 0.431 27   4.631  0.0044
## 204 - 205       0.00299 0.431 27   0.007  1.0000
## 204 - 215       1.90614 0.431 27   4.425  0.0074
## 204 - 216       1.30765 0.431 27   3.035  0.1691
## 204 - 220       0.04024 0.431 27   0.093  1.0000
## 204 - 221      -0.34632 0.431 27  -0.804  0.9997
## 204 - 227       0.74869 0.431 27   1.738  0.8620
## 204 - 228       1.23976 0.403 27   3.077  0.1563
## 204 - B728a     1.18965 0.431 27   2.762  0.2756
## 204 - Cit7      0.62360 0.431 27   1.448  0.9559
## 204 - pisi      1.63845 0.431 27   3.803  0.0331
## 205 - 215       1.90314 0.431 27   4.418  0.0075
## 205 - 216       1.30465 0.431 27   3.029  0.1713
## 205 - 220       0.03724 0.431 27   0.086  1.0000
## 205 - 221      -0.34931 0.431 27  -0.811  0.9997
## 205 - 227       0.74569 0.431 27   1.731  0.8650
## 205 - 228       1.23677 0.403 27   3.069  0.1586
## 205 - B728a     1.18665 0.431 27   2.755  0.2788
## 205 - Cit7      0.62060 0.431 27   1.441  0.9574
## 205 - pisi      1.63546 0.431 27   3.796  0.0336
## 215 - 216      -0.59849 0.431 27  -1.389  0.9671
## 215 - 220      -1.86590 0.431 27  -4.331  0.0093
## 215 - 221      -2.25246 0.431 27  -5.229  0.0010
## 215 - 227      -1.15745 0.431 27  -2.687  0.3114
## 215 - 228      -0.66637 0.403 27  -1.654  0.8961
## 215 - B728a    -0.71649 0.431 27  -1.663  0.8925
## 215 - Cit7     -1.28254 0.431 27  -2.977  0.1886
## 215 - pisi     -0.26768 0.431 27  -0.621  1.0000

```

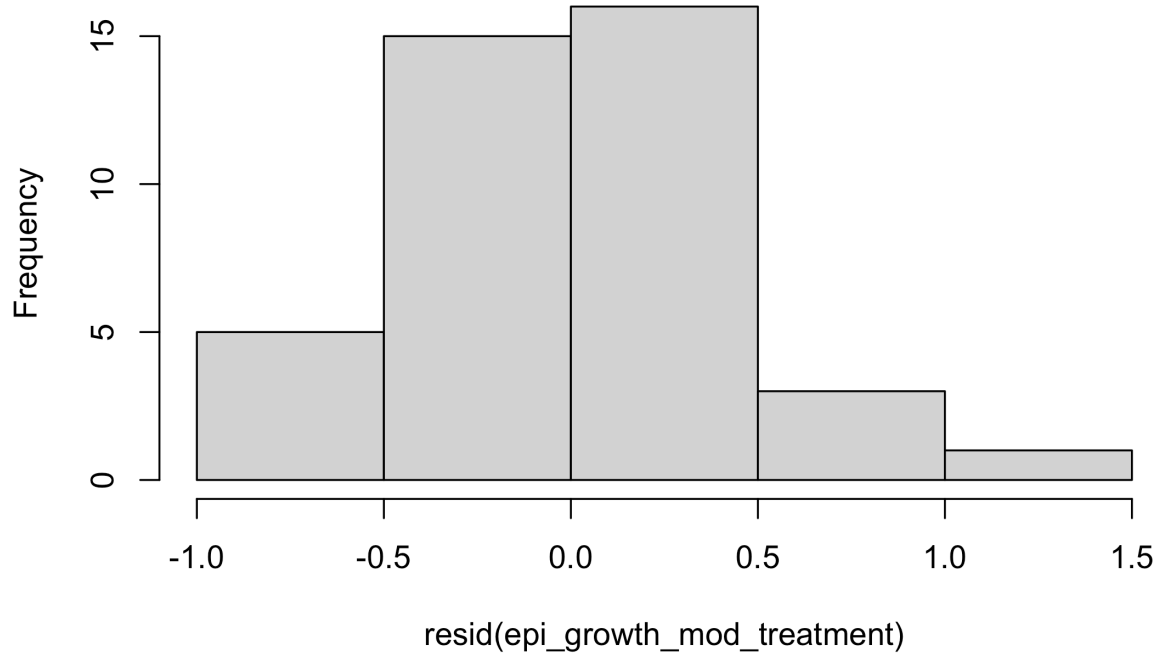
```

## 216 - 220      -1.26741 0.431 27  -2.942 0.2011
## 216 - 221      -1.65397 0.431 27  -3.839 0.0304
## 216 - 227      -0.55896 0.431 27  -1.298 0.9802
## 216 - 228      -0.06788 0.403 27  -0.168 1.0000
## 216 - B728a    -0.11800 0.431 27  -0.274 1.0000
## 216 - Cit7     -0.68405 0.431 27  -1.588 0.9188
## 216 - pisi      0.33081 0.431 27   0.768 0.9998
## 220 - 221      -0.38656 0.431 27  -0.897 0.9992
## 220 - 227       0.70845 0.431 27   1.645 0.8995
## 220 - 228       1.19953 0.403 27   2.977 0.1887
## 220 - B728a    1.14941 0.431 27   2.668 0.3208
## 220 - Cit7      0.58336 0.431 27   1.354 0.9727
## 220 - pisi      1.59822 0.431 27   3.710 0.0410
## 221 - 227       1.09501 0.431 27   2.542 0.3886
## 221 - 228       1.58608 0.403 27   3.936 0.0243
## 221 - B728a    1.53597 0.431 27   3.565 0.0567
## 221 - Cit7      0.96992 0.431 27   2.251 0.5662
## 221 - pisi      1.98477 0.431 27   4.607 0.0047
## 227 - 228       0.49108 0.403 27   1.219 0.9880
## 227 - B728a    0.44096 0.431 27   1.024 0.9973
## 227 - Cit7     -0.12509 0.431 27  -0.290 1.0000
## 227 - pisi      0.88977 0.431 27   2.065 0.6844
## 228 - B728a   -0.05012 0.403 27  -0.124 1.0000
## 228 - Cit7     -0.61617 0.403 27  -1.529 0.9362
## 228 - pisi      0.39869 0.403 27   0.989 0.9980
## B728a - Cit7   -0.56605 0.431 27  -1.314 0.9782
## B728a - pisi    0.44881 0.431 27   1.042 0.9969
## Cit7 - pisi     1.01486 0.431 27   2.356 0.5000
##
## P value adjustment: tukey method for comparing a family of 13 estimates

```

```
hist(resid(epi_growth_mod_treatment))
```

Histogram of resid(epi_growth_mod_treatment)

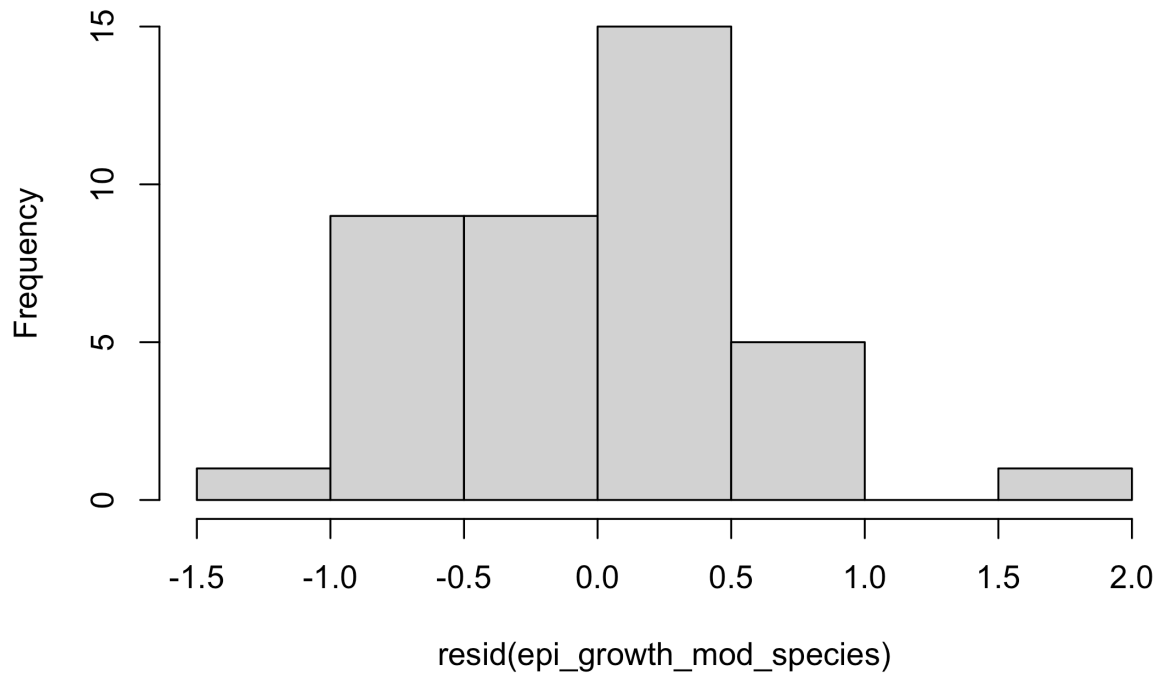


```
# stats per species
epi_growth_mod_species = lm(CFU_per_10_leafdiscs_log_10 ~ species_complex, data = epi_growth_mean_per_r
emmeans(epi_growth_mod_species, pairwise ~ species_complex)
```

```
## $emmeans
##   species_complex emmean    SE df lower.CL upper.CL
## P. fluorescens    4.92 0.129 37    4.66    5.18
## P. putida         3.60 0.341 37    2.91    4.29
## P. syringae       3.59 0.148 37    3.29    3.89
##
## Confidence level used: 0.95
##
## $contrasts
##   contrast              estimate    SE df t.ratio p.value
## P. fluorescens - P. putida    1.31844 0.364 37   3.619  0.0025
## P. fluorescens - P. syringae  1.32533 0.196 37   6.767 <.0001
## P. putida - P. syringae       0.00689 0.371 37   0.019  0.9998
##
## P value adjustment: tukey method for comparing a family of 3 estimates
```

```
hist(resid(epi_growth_mod_species))
```


Histogram of resid(epi_growth_mod_species)



Combine epiphytic and virulence data

```
# Combine strain_stats and surv_probs using left_join
epi_virulence_data <- left_join(epi_growth_mean_per_strain, surv_probs, by = "treatment")

# Print the combined data
print(epi_virulence_data)
```

```
## # A tibble: 13 x 22
##   treatment CFU_per_10_leafdiscs~1 sd_CFU sample person species_complex.x block
##   <chr>          <dbl>    <dbl> <chr>  <chr>  <chr>          <chr>
## 1 194            5.07      NA 194-A1 Havi   P. fluorescens 2-1
## 2 200            5.26      NA 200-A1 Havi   P. fluorescens 2-6
## 3 204            4.93      NA 204-A1 Havi   P. fluorescens 2-3
## 4 205            4.87      NA 205-A1 Sara  P. fluorescens 3
## 5 215            3        NA 215-A1 Sara  P. syringae    3
## 6 216            3.59      NA 216-A1 Sara  P. putida      3
## 7 220            4.82      NA 220-A1 Sara  P. fluorescens 5
## 8 221            5.25      NA 221-A1 Havi   P. fluorescens 2-7
## 9 227            4.16      NA 227-A1 Sara  P. fluorescens 5
## 10 228            3.83      NA 228-A1 Sara  P. syringae    5
## 11 B728a         3.72      NA B728a~ Sara  P. syringae    4
## 12 Cit7          4.28      NA Cit7~~ Havi   P. syringae    2-3
```

```
## 13 pisi 3.32 NA pisi-- Havi P. syringae 2-4
## # i abbreviated name: 1: CFU_per_10_leafdiscs_log_10
## # i 15 more variables: plant_rep <chr>, time <dbl>, surv_prob <dbl>,
## # std_error_data <dbl>, strain <chr>, `~80` <chr>, previous_work <chr>,
## # species_complex.y <chr>, species_match <chr>, collector <chr>,
## # source <chr>, ANI <chr>, genome_match <chr>, `Reseq/Genbank` <chr>,
## # Paper <chr>
```

```
# Calculate correlation coefficient between survival probability and epiphytic
# growth ability
correlation <- -1 * cor(epi_virulence_data$surv_prob, epi_virulence_data$CFU_per_10_leafdiscs_log_10,
  method = "pearson")
```

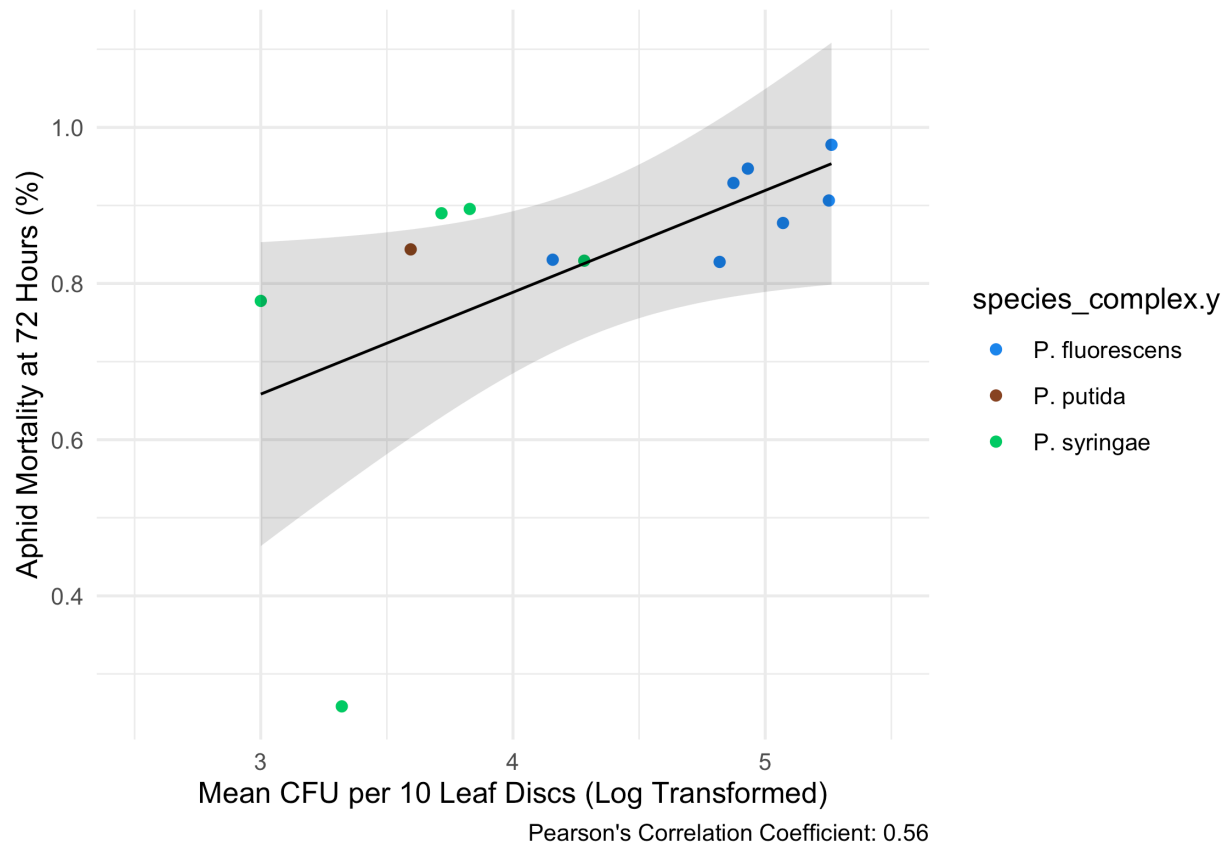
Plot epi virulence plot

```
# Create scatter plot for 72 hours
epi_virulence_plot_strains <- ggplot(epi_virulence_data, aes(x = CFU_per_10_leafdiscs_log_10,
  y = 1 - surv_prob)) + geom_point(aes(color = species_complex.y)) + geom_smooth(method = "lm",
  se = TRUE, color = "black", fill = "black", alpha = 0.15, linewidth = 0.5) +
  labs(x = "Mean CFU per 10 Leaf Discs (Log Transformed)", y = "Aphid Mortality at 72 Hours (%)",
    caption = paste("Pearson's Correlation Coefficient:", round(correlation,
      2))) + scale_x_continuous(limits = c(2.5, 5.5)) + scale_fill_manual(values = species_colors) +
  scale_color_manual(values = species_colors) + theme_minimal()

epi_virulence_plot_strains
```

```
## `geom_smooth()` using formula = 'y ~ x'
```

```
## Warning: No shared levels found between `names(values)` of the manual scale and the
## data's fill values.
```



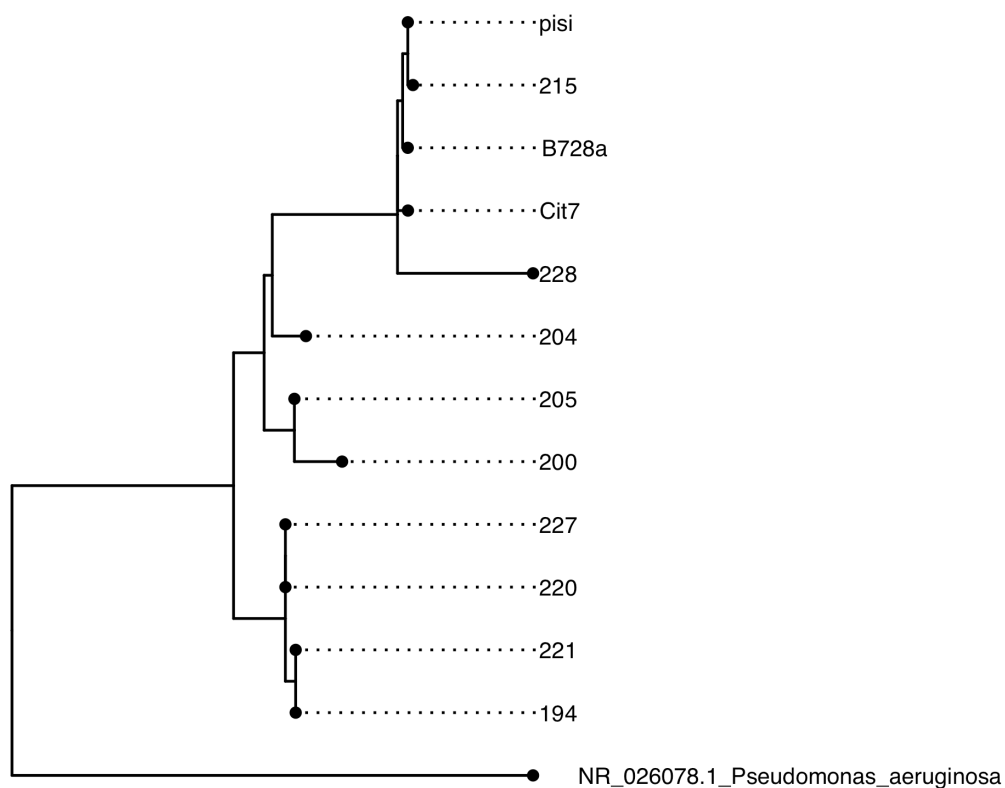
Make Phylogenetic Tree of Strains

```
# Load the tree from the .contree file
tree <- read.tree("tree/EpiVir_IQTree_2024july9/EpiVir_16S.contree")

# Root the tree at the midpoint
midpoint_tree <- midpoint(tree)

# Visualize the tree with customizations
phylo_tree <- ggtree(midpoint_tree) + geom_tiplab(size = 3, hjust = -0.1, align = TRUE) +
  geom_tippoint() + ggplot2::xlim(0, 0.14)
# +
# geom_text(aes(label=node), hjust=-1)
# + geom_cladelabel(node=17, label='Some random clade', color='red', offset=.8)

phylo_tree
```



Combine my tree and my barplot

```
# https://4va.github.io/biodatasci/r-ggtree.html#connecting\_taxa
# https://yulab-smu.top/treedata-book/chapter7.html

surv_plot_no_legend

surv_plot_no_legend %>%
  insert_left(phylo_tree)
# note: the tips are not lining up properly
```

Session Information

```
devtools::session_info()
```

```
## - Session info -----
## setting value
```

```

## version R version 4.4.0 (2024-04-24)
## os      macOS Ventura 13.4
## system  x86_64, darwin20
## ui      X11
## language (EN)
## collate en_US.UTF-8
## ctype   en_US.UTF-8
## tz      America/New_York
## date    2024-07-22
## pandoc  3.1.11 @ /Applications/RStudio.app/Contents/Resources/app/quarto/bin/tools/x86_64/ (via rm
##
## - Packages -----
## ! package      * version    date (UTC) lib source
##   abind          1.4-5      2016-07-21 [1] RSPM (R 4.4.0)
##   ape            * 5.8       2024-04-11 [1] RSPM (R 4.4.0)
##   P aplot        * 0.2.3     2024-06-17 [?] RSPM
##   backports      1.5.0     2024-05-23 [1] RSPM (R 4.4.0)
##   beeswarm       0.4.0     2021-06-01 [1] RSPM (R 4.4.0)
##   P BiocManager  * 1.30.23   2024-05-04 [?] RSPM
##   bit            4.0.5     2022-11-15 [1] RSPM (R 4.4.0)
##   bit64          4.0.5     2020-08-30 [1] RSPM (R 4.4.0)
##   broom          1.0.6     2024-05-17 [1] RSPM (R 4.4.0)
##   broom.helpers  1.15.0    2024-04-05 [1] RSPM (R 4.4.0)
##   P cachem       1.1.0     2024-05-16 [?] RSPM
##   car            3.1-2     2023-03-30 [1] RSPM (R 4.4.0)
##   carData        3.0-5     2022-01-06 [1] RSPM (R 4.4.0)
##   cellranger     1.1.0     2016-07-27 [1] RSPM (R 4.4.0)
##   P cli          3.6.3     2024-06-21 [?] RSPM
##   P clusterGeneration 1.3.8     2023-08-16 [?] RSPM
##   P coda         0.19-4.1  2024-01-31 [?] RSPM
##   P codetools    0.2-20    2024-03-31 [?] CRAN (R 4.4.0)
##   P colorspace   2.1-0     2023-01-23 [?] CRAN (R 4.4.0)
##   P combinat     0.0-8     2012-10-29 [?] RSPM
##   cowplot        * 1.1.3     2024-01-22 [1] RSPM (R 4.4.0)
##   P crayon       1.5.3     2024-06-20 [?] RSPM
##   data.table     1.15.4    2024-03-30 [1] RSPM (R 4.4.0)
##   P DEoptim      2.2-8     2022-11-11 [?] RSPM
##   P devtools     * 2.4.5     2022-10-11 [?] RSPM
##   P digest       0.6.36    2024-06-23 [?] RSPM
##   P doParallel   1.0.17    2022-02-07 [?] RSPM
##   dplyr          * 1.1.4     2023-11-17 [1] RSPM (R 4.4.0)
##   P ellipsis     0.3.2     2021-04-29 [?] RSPM
##   emmeans        * 1.10.3    2024-07-01 [1] RSPM (R 4.4.0)
##   estimability   1.5.1     2024-05-12 [1] RSPM (R 4.4.0)
##   P evaluate     0.24.0    2024-06-10 [?] RSPM
##   P expm         0.999-9   2024-01-11 [?] RSPM
##   P fansi        1.0.6     2023-12-08 [?] CRAN (R 4.4.0)
##   P farver       2.1.2     2024-05-13 [?] CRAN (R 4.4.0)
##   P fastmap      1.2.0     2024-05-15 [?] RSPM
##   P fastmatch    1.1-4     2023-08-18 [?] RSPM
##   forcats        * 1.0.0     2023-01-29 [1] RSPM (R 4.4.0)
##   P foreach      1.5.2     2022-02-02 [?] RSPM
##   formatR        * 1.14      2023-01-17 [1] RSPM (R 4.4.0)
##   P fs           1.6.4     2024-04-25 [?] CRAN (R 4.4.0)

```

##	generics	0.1.3	2022-07-05	[1]	RSPM (R 4.4.0)
##	ggbeeswarm	* 0.7.2	2023-04-29	[1]	RSPM (R 4.4.0)
##	ggfun	0.1.5	2024-05-28	[1]	RSPM (R 4.4.0)
##	P ggplot2	* 3.5.1	2024-04-23	[?]	CRAN (R 4.4.0)
##	ggplotify	0.1.2	2023-08-09	[1]	RSPM (R 4.4.0)
##	ggpubr	* 0.6.0	2023-02-10	[1]	RSPM (R 4.4.0)
##	ggsignif	0.6.4	2022-10-13	[1]	RSPM (R 4.4.0)
##	ggsurvfit	* 1.1.0	2024-05-08	[1]	RSPM (R 4.4.0)
##	P ggtree	* 3.12.0	2024-04-30	[?]	Bioconduc~
##	P glue	1.7.0	2024-01-09	[?]	CRAN (R 4.4.0)
##	gridExtra	* 2.3	2017-09-09	[1]	RSPM (R 4.4.0)
##	gridGraphics	0.5-1	2020-12-13	[1]	RSPM (R 4.4.0)
##	gt	0.10.1	2024-01-17	[1]	RSPM (R 4.4.0)
##	P gtable	0.3.5	2024-04-22	[?]	CRAN (R 4.4.0)
##	gtsummary	* 1.7.2	2023-07-15	[1]	RSPM (R 4.4.0)
##	here	* 1.0.1	2020-12-13	[1]	RSPM (R 4.4.0)
##	hms	1.1.3	2023-03-21	[1]	RSPM (R 4.4.0)
##	P htmltools	0.5.8.1	2024-04-04	[?]	CRAN (R 4.4.0)
##	P htmlwidgets	1.6.4	2023-12-06	[?]	CRAN (R 4.4.0)
##	P httpuv	1.6.15	2024-03-26	[?]	RSPM
##	P igraph	2.0.3	2024-03-13	[?]	RSPM
##	P iterators	1.0.14	2022-02-05	[?]	RSPM
##	P jsonlite	1.8.8	2023-12-04	[?]	CRAN (R 4.4.0)
##	km.ci	0.5-6	2022-04-06	[1]	RSPM (R 4.4.0)
##	KMsurv	0.1-5	2012-12-03	[1]	RSPM (R 4.4.0)
##	P knitr	* 1.48	2024-07-07	[?]	RSPM
##	P labeling	0.4.3	2023-08-29	[?]	CRAN (R 4.4.0)
##	P later	1.3.2	2023-12-06	[?]	RSPM
##	P lattice	0.22-6	2024-03-20	[?]	CRAN (R 4.4.0)
##	lazyeval	0.2.2	2019-03-15	[1]	RSPM (R 4.4.0)
##	P lifecycle	1.0.4	2023-11-07	[?]	CRAN (R 4.4.0)
##	lubridate	* 1.9.3	2023-09-27	[1]	RSPM (R 4.4.0)
##	P magrittr	2.0.3	2022-03-30	[?]	CRAN (R 4.4.0)
##	P maps	* 3.4.2	2023-12-15	[?]	RSPM
##	P MASS	7.3-61	2024-06-13	[?]	CRAN (R 4.4.0)
##	P Matrix	1.7-0	2024-03-22	[?]	CRAN (R 4.4.0)
##	P memoise	2.0.1	2021-11-26	[?]	CRAN (R 4.4.0)
##	P mgcv	1.9-1	2023-12-21	[?]	CRAN (R 4.4.0)
##	P mime	0.12	2021-09-28	[?]	CRAN (R 4.4.0)
##	P miniUI	0.1.1.1	2018-05-18	[?]	RSPM
##	P mnormt	2.1.1	2022-09-26	[?]	RSPM
##	P munsell	0.5.1	2024-04-01	[?]	CRAN (R 4.4.0)
##	mvtnorm	1.2-5	2024-05-21	[1]	RSPM (R 4.4.0)
##	P nlme	3.1-165	2024-06-06	[?]	CRAN (R 4.4.0)
##	numDeriv	2016.8-1.1	2019-06-06	[1]	RSPM (R 4.4.0)
##	P optimParallel	1.0-2	2021-02-11	[?]	RSPM
##	P pacman	0.5.1	2019-03-11	[?]	CRAN (R 4.4.0)
##	paletteer	* 1.6.0	2024-01-21	[1]	RSPM (R 4.4.0)
##	patchwork	1.2.0	2024-01-08	[1]	RSPM (R 4.4.0)
##	P phangorn	* 2.11.1	2023-01-23	[?]	RSPM
##	P phytools	* 2.3-0	2024-06-13	[?]	RSPM
##	P pillar	1.9.0	2023-03-22	[?]	CRAN (R 4.4.0)
##	P pkgbuild	1.4.4	2024-03-17	[?]	RSPM
##	P pkgconfig	2.0.3	2019-09-22	[?]	CRAN (R 4.4.0)

```

## P pkgload          1.4.0      2024-06-28 [?] RSPM
## P profvis          0.3.8      2023-05-02 [?] RSPM
## P promises         1.3.0      2024-04-05 [?] RSPM
## P purrr            * 1.0.2     2023-08-10 [?] CRAN (R 4.4.0)
## P quadprog         1.5-8      2019-11-20 [?] RSPM
## P R6               2.5.1      2021-08-19 [?] CRAN (R 4.4.0)
## P RColorBrewer     * 1.1-3     2022-04-03 [?] CRAN (R 4.4.0)
## P Rcpp            1.0.12      2024-01-09 [?] CRAN (R 4.4.0)
##   readr            * 2.1.5     2024-01-10 [1] RSPM (R 4.4.0)
##   readxl           * 1.4.3     2023-07-06 [1] RSPM (R 4.4.0)
## P rematch2        2.1.2      2020-05-01 [?] CRAN (R 4.4.0)
## P remotes         2.5.0      2024-03-17 [?] CRAN (R 4.4.0)
## P renv            1.0.7      2024-04-11 [1] RSPM (R 4.4.0)
## P rlang           1.1.4      2024-06-04 [?] RSPM
## P rmarkdown       2.27       2024-05-17 [?] RSPM
## P rprojroot       2.0.4      2023-11-05 [?] CRAN (R 4.4.0)
##   rstatix         0.7.2      2023-02-01 [1] RSPM (R 4.4.0)
## P rstudioapi      0.16.0     2024-03-24 [?] CRAN (R 4.4.0)
## P scales          1.3.0      2023-11-28 [?] CRAN (R 4.4.0)
## P scatterplot3d   0.3-44     2023-05-05 [?] RSPM
## P sessioninfo     1.2.2      2021-12-06 [?] RSPM
## P shiny           1.8.1.1    2024-04-02 [?] RSPM
## P stringi         1.8.4      2024-05-06 [?] RSPM
## P stringr         * 1.5.1     2023-11-14 [?] CRAN (R 4.4.0)
## P survival        * 3.7-0     2024-06-05 [?] CRAN (R 4.4.0)
##   survminer       * 0.4.9     2021-03-09 [1] RSPM (R 4.4.0)
##   survMisc        0.5.6      2022-04-07 [1] RSPM (R 4.4.0)
## P tibble          * 3.2.1     2023-03-20 [?] CRAN (R 4.4.0)
##   tidycmprsk      * 1.0.0     2023-10-30 [1] RSPM (R 4.4.0)
##   tidyr           * 1.3.1     2024-01-24 [1] RSPM (R 4.4.0)
##   tidyselect      1.2.1     2024-03-11 [1] RSPM (R 4.4.0)
##   tidytree        0.4.6     2023-12-12 [1] RSPM (R 4.4.0)
##   tidyverse       * 2.0.0     2023-02-22 [1] RSPM (R 4.4.0)
##   timechange      0.3.0     2024-01-18 [1] RSPM (R 4.4.0)
##   treeio         * 1.28.0    2024-04-30 [1] Bioconductor 3.19 (R 4.4.0)
##   tzdb           0.4.0     2023-05-12 [1] RSPM (R 4.4.0)
## P urlchecker      1.0.1      2021-11-30 [?] RSPM
## P usethis         * 2.2.3     2024-02-19 [?] RSPM
## P utf8            1.2.4      2023-10-22 [?] CRAN (R 4.4.0)
## P vctrs           0.6.5      2023-12-01 [?] CRAN (R 4.4.0)
##   vipor          0.4.7      2023-12-18 [1] RSPM (R 4.4.0)
##   vroom          1.6.5      2023-12-05 [1] RSPM (R 4.4.0)
## P withr           3.0.0      2024-01-16 [?] CRAN (R 4.4.0)
## P xfun            0.45       2024-06-16 [?] RSPM
## P xml2            1.3.6      2023-12-04 [?] CRAN (R 4.4.0)
## P xtable          1.8-4      2019-04-21 [?] RSPM
## P yaml            2.3.9      2024-07-05 [?] RSPM
##   yulab.utils     0.1.4      2024-01-28 [1] RSPM (R 4.4.0)
##   zoo             1.8-12     2023-04-13 [1] RSPM (R 4.4.0)
##
## [1] /Users/zahavahrojer/Desktop/Cornell/Hendry Lab/pseud-epi-growth/renv/library/macos/R-4.4/x86_64
## [2] /Users/zahavahrojer/Library/Caches/org.R-project.R/R/renv/sandbox/macos/R-4.4/x86_64-apple-darw
##
## P -- Loaded and on-disk path mismatch.

```


##
