Comparison of gsw by Population and Leaf Surface

Load Data

This merges the Cojo and CojoHQ population data and adds 16 to the plant ids in the Cojo group so that the plant ids are different. The Cojo data were taken on April 19, 2025 and the CojoHQ data were taken on April 17, 2025. This code also filters out gsw values that are greater than 0.05 or less than -0.05.

```
# Load the data
data <- read.csv("~/GitHub/CApoppy/data/processed/porometer_4pops.csv", skip = 1, header = TI

# Clean the data: remove NA values and ensure factor types
data_clean <- data %>%
  mutate(Date = as.Date(Date)) %>%  # Convert Date column to Date type
  filter(!is.na(gsw), !is.na(Population), !is.na(Plant), !is.na(`Top.or.Bottom`)) %>%
  filter(gsw < 0.05, gsw > -0.05) %>%
  mutate(
    Population = case_when(
      Population %in% c("Cojo", "CojoHQ") ~ "Cojo",
      TRUE ~ as.character(Population)
    ),
    Plant = case_when(
      Date == as.Date("2025-04-19") ~ Plant + 16,
      TRUE ~ Plant
    ),
    Population = factor(Population),
    TopBottom = factor(`Top.or.Bottom`)
  )

head(data_clean)
```

```
  Obs.     Time       Date     configName configAuthor remark     Population
1    1 12:10:22 2025-03-28 Petal_2025_low   glb and ks     NA Pt. Conception
2    2 12:10:38 2025-03-28 Petal_2025_low   glb and ks     NA Pt. Conception
3    1 12:21:15 2025-03-28 Petal_2025_low   glb and ks     NA Pt. Conception
4    2 12:21:34 2025-03-28 Petal_2025_low   glb and ks     NA Pt. Conception
5    3 12:31:42 2025-03-28 Petal_2025_low   glb and ks     NA Pt. Conception
6    4 12:31:57 2025-03-28 Petal_2025_low   glb and ks     NA Pt. Conception
  Plant Top.or.Bottom          gsw      gbw          gtw   E_apparent   VPcham
1     1           Top 1.950072e-03 1.901364 1.948074e-03 0.0173899660 1.237689
2     1        Bottom 2.471293e-03 1.897689 2.468079e-03 0.0236772920 1.248865
3    15           Top 4.742870e-06 1.897689 4.742860e-06 0.0000328845 1.269975
4    15        Bottom 6.559651e-03 1.884782 6.536900e-03 0.0468847520 1.268845
5     2           Top 6.458380e-05 1.892166 6.458160e-05 0.0005550320 1.255998
6     2        Bottom 3.990159e-03 1.903200 3.981811e-03 0.0363948050 1.253970
     VPref   VPleaf   VPDleaf    H2O_r    H2O_s H2O_leaf leaf_area leaf_width
1 1.236726 2.127955 0.8902664 12.19557 12.20507 20.98368 0.4417875        7.5
2 1.247551 2.205180 0.9563155 12.30220 12.31517 21.74520 0.4417875        7.5
3 1.269973 1.961881 0.6919060 12.52494 12.52496 19.34794 0.4417875        7.5
4 1.266219 1.984349 0.7155037 12.48830 12.51419 19.57144 0.4417875        7.5
5 1.255967 2.113328 0.8573304 12.38144 12.38175 20.83328 0.4417875        7.5
6 1.251956 2.165589 0.9116189 12.34242 12.36227 21.34847 0.4417875        7.5
   rh_s  rh_r  Tref Tmeas Tleaf  P_atm flow flow_s leak_pct Qamb  batt
1 56.32 56.28 18.94 18.43 18.43 101.41 79.9   79.8      0.1  164 4.141
2 56.76 56.70 18.96 19.00 19.00 101.41 79.7   79.2      0.6   20 4.134
3 57.45 57.45 19.04 17.14 17.14 101.40 79.7   79.5      0.2  180 4.132
4 57.64 57.52 18.97 17.32 17.32 101.39 79.0   80.0     -1.3   80 4.123
5 55.77 55.77 19.34 18.32 18.32 101.44 79.4   79.9     -0.6 1304 4.122
6 55.68 55.59 19.34 18.71 18.71 101.44 80.0   79.6      0.5  222 4.118
  match_time match_date rh_adj type gsw1sec gsw2sec   gsw4sec flr1sec flr2sec
1   12:10:06 2025-03-28  -0.57    1   0.000  -0.001    -0.003  -0.017  -0.033
2   12:10:06 2025-03-28  -0.57    1   0.000   0.000 -9999.000  -0.016  -0.026
3   12:19:42 2025-03-28  -0.44    1  -0.001  -0.001 -9999.000  -0.013  -0.024
4   12:19:42 2025-03-28  -0.44    1   0.000   0.000     0.001  -0.009  -0.023
5   12:31:32 2025-03-28  -0.45    1  -0.001   0.001 -9999.000  -0.001  -0.008
6   12:31:32 2025-03-28  -0.45    1   0.000   0.001 -9999.000  -0.007  -0.008
    flr4sec auto flow_set gsw_limit gsw_period       aw Bla     Blb Blc Bld
1    -0.079    1       75     0.001          2 0.058905   0 0.02923   0   0
2 -9999.000    1       75     0.001          2 0.058905   0 0.02923   0   0
3 -9999.000    1       75     0.001          2 0.058905   0 0.02923   0   0
4    -0.052    1       75     0.001          2 0.058905   0 0.02923   0   0
5 -9999.000    1       75     0.001          2 0.058905   0 0.02923   0   0
6 -9999.000    1       75     0.001          2 0.058905   0 0.02923   0   0
      Ble  chamber   v_humA   v_humB v_flowIn v_flowOut   v_temp     v_irt
```

```
1 -6.8e-05 standard 2.490726 2.529711 1.062626  0.757644 0.347634 -0.004699
2 -6.8e-05 standard 2.491302 2.530333 1.060964  0.756269 0.347351  0.001472
3 -6.8e-05 standard 2.492319 2.531106 1.061440  0.757073 0.346308 -0.019909
4 -6.8e-05 standard 2.492435 2.531398 1.056507  0.758120 0.347254 -0.017229
5 -6.8e-05 standard 2.489929 2.528647 1.059145  0.757752 0.342175 -0.010379
6 -6.8e-05 standard 2.489684 2.528519 1.063212  0.757273 0.342179 -0.006039
    v_pres    v_par      v_F    i_LED    b_rhr    m_rhr span_rhr    b_rhs
1 0.049523 0.251111 48.05231 0.000142 2.400461 -5.3e-05        1 2.435166
2 0.050987 0.124378 47.56844 0.000135 2.400461 -5.3e-05        1 2.435166
3 0.140822 0.264602 64.41235 0.000134 2.400461 -5.3e-05        1 2.435166
4 0.142180 0.177699 63.91239 0.000133 2.400461 -5.3e-05        1 2.435166
5 0.186324 1.250014 58.36594 0.000135 2.400461 -5.3e-05        1 2.435166
6 0.187256 0.301427 58.24292 0.000134 2.400461 -5.3e-05        1 2.435166
     m_rhs span_rhs z_flowIn z_flowOut z_quantum z_flr flashId lciSerNum
1 -5.8e-05        1 0.601058  0.603298  0.107219     0      NA PFA-00225
2 -5.8e-05        1 0.601058  0.603298  0.107219     0      NA PFA-00225
3 -5.8e-05        1 0.601058  0.603298  0.107219     0      NA PFA-00225
4 -5.8e-05        1 0.601058  0.603298  0.107219     0      NA PFA-00225
5 -5.8e-05        1 0.601058  0.603298  0.107219     0      NA PFA-00225
6 -5.8e-05        1 0.601058  0.603298  0.107219     0      NA PFA-00225
  lcpSerNum lcfSerNum lcrhSerNum version          configUpdatedAt TopBottom
1 PSA-00237        NA  RHS-00303   3.0.0 2025-03-08T00:27:09.674Z       Top
2 PSA-00237        NA  RHS-00303   3.0.0 2025-03-08T00:27:09.674Z    Bottom
3 PSA-00237        NA  RHS-00303   3.0.0 2025-03-08T00:27:09.674Z       Top
4 PSA-00237        NA  RHS-00303   3.0.0 2025-03-08T00:27:09.674Z    Bottom
5 PSA-00237        NA  RHS-00303   3.0.0 2025-03-08T00:27:09.674Z       Top
6 PSA-00237        NA  RHS-00303   3.0.0 2025-03-08T00:27:09.674Z    Bottom
```

Summary Statistics

```r
data_clean %>%
  group_by(Population, TopBottom) %>%
  summarise(
    mean_gsw = mean(gsw),
    sd_gsw = sd(gsw),
    n = n(),
    .groups = 'drop'
  )
```

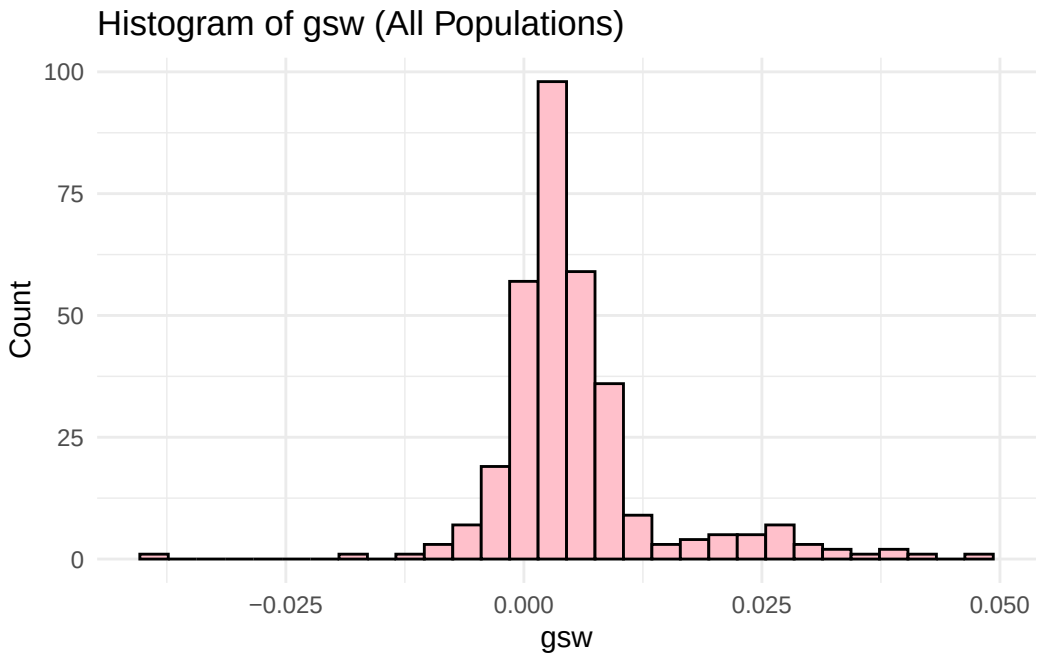
```
# A tibble: 8 x 5
```

```
  Population     TopBottom mean_gsw  sd_gsw     n
  <fct>          <fct>        <dbl>   <dbl> <int>
1 Cojo           Bottom     0.00559 0.00468    63
2 Cojo           Top        0.00171 0.00256    64
3 Percos         Bottom     0.00607 0.00735    69
4 Percos         Top        0.00418 0.0109     71
5 Perry          Bottom     0.0157  0.0156     13
6 Perry          Top        0.00877 0.0116     13
7 Pt. Conception Bottom     0.00731 0.00878    16
8 Pt. Conception Top        0.00997 0.0127     16
```

Histogram of gsw by Population and Leaf Surface

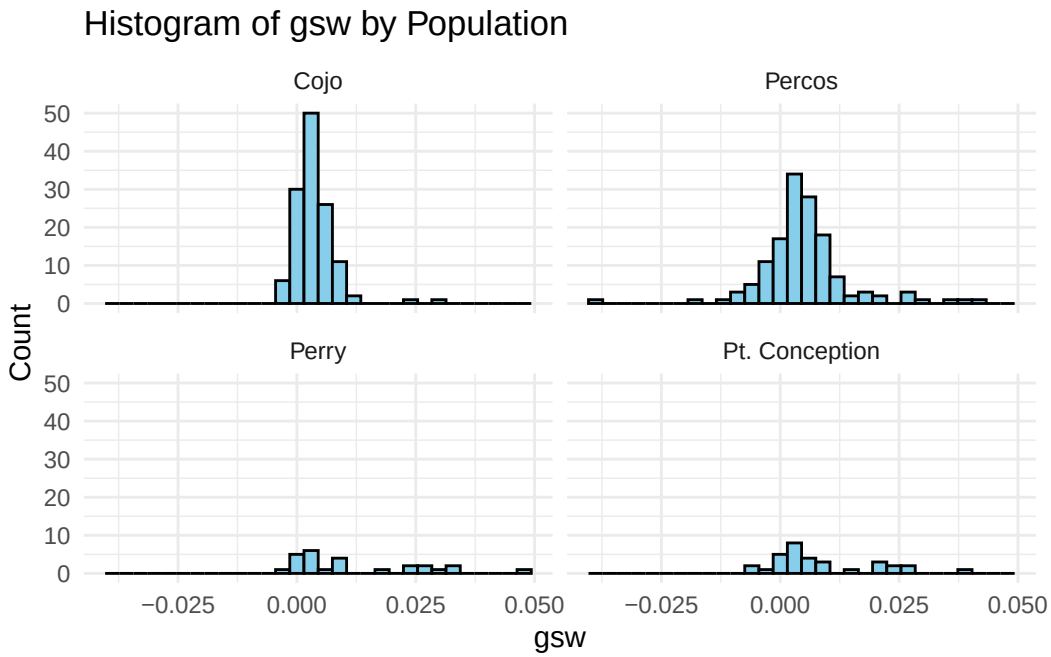
```r
# Overall histogram (all populations combined)
hist_overall <- ggplot(data_clean, aes(x = gsw)) +
  geom_histogram( color = "black", fill = "pink") +
  labs(title = "Histogram of gsw (All Populations)", x = "gsw", y = "Count") +
  theme_minimal()

# Histograms per population
hist_by_population <- ggplot(data_clean, aes(x = gsw)) +
  geom_histogram(color = "black", fill = "skyblue") +
  labs(title = "Histogram of gsw by Population", x = "gsw", y = "Count") +
  facet_wrap(~ Population) +
  theme_minimal()

# Show the overall histogram
print(hist_overall)
```

```
`stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```



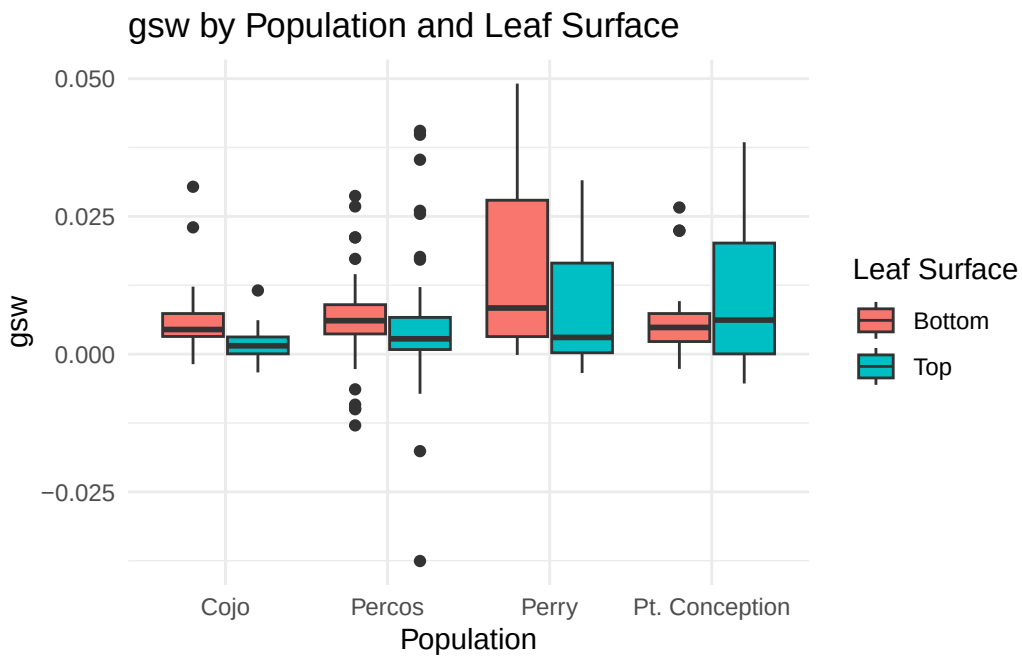

```
# Show histograms for each population
print(hist_by_population)
```

```
`stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```



Boxplot of gsw by Population and Leaf Surface

```
ggplot(data_clean, aes(x = Population, y = gsw, fill = TopBottom)) +
  geom_boxplot(position = position_dodge(width = 0.8)) +
  labs(
    title = "gsw by Population and Leaf Surface",
    x = "Population", y = "gsw", fill = "Leaf Surface"
  ) +
  theme_minimal()
```



Two-Way ANOVA

```
anova2 <- aov(gsw ~ Population * TopBottom, data = data_clean)
summary(anova2)
```

```
                     Df   Sum Sq   Mean Sq F value   Pr(>F)
Population            3 0.001951 0.0006503   9.437 5.45e-06 ***
TopBottom             1 0.000557 0.0005566   8.077  0.00477 **
Population:TopBottom  3 0.000412 0.0001372   1.991  0.11529
Residuals           317 0.021845 0.0000689
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Post-Hoc Comparison (Tukey HSD)

```
# Tukey post-hoc for interaction effects
TukeyHSD(anova2)
```

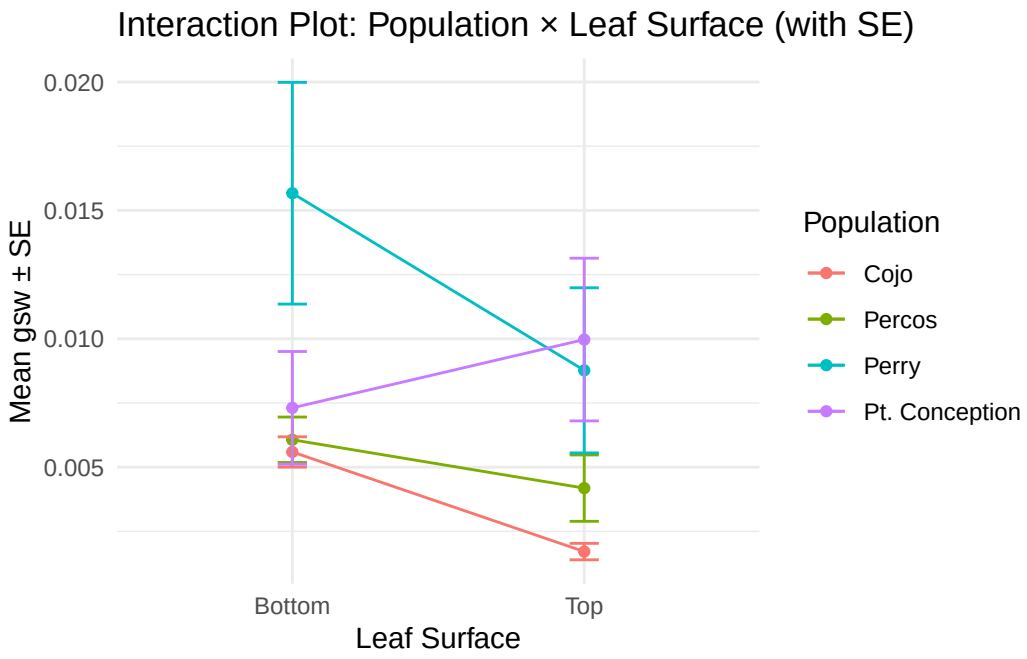
```
  Tukey multiple comparisons of means
    95% family-wise confidence level

Fit: aov(formula = gsw ~ Population * TopBottom, data = data_clean)

$Population
                              diff           lwr         upr     p adj
Percos-Cojo            0.001474540 -0.0011527727 0.004101853 0.4694804
Perry-Cojo             0.008583589  0.0039685092 0.013198668 0.0000143
Pt. Conception-Cojo    0.005002566  0.0007618057 0.009243326 0.0133201
Perry-Percos           0.007109049  0.0025305262 0.011687572 0.0004383
Pt. Conception-Percos  0.003528026 -0.0006729213 0.007728973 0.1341910
Pt. Conception-Perry  -0.003581023 -0.0092417777 0.002079732 0.3610922

$TopBottom
                   diff          lwr           upr    p adj
Top-Bottom -0.002617487 -0.004429505 -0.0008054684 0.004773

$`Population:TopBottom`
                                                 diff          lwr
Percos:Bottom-Cojo:Bottom                  0.000474295 -0.003939612
Perry:Bottom-Cojo:Bottom                   0.010077624  0.002361559
Pt. Conception:Bottom-Cojo:Bottom          0.001716645 -0.005374467
Cojo:Top-Cojo:Bottom                      -0.003880277 -0.008375722
Percos:Top-Cojo:Bottom                    -0.001409139 -0.005793275
Perry:Top-Cojo:Bottom                      0.003178723 -0.004537342
Pt. Conception:Top-Cojo:Bottom             0.004377657 -0.002713455
Perry:Bottom-Percos:Bottom                 0.009603329  0.001944864
Pt. Conception:Bottom-Percos:Bottom        0.001242350 -0.005786042
Cojo:Top-Percos:Bottom                    -0.004354572 -0.008750417
Percos:Top-Percos:Bottom                  -0.001883434 -0.006165382
Perry:Top-Percos:Bottom                    0.002704428 -0.004954037
Pt. Conception:Top-Percos:Bottom           0.003903362 -0.003125030
Pt. Conception:Bottom-Perry:Bottom        -0.008360979 -0.017818958
Cojo:Top-Perry:Bottom                     -0.013957901 -0.021663648
Percos:Top-Perry:Bottom                   -0.011486763 -0.019128108
Perry:Top-Perry:Bottom                    -0.006898900 -0.016834048
Pt. Conception:Top-Perry:Bottom           -0.005699967 -0.015157946
Cojo:Top-Pt. Conception:Bottom            -0.005596922 -0.012676804
Percos:Top-Pt. Conception:Bottom          -0.003125784 -0.010135517
Perry:Top-Pt. Conception:Bottom            0.001462079 -0.007995901
Pt. Conception:Top-Pt. Conception:Bottom   0.002661012 -0.006294410
Percos:Top-Cojo:Top                        0.002471138 -0.001894812
```

```
Perry:Top-Cojo:Top                           0.007059001 -0.000646746
Pt. Conception:Top-Cojo:Top                  0.008257934  0.001178052
Perry:Top-Percos:Top                         0.004587863 -0.003053482
Pt. Conception:Top-Percos:Top                0.005786796 -0.001222937
Pt. Conception:Top-Perry:Top                 0.001198933 -0.008259046
                                                      upr     p adj
Percos:Bottom-Cojo:Bottom                    4.888202e-03 0.9999801
Perry:Bottom-Cojo:Bottom                     1.779369e-02 0.0021160
Pt. Conception:Bottom-Cojo:Bottom            8.807756e-03 0.9957397
Cojo:Top-Cojo:Bottom                         6.151671e-04 0.1478267
Percos:Top-Cojo:Bottom                       2.974996e-03 0.9768963
Perry:Top-Cojo:Bottom                        1.089479e-02 0.9137033
Pt. Conception:Top-Cojo:Bottom               1.146877e-02 0.5631611
Perry:Bottom-Percos:Bottom                   1.726179e-02 0.0038694
Pt. Conception:Bottom-Percos:Bottom          8.270741e-03 0.9994333
Cojo:Top-Percos:Bottom                       4.127225e-05 0.0542424
Percos:Top-Percos:Bottom                     2.398513e-03 0.8819637
Perry:Top-Percos:Bottom                      1.036289e-02 0.9610858
Pt. Conception:Top-Percos:Bottom             1.093175e-02 0.6908201
Pt. Conception:Bottom-Perry:Bottom           1.097000e-03 0.1271703
Cojo:Top-Perry:Bottom                       -6.252154e-03 0.0000019
Percos:Top-Perry:Bottom                     -3.845418e-03 0.0001737
Perry:Top-Perry:Bottom                       3.036248e-03 0.4050588
Pt. Conception:Top-Perry:Bottom              3.758012e-03 0.5939728
Cojo:Top-Pt. Conception:Bottom               1.482960e-03 0.2390252
Percos:Top-Pt. Conception:Bottom             3.883949e-03 0.8742460
Perry:Top-Pt. Conception:Bottom              1.092006e-02 0.9997669
Pt. Conception:Top-Pt. Conception:Bottom     1.161643e-02 0.9853004
Percos:Top-Cojo:Top                          6.837088e-03 0.6695655
Perry:Top-Cojo:Top                           1.476475e-02 0.0998472
Pt. Conception:Top-Cojo:Top                  1.533782e-02 0.0100692
Perry:Top-Percos:Top                         1.222921e-02 0.5987064
Pt. Conception:Top-Percos:Top                1.279653e-02 0.1912442
Pt. Conception:Top-Perry:Top                 1.065691e-02 0.9999387
```

Interaction Plot

```
gginteraction <- ggplot(data_clean, aes(x = TopBottom, y = gsw, color = Population, group = I
  stat_summary(fun = mean, geom = "line") +
  stat_summary(fun = mean, geom = "point") +
  labs(title = "Interaction Plot: Population × Leaf Surface", x = "Leaf Surface", y = "Mean g
```

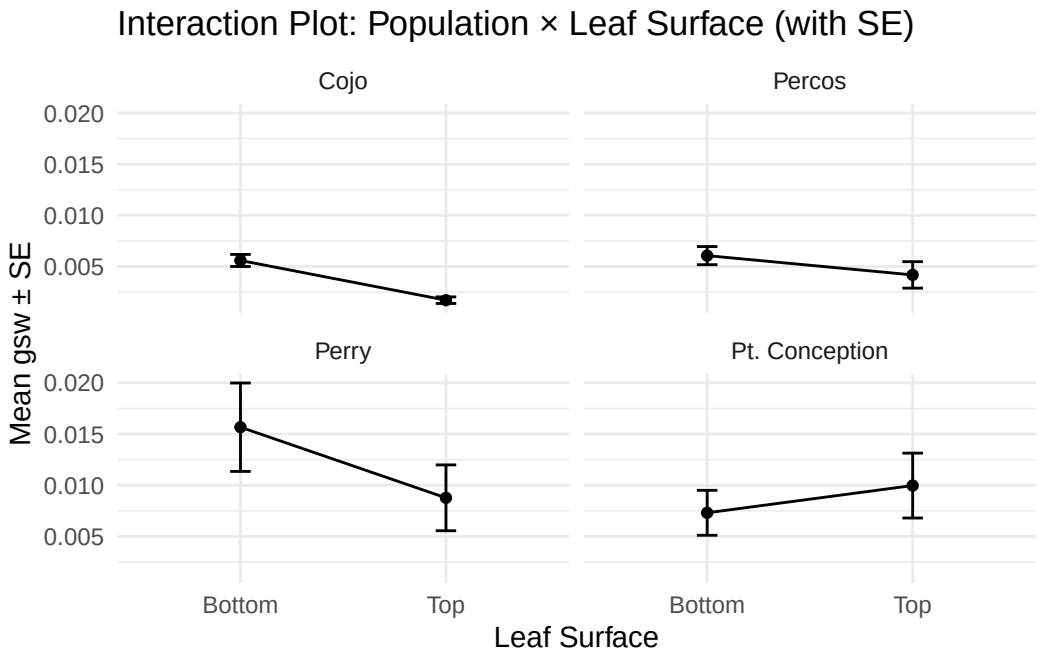
```
  stat_summary(fun.data = mean_se, geom = "errorbar", width = 0.1) +
  labs(
    title = "Interaction Plot: Population × Leaf Surface (with SE)",
    x = "Leaf Surface",
    y = "Mean gsw ± SE"
  ) +
  theme_minimal()

gginteraction
```



Separate figures for each population

```
gginteraction2 <- ggplot(data_clean, aes(x = TopBottom, y = gsw, group = Population)) +
  stat_summary(fun = mean, geom = "line") +
  stat_summary(fun = mean, geom = "point") +
  stat_summary(fun.data = mean_se, geom = "errorbar", width = 0.1) +
  labs(
    title = "Interaction Plot: Population × Leaf Surface (with SE)",
    x = "Leaf Surface",
    y = "Mean gsw ± SE"
  ) +
  facet_wrap(~ Population) +  # Creates one plot per population
```

```
  theme_minimal()

gginteraction2
```




```
library(broom)

library(dplyr)
library(tidyr)
library(purrr)
library(broom)



t_test_results <- data_clean %>%
  filter(TopBottom %in% c("Top", "Bottom")) %>%
  select(Population, Plant, TopBottom, gsw) %>%
  pivot_wider(names_from = TopBottom, values_from = gsw) %>%
  filter(!is.na(Top) & !is.na(Bottom)) %>%
  group_by(Population) %>%
  summarise(
    n = n(),  # number of plants with both Top and Bottom values
    t_test = list(t.test(Top, Bottom, paired = TRUE)),
```

```
    .groups = "drop"
  ) %>%
  mutate(tidy_result = map(t_test, tidy)) %>%
  unnest(tidy_result) %>%
  mutate(
    sig = case_when(
      p.value < 0.001 ~ "***",
      p.value < 0.01 ~ "**",
      p.value < 0.05 ~ "*",
      TRUE ~ "n.s."
    )
  ) %>%
  select(Population, n, estimate, statistic, p.value, sig, conf.low, conf.high)

print(t_test_results)
```

```
# A tibble: 4 x 8
  Population         n estimate statistic      p.value sig   conf.low conf.high
  <fct>          <int>    <dbl>     <dbl>        <dbl> <chr>    <dbl>     <dbl>
1 Cojo              62 -0.00392    -6.23  0.0000000478 ***   -0.00518 -0.00266
2 Percos            68 -0.00142    -1.39  0.170        n.s.  -0.00347  0.000626
3 Perry             13 -0.00690    -2.41  0.0331       *     -0.0131  -0.000655
4 Pt. Conception    16  0.00266     0.823 0.423        n.s.  -0.00423  0.00955
```