Trabalho final - planejamento de experimentos

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Contents

Importação da base de dados

```
(dados <- readr::read_table("Tree_throughfall.txt")[,1:11])
```

```
## # A tibble: 2,100 x 11
##    Date  Pluviometer  Plot Distance  Tree    sp  tree number rainfall rainfall_1
##    <chr> <chr>       <dbl>    <dbl> <dbl> <dbl> <dbl>  <dbl>    <dbl>      <dbl>
##  1 26/0~ P58             1      100     1     5  5.97      2     3.52       2.42
##  2 26/0~ P59             1      100     1     5  5.97      2     2.4        3.54
##  3 26/0~ P60             1      100     1     5  5.97      2     2.64       3.3
##  4 26/0~ P61             1      250     1     5  5.97      2     1.6        4.34
##  5 26/0~ P62             1      250     1     5  5.97      2     2          3.94
##  6 26/0~ P63             1      250     1     5  5.97      2     2.4        3.54
##  7 26/0~ P64             1      100     2     6  5.97      2     2.4        3.52
##  8 26/0~ P65             1      100     2     6  5.97      2     3.04       2.88
##  9 26/0~ P66             1      100     2     6  5.97      2     4          1.92
## 10 26/0~ P67             1      250     2     6  5.97      2     3.84       2.08
## # ... with 2,090 more rows, and 1 more variable: size <dbl>
```

Tratamento

```
colnames(dados) <- c("date", "pluviometro", "plot", "distance", "tree_sp", "tree_number", "rainfall", "
```

```
dados <- dados %>%
  transform(date = as.Date(date, format = "%d/%m/%Y"),
         plot = as.factor(plot),
         rainfall_size = as.factor(rainfall_size),
         tree_sp = as.factor(tree_sp),
         tree_number = as.factor(tree_number),
         distance = as.factor(distance))

glimpse(dados)
```

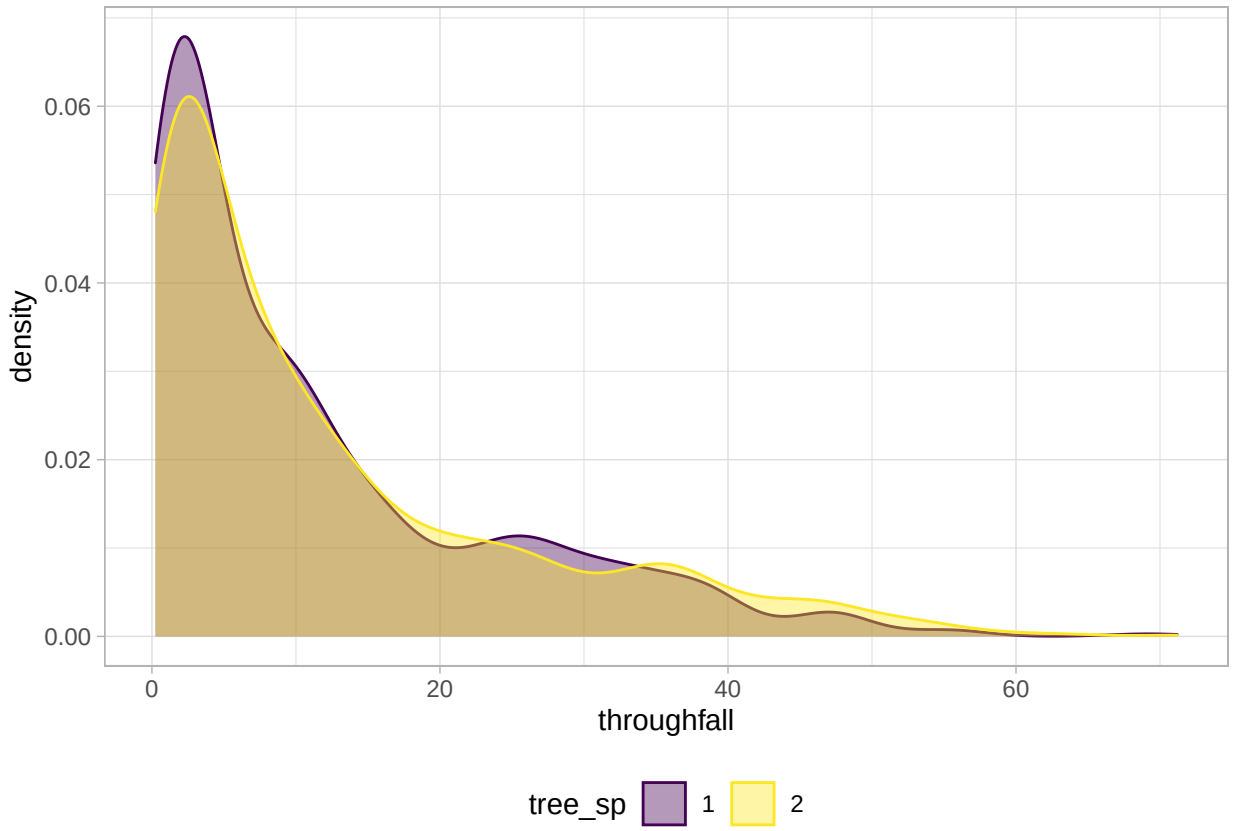
```
## Rows: 2,100
## Columns: 11
## $ date          <date> 2013-05-26, 2013-05-26, 2013-05-26, 2013-05-26, 2013-05~
## $ pluviometro   <chr> "P58", "P59", "P60", "P61", "P62", "P63", "P64", "P65", ~
## $ plot          <fct> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,~
## $ distance      <fct> 100, 100, 100, 250, 250, 250, 100, 100, 100, 250, 250, 1~
## $ tree_sp       <fct> 1, 1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 1, 1, 1, 1, 1, 2, 2, 2,~
## $ tree_number   <fct> 5, 5, 5, 5, 5, 5, 6, 6, 6, 6, 6, 6, 6, 6, 6, 6, 5, 5, 5,~
## $ rainfall      <dbl> 5.97, 5.97, 5.97, 5.97, 5.97, 5.97, 5.97, 5.97, 5.97, 5.~
## $ rainfall_size <fct> 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2,~
## $ throughfall   <dbl> 3.52, 2.40, 2.64, 1.60, 2.00, 2.40, 2.40, 3.04, 4.00, 3.~
## $ interception  <dbl> 2.42, 3.54, 3.30, 4.34, 3.94, 3.54, 3.52, 2.88, 1.92, 2.~
## $ lai           <dbl> 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.33, 0.33, 0.33, 0.~
```

Descritiva

Gráficos

Desidade da throughfall por tree_sp

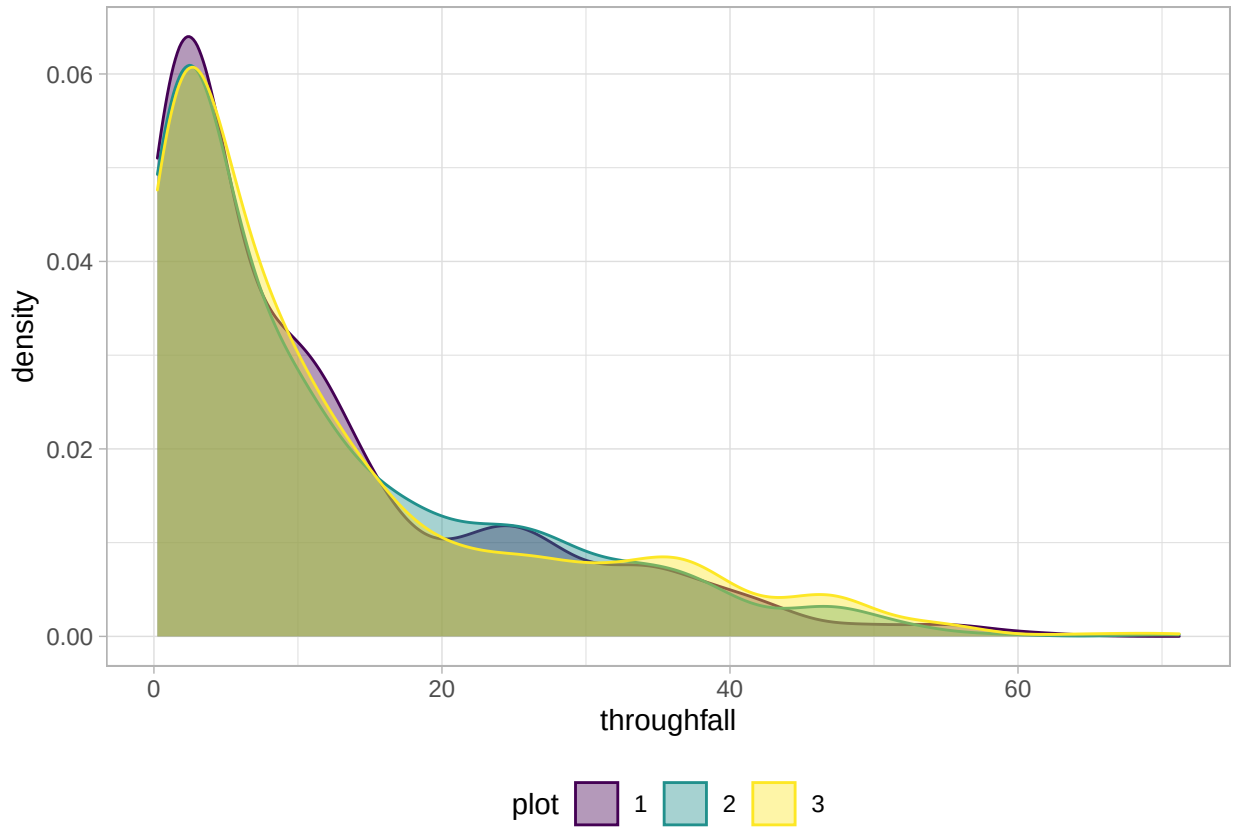
```
dados %>%
  ggplot(aes(throughfall)) +
  geom_density(aes(color = tree_sp, fill = tree_sp), alpha = 0.4) +
  scale_fill_viridis_d() +
  scale_color_viridis_d() +
  theme(legend.position = "bottom")
```



Podemos observar que temos uma densidade maior para a espécie 1 quando estamos tratando de valores menores de throughfall enquanto a espécie 2 se sobressai na maior parte dos valores acima de 20 (maiores). Desse modo podemos supor que a espécie 2 acaba tendo um melhor desempenho tendo como objetivo uma maior quantidade de água que cai das árvores (throughfall). Além disso vemos que a densidade de ambas as espécies é extremamente similar, o que indica que podemos ter resultados próximos para throughfall independente da espécie escolhida para fazer a sombra para a plantação de café.

Desidade da throughfall por plot

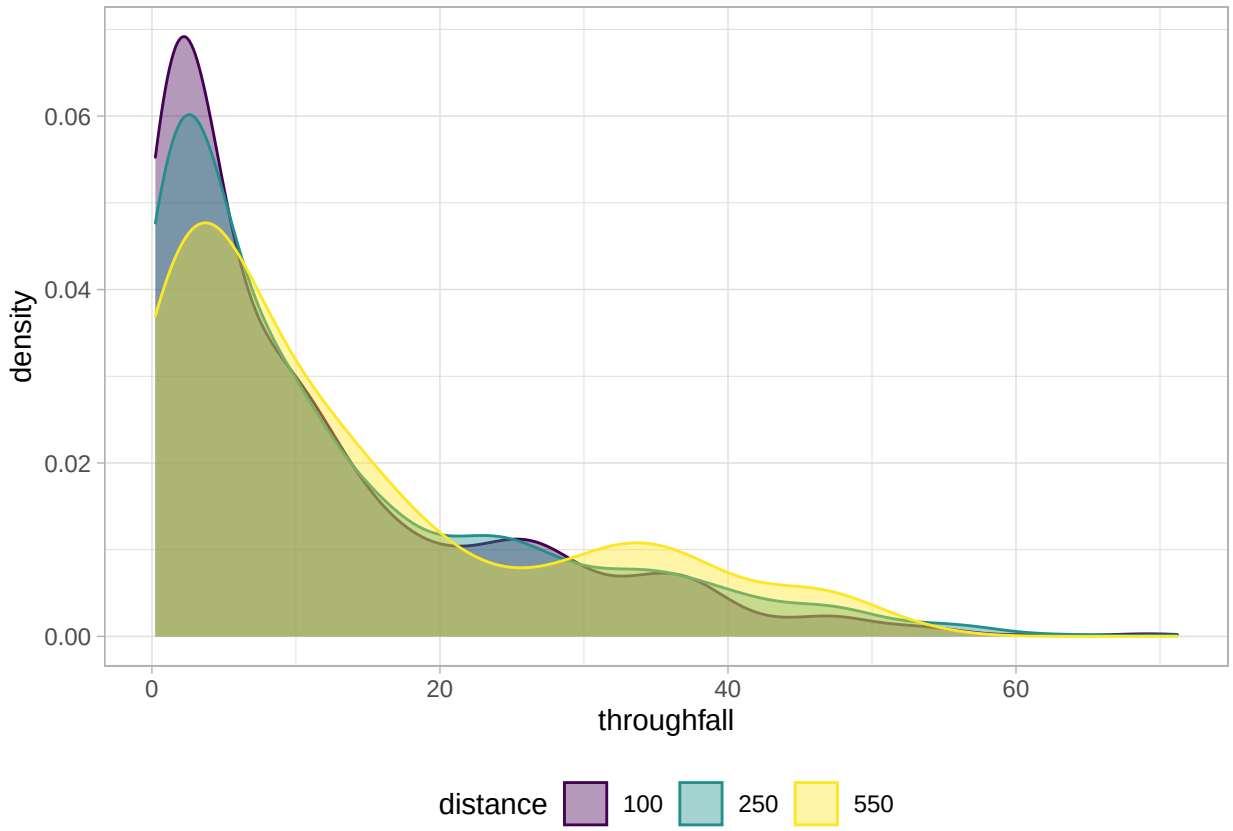
```
dados %>%
  ggplot(aes(throughfall)) +
  geom_density(aes(color = plot, fill = plot), alpha = 0.4) +
  scale_fill_viridis_d() +
  scale_color_viridis_d() +
  theme(legend.position = "bottom")
```



Novamente podemos ver que temos densidades bastante parecidas para todos níveis da variável `plot` com o nível 1 se sobressaindo para resultados menores de throughfall, nível 2 se sobressaindo para resultados intermediários de throughfall e nível 3 apresentando maior densidade para maiores resultados de throughfall.

Desidade da throughfall por distance

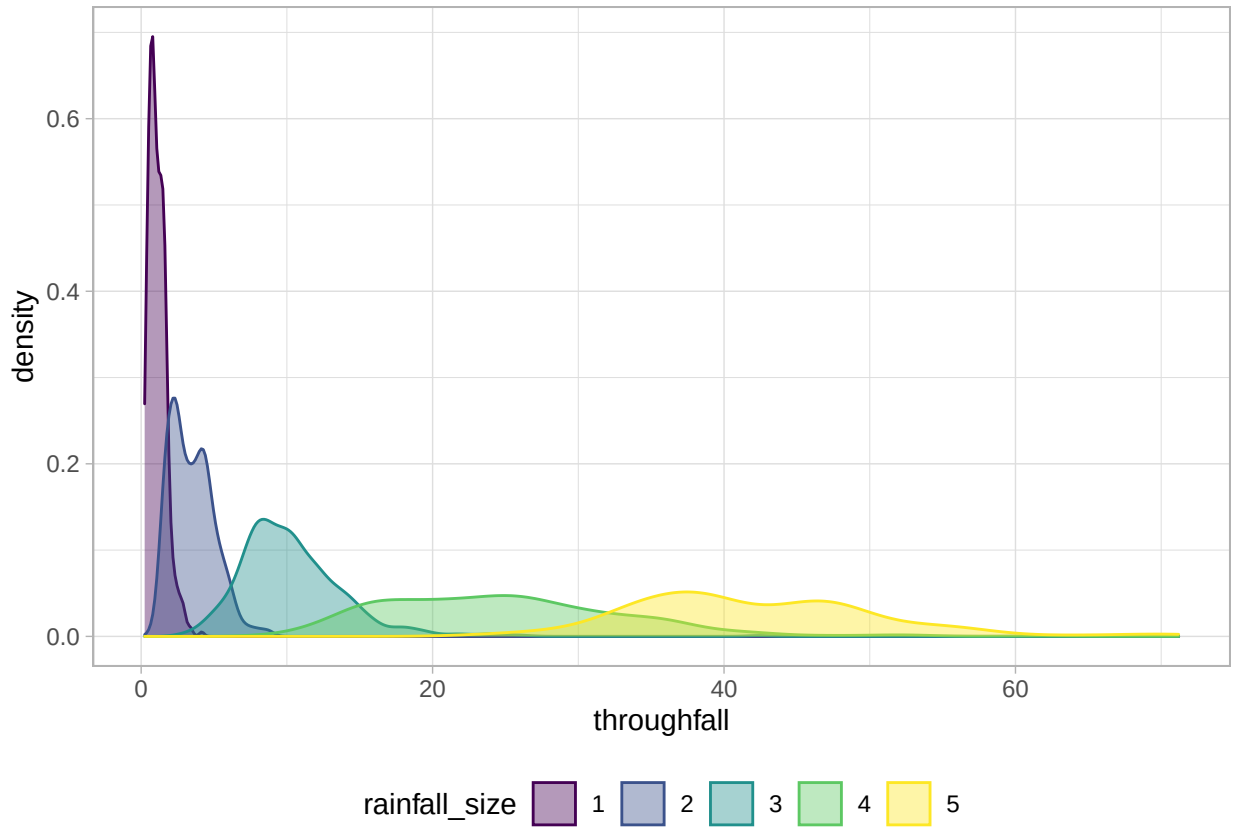
```
dados %>%
  ggplot(aes(throughfall)) +
  geom_density(aes(color = distance, fill = distance), alpha = 0.4) +
  scale_fill_viridis_d() +
  scale_color_viridis_d() +
  theme(legend.position = "bottom")
```



No gráfico acima podemos concluir que quanto maior a distância menor a densidade para resultados pequenos (0-10) de throughfall. Além disso, a medida que esses resultados vão melhorando vemos um melhor desempenho para as distâncias maiores (250 e 550).

Desidade da throughfall por rainfall_size

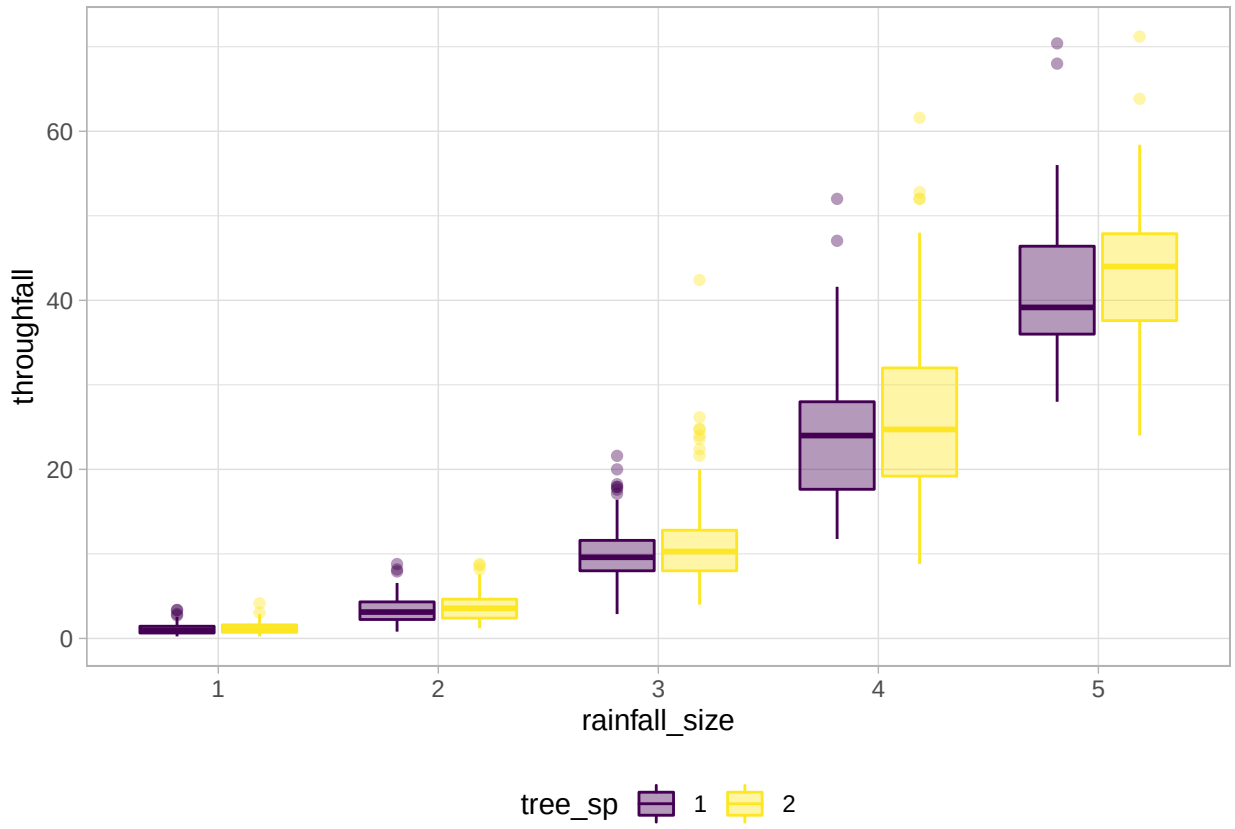
```
dados %>%
  ggplot(aes(throughfall)) +
  geom_density(aes(color = rainfall_size, fill = rainfall_size), alpha = 0.4) +
  scale_fill_viridis_d() +
  scale_color_viridis_d() +
  theme(legend.position = "bottom")
```



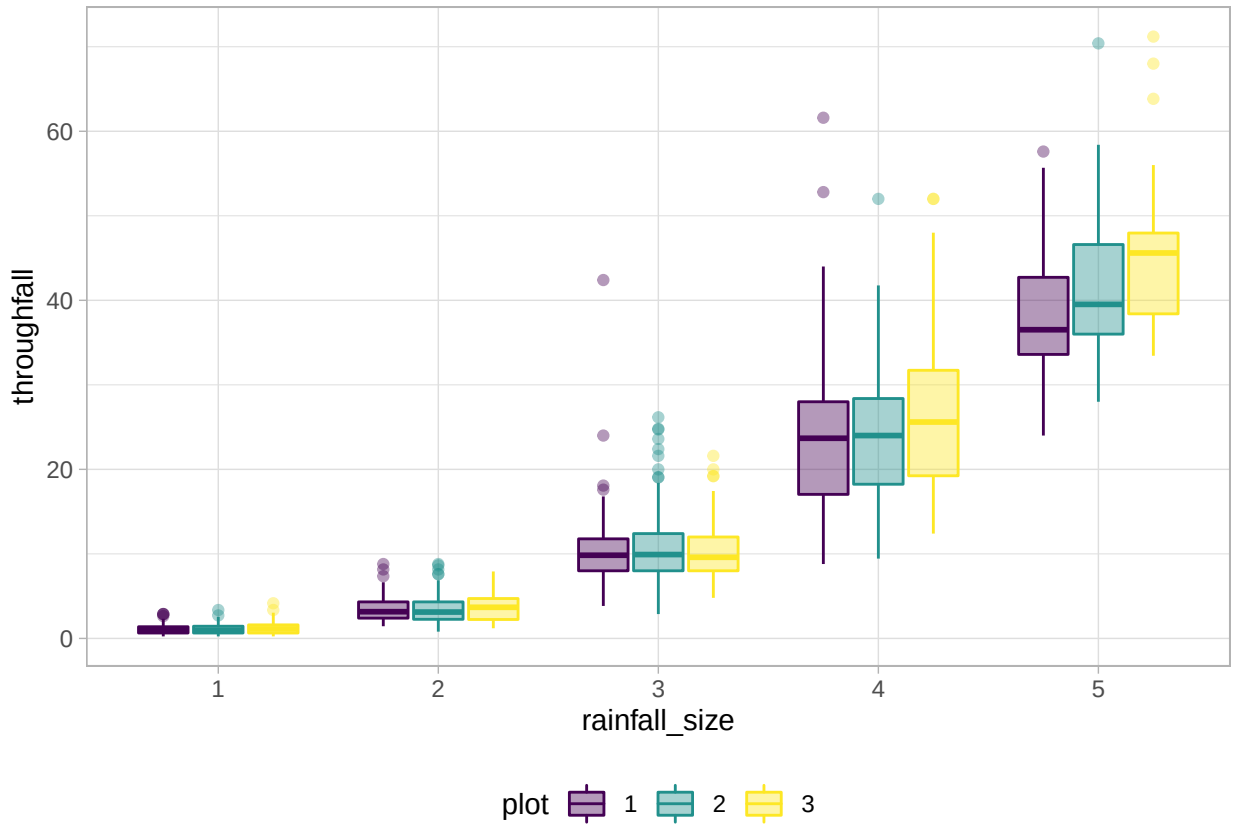
Para a variável `rainfall_size` é visível que existe uma distinção clara entre os níveis possíveis, pois é fácil perceber que cada uma das categorias temos intervalos de throughfall muito bem definidos. Ademais, podemos ver que as varáveis tem uma relação direta, para níveis maiores de rainfall_size temos mariores valores de throughfall.

Boxplot

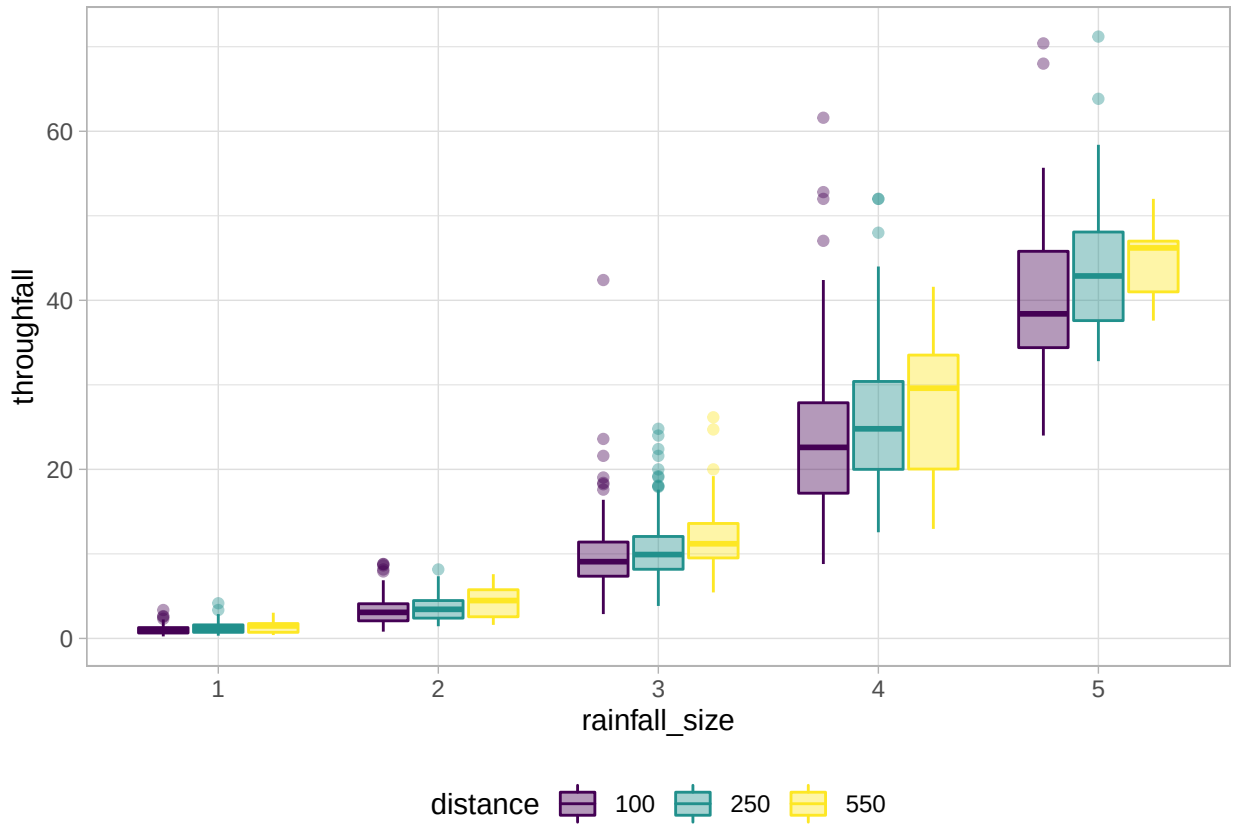
```
dados %>%
  ggplot(aes(rainfall_size, throughfall, color = tree_sp, fill = tree_sp)) +
  geom_boxplot(alpha = 0.4) +
  scale_fill_viridis_d() +
  scale_color_viridis_d() +
  theme(legend.position = "bottom")
```



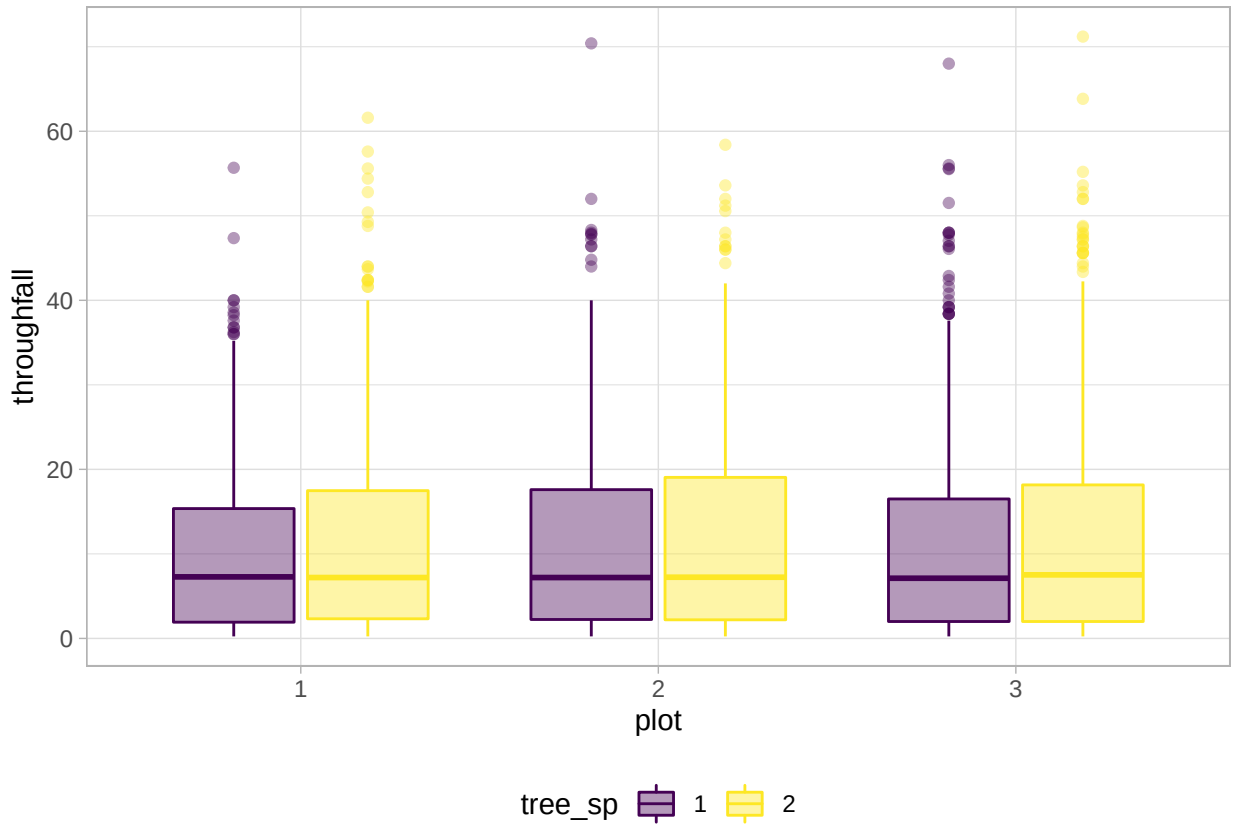

```
dados %>%
  ggplot(aes(rainfall_size, throughfall, color = plot, fill = plot)) +
  geom_boxplot(alpha = 0.4) +
  scale_fill_viridis_d() +
  scale_color_viridis_d() +
  theme(legend.position = "bottom")
```



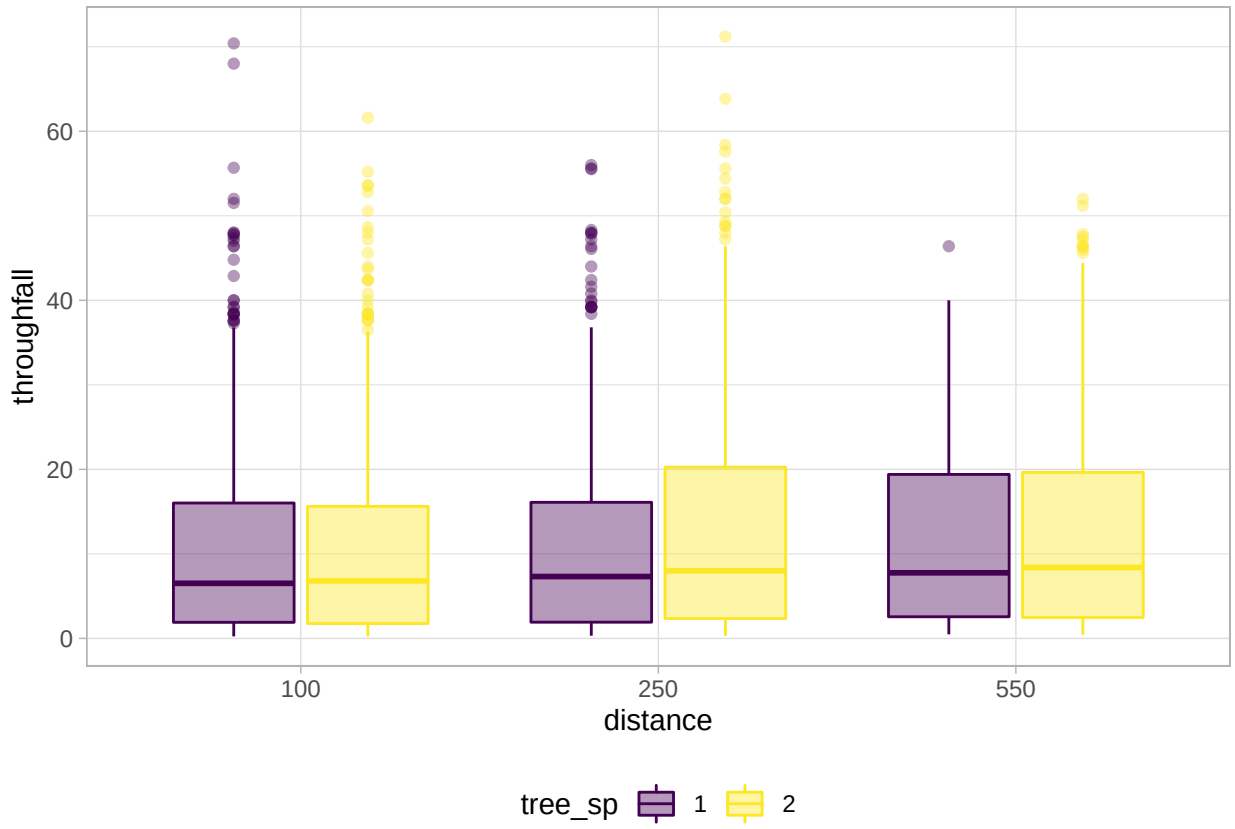

```
dados %>%
  ggplot(aes(rainfall_size, throughfall, color = distance, fill = distance)) +
  geom_boxplot(alpha = 0.4) +
  scale_fill_viridis_d() +
  scale_color_viridis_d() +
  theme(legend.position = "bottom")
```



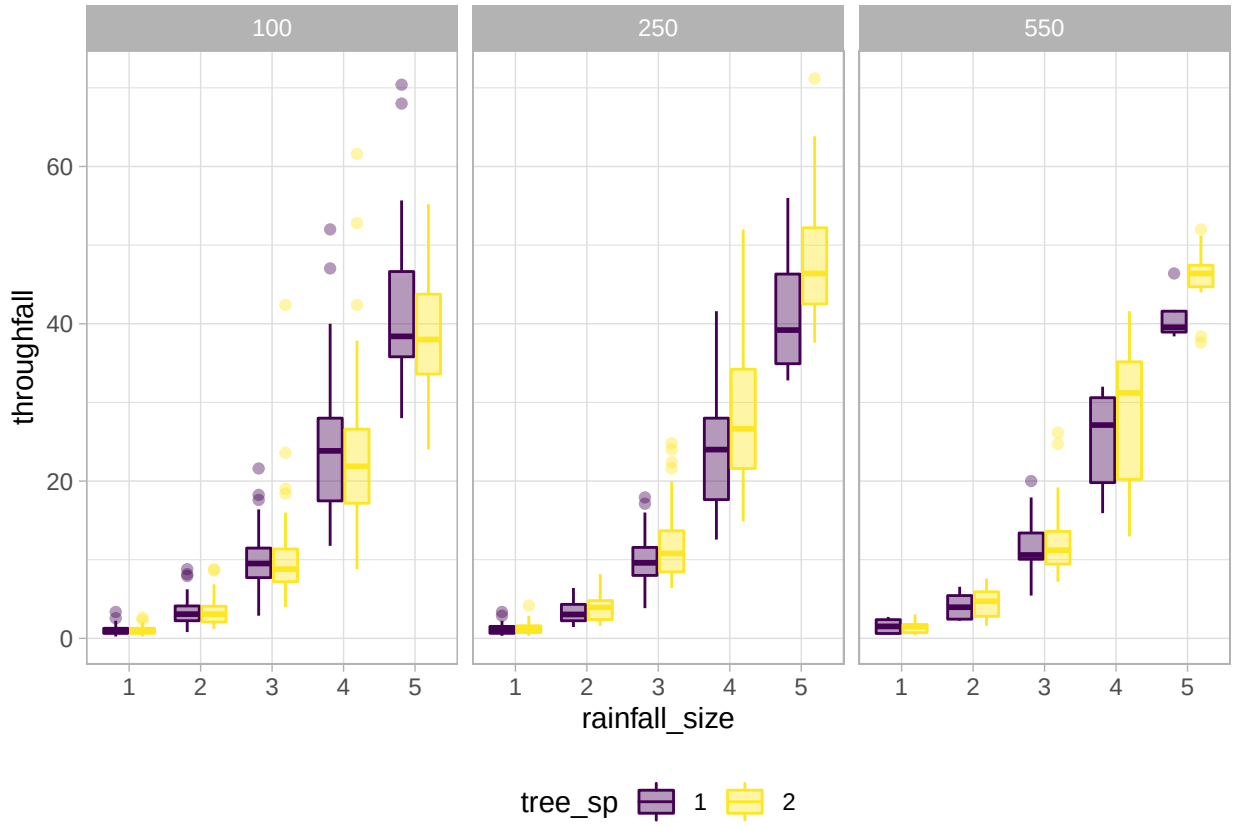

```
dados %>%
  ggplot(aes(plot, throughfall, color = tree_sp, fill = tree_sp)) +
  geom_boxplot(alpha = 0.4) +
  scale_fill_viridis_d() +
  scale_color_viridis_d() +
  theme(legend.position = "bottom")
```



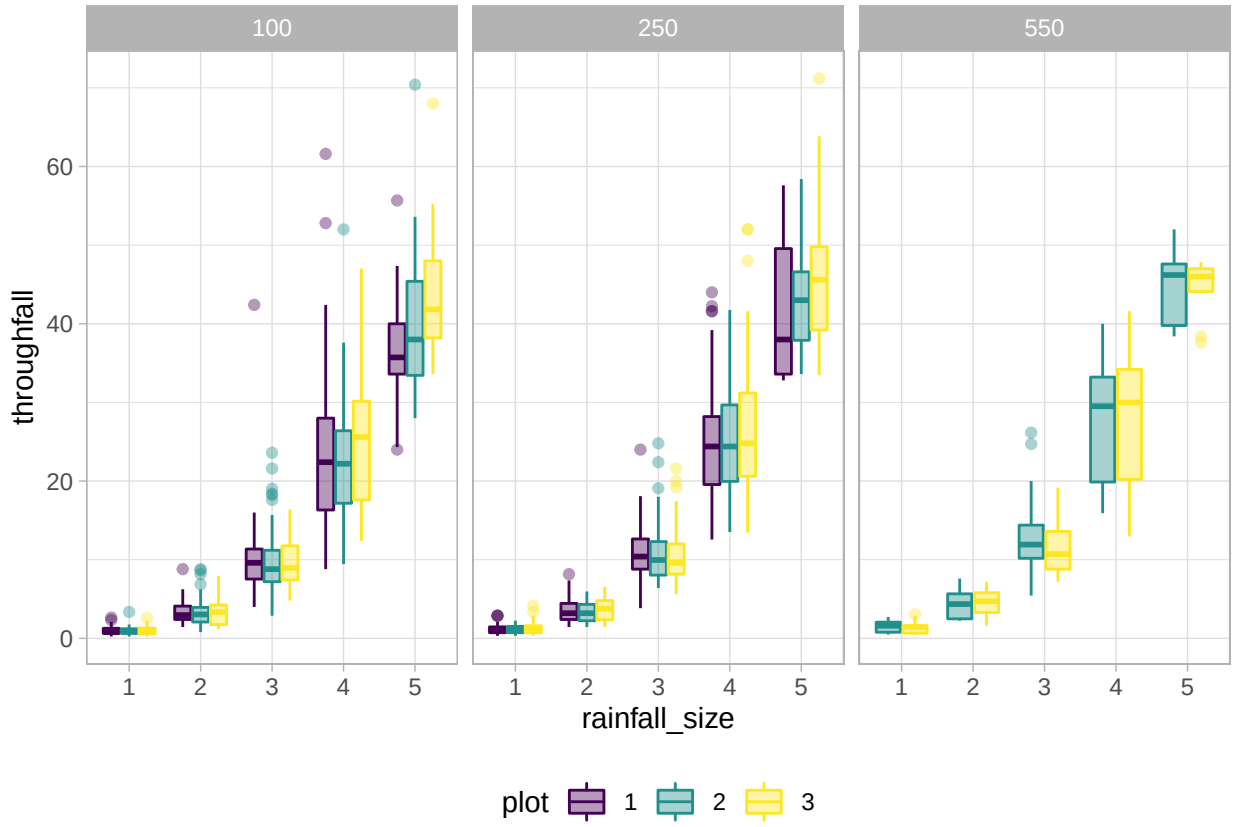

```
dados %>%
  ggplot(aes(distance, throughfall, color = tree_sp, fill = tree_sp)) +
  geom_boxplot(alpha = 0.4) +
  scale_fill_viridis_d() +
  scale_color_viridis_d() +
  theme(legend.position = "bottom")
```



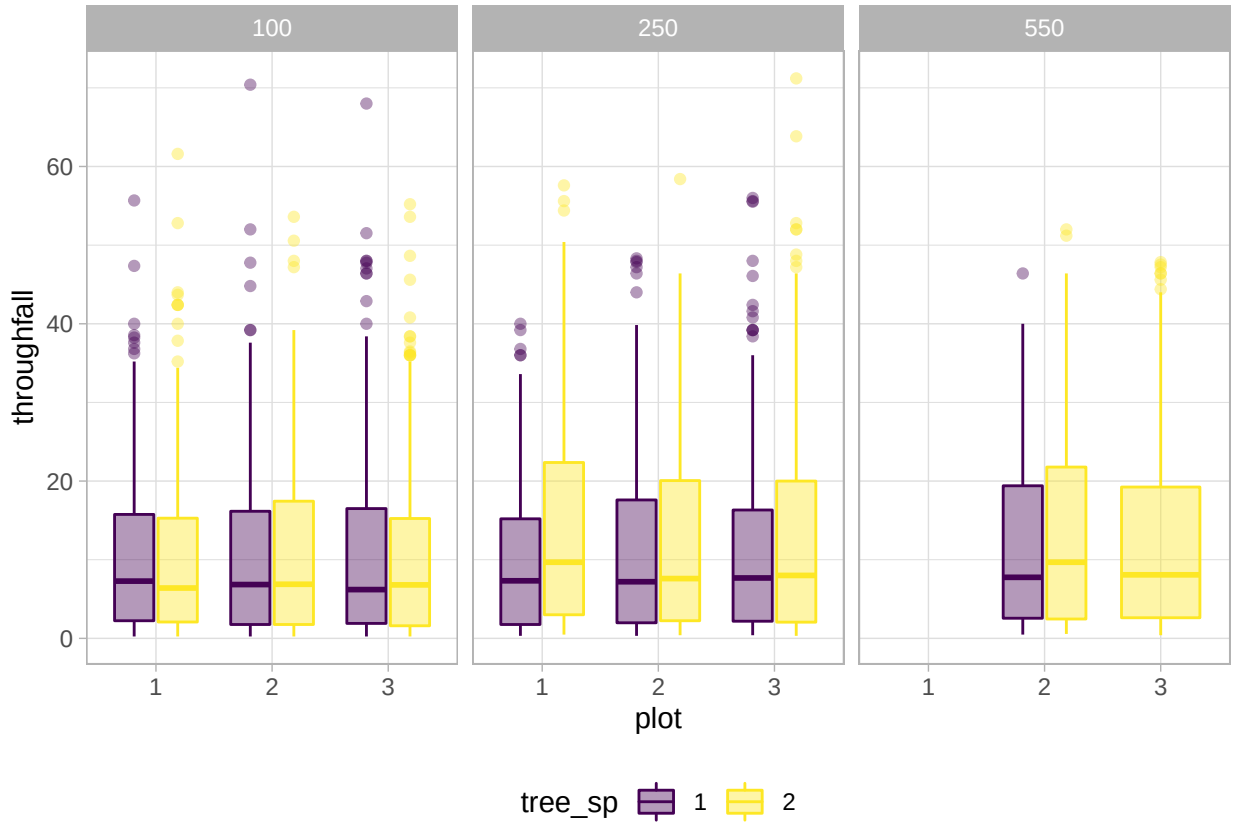

```
dados %>%
  ggplot(aes(rainfall_size, throughfall, color = tree_sp, fill = tree_sp)) +
  geom_boxplot(alpha = 0.4) +
  facet_wrap(~distance) +
  scale_fill_viridis_d() +
  scale_color_viridis_d() +
  theme(legend.position = "bottom")
```




```
dados %>%
  ggplot(aes(rainfall_size, throughfall, color = plot, fill = plot)) +
  geom_boxplot(alpha = 0.4) +
  facet_wrap(~distance) +
  scale_fill_viridis_d() +
  scale_color_viridis_d() +
  theme(legend.position = "bottom")
```




```
dados %>%
  ggplot(aes(plot, throughfall, color = tree_sp, fill = tree_sp)) +
  geom_boxplot(alpha = 0.4) +
  facet_wrap(~distance) +
  scale_fill_viridis_d() +
  scale_color_viridis_d() +
  theme(legend.position = "bottom")
```



Testes

Anova simples

```
aov(throughfall ~ rainfall_size, data = dados) %>% summary
```

```
##                 Df Sum Sq Mean Sq F value Pr(>F)
## rainfall_size    4 302136   75534    3257 <2e-16 ***
## Residuals     2095  48591      23
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
aov(throughfall ~ tree_sp, data = dados) %>% summary
```

```
##               Df Sum Sq Mean Sq F value Pr(>F)
## tree_sp        1    449   448.7   2.688  0.101
## Residuals   2098 350278   167.0
```

```
aov(throughfall ~ plot, data = dados) %>% summary
```

```
##               Df Sum Sq Mean Sq F value Pr(>F)
## plot           2    298   148.8    0.89  0.411
## Residuals   2097 350429   167.1
```

```
aov(throughfall ~ distance, data = dados) %>% summary
```

```
##               Df Sum Sq Mean Sq F value Pr(>F)
## distance       2   1252   626.1   3.757 0.0235 *
## Residuals   2097 349474   166.7
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Anova com interação

```
aov(throughfall ~ tree_sp*rainfall_size, data = dados) %>% summary
```

```
##                          Df Sum Sq Mean Sq  F value Pr(>F)
## tree_sp                   1    449     449   19.598  1e-05 ***
## rainfall_size             4 302136   75534 3298.946 <2e-16 ***
## tree_sp:rainfall_size     4    289      72    3.153 0.0135 *
## Residuals              2090  47853      23
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
aov(throughfall ~ plot*rainfall_size, data = dados) %>% summary
```

```
##                       Df Sum Sq Mean Sq  F value   Pr(>F)
## plot                   2    298     149    6.559  0.00145 **
## rainfall_size          4 302136   75534 3329.724  < 2e-16 ***
## plot:rainfall_size     8    996     124    5.487 7.07e-07 ***
## Residuals           2085  47298      23
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
aov(throughfall ~ distance*rainfall_size, data = dados) %>% summary
```

```
##                           Df Sum Sq Mean Sq  F value   Pr(>F)
## distance                   2   1252     626   28.059 9.45e-13 ***
## rainfall_size              4 302136   75534 3385.252  < 2e-16 ***
## distance:rainfall_size     8    817     102    4.577 1.52e-05 ***
## Residuals               2085  46522      22
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
aov(throughfall ~ tree_sp*plot, data = dados) %>% summary
```

```
##                Df Sum Sq Mean Sq F value Pr(>F)
## tree_sp         1    449   448.7   2.685  0.101
## plot            2    219   109.4   0.655  0.520
## tree_sp:plot    2    116    57.9   0.346  0.707
## Residuals    2094 349943   167.1
```

```r
aov(throughfall ~ tree_sp*distance, data = dados) %>% summary
```

```
##                   Df Sum Sq Mean Sq F value Pr(>F)
## tree_sp            1    449   448.7   2.696  0.101
## distance           2   1128   563.8   3.388  0.034 *
## tree_sp:distance   2    672   336.0   2.019  0.133
## Residuals       2094 348478   166.4
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
aov(throughfall ~ plot*rainfall_size*distance, data = dados) %>% summary
```

```
##                              Df Sum Sq Mean Sq  F value   Pr(>F)
## plot                          2    298     149    6.753  0.00119 **
## rainfall_size                 4 302136   75534 3428.400  < 2e-16 ***
## distance                      2   1087     544   24.677 2.57e-11 ***
## plot:rainfall_size            8    996     124    5.649 4.07e-07 ***
## plot:distance                 3     51      17    0.779  0.50587
## rainfall_size:distance        8    671      84    3.804  0.00019 ***
## plot:rainfall_size:distance  12    103       9    0.389  0.96812
## Residuals                  2060  45386      22
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

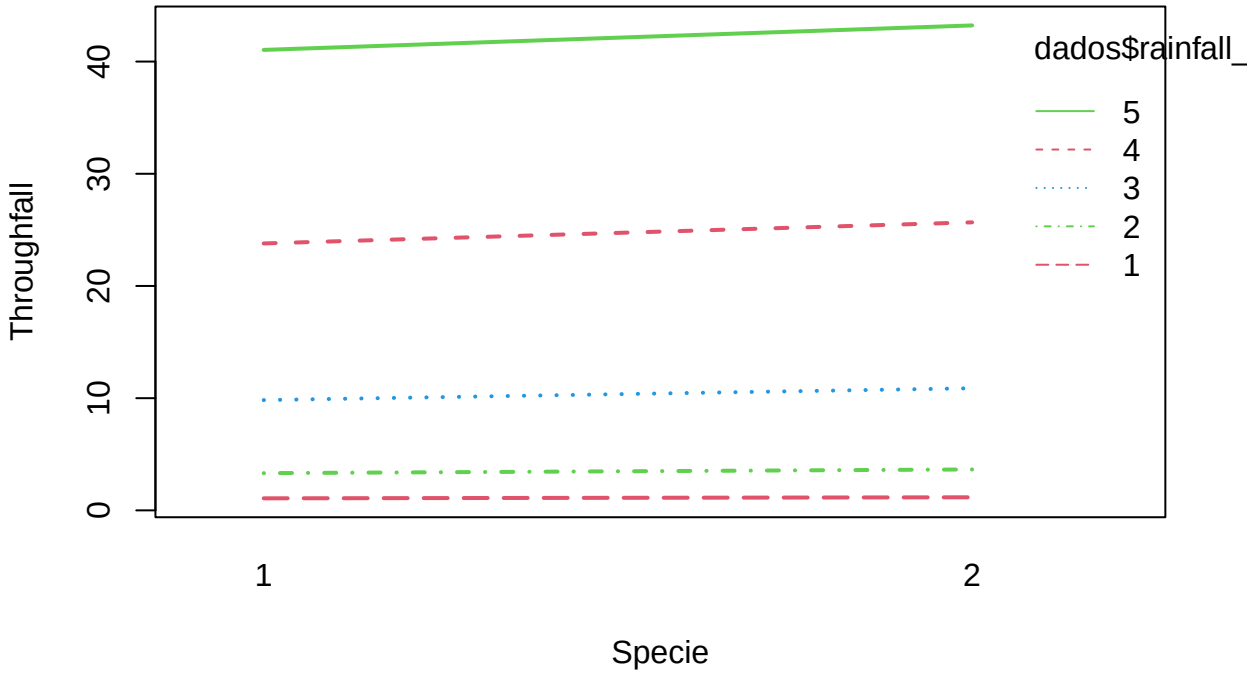
```r
aov(throughfall ~ tree_sp*plot*distance, data = dados) %>% summary
```

```
##                         Df Sum Sq Mean Sq F value Pr(>F)
## tree_sp                  1    449   448.7   2.692 0.1010
## plot                     2    219   109.4   0.656 0.5189
## distance                 2   1002   501.0   3.005 0.0497 *
## tree_sp:plot             2    238   119.0   0.714 0.4898
## tree_sp:distance         2    725   362.4   2.174 0.1140
## plot:distance            3    129    43.0   0.258 0.8557
## tree_sp:plot:distance    2    352   176.0   1.056 0.3481
## Residuals             2085 347613   166.7
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

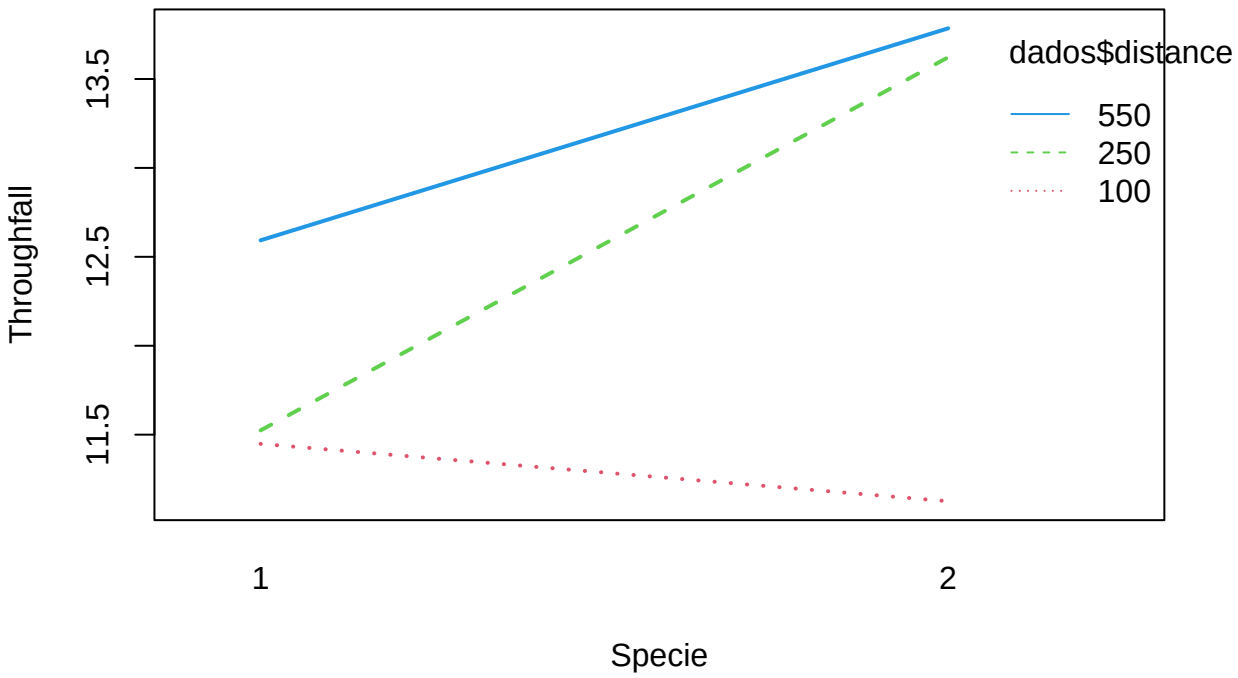
```r
aov(throughfall ~ tree_sp*rainfall_size*distance, data = dados) %>% summary
```

```
##                                 Df Sum Sq Mean Sq  F value   Pr(>F)
## tree_sp                          1    449     449   20.954 4.98e-06 ***
## rainfall_size                    4 302136   75534 3527.217  < 2e-16 ***
## distance                         2   1128     564   26.329 5.11e-12 ***
## tree_sp:rainfall_size            4    289      72    3.371  0.00929 **
## tree_sp:distance                 2    672     336   15.689 1.73e-07 ***
## rainfall_size:distance           8    771      96    4.503 1.94e-05 ***
## tree_sp:rainfall_size:distance   8    954     119    5.570 5.33e-07 ***
## Residuals                     2070  44328      21
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

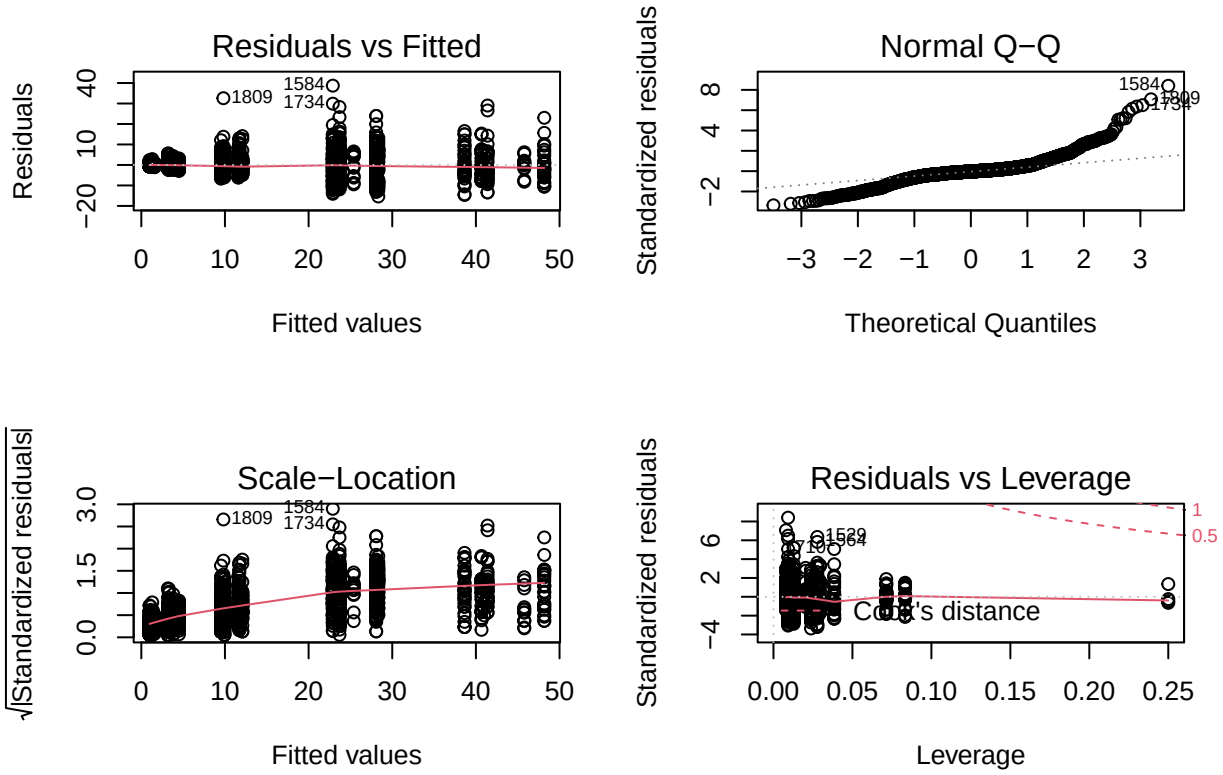
```
interaction.plot(dados$tree_sp, dados$rainfall_size, dados$throughfall, legend=T, col=2:4, lwd=2, xlab =
```




```
interaction.plot(dados$tree_sp, dados$distance, dados$throughfall, legend=T, col=2:4, lwd=2, xlab = "Sp
```




```
fit <- aov(throughfall ~ tree_sp*rainfall_size*distance, data = dados)
par(mfrow = c(2, 2))
plot(fit)
```




```
fit_lsmeans <- lsmeans::lsmeans(fit, ~tree_sp|(rainfall_size*distance))
pairs(fit_lsmeans)
```

```
## rainfall_size = 1, distance = 100:
##  contrast estimate    SE   df t.ratio p.value
##  1 - 2     0.00296 0.630 2070   0.005  0.9962
##
## rainfall_size = 2, distance = 100:
##  contrast estimate    SE   df t.ratio p.value
##  1 - 2     0.10095 0.583 2070   0.173  0.8625
##
## rainfall_size = 3, distance = 100:
##  contrast estimate    SE   df t.ratio p.value
##  1 - 2    -0.28381 0.583 2070  -0.487  0.6265
##
## rainfall_size = 4, distance = 100:
##  contrast estimate    SE   df t.ratio p.value
##  1 - 2     0.79926 0.630 2070   1.269  0.2045
##
## rainfall_size = 5, distance = 100:
##  contrast estimate    SE   df t.ratio p.value
##  1 - 2     2.75139 1.091 2070   2.523  0.0117
##
## rainfall_size = 1, distance = 250:
##  contrast estimate    SE   df t.ratio p.value
```

```
##  1 - 2    -0.18932 0.696 2070  -0.272  0.7857
##
## rainfall_size = 2, distance = 250:
##  contrast estimate    SE   df t.ratio p.value
##  1 - 2    -0.54798 0.644 2070  -0.850  0.3952
##
## rainfall_size = 3, distance = 250:
##  contrast estimate    SE   df t.ratio p.value
##  1 - 2    -1.78480 0.644 2070  -2.770  0.0057
##
## rainfall_size = 4, distance = 250:
##  contrast estimate    SE   df t.ratio p.value
##  1 - 2    -4.37906 0.696 2070  -6.291  <.0001
##
## rainfall_size = 5, distance = 250:
##  contrast estimate    SE   df t.ratio p.value
##  1 - 2    -7.50480 1.206 2070  -6.225  <.0001
##
## rainfall_size = 1, distance = 550:
##  contrast estimate    SE   df t.ratio p.value
##  1 - 2     0.17905 1.515 2070   0.118  0.9059
##
## rainfall_size = 2, distance = 550:
##  contrast estimate    SE   df t.ratio p.value
##  1 - 2    -0.54694 1.402 2070  -0.390  0.6966
##
## rainfall_size = 3, distance = 550:
##  contrast estimate    SE   df t.ratio p.value
##  1 - 2    -0.48408 1.402 2070  -0.345  0.7300
##
## rainfall_size = 4, distance = 550:
##  contrast estimate    SE   df t.ratio p.value
##  1 - 2    -2.93810 1.515 2070  -1.940  0.0526
##
## rainfall_size = 5, distance = 550:
##  contrast estimate    SE   df t.ratio p.value
##  1 - 2    -4.80286 2.624 2070  -1.831  0.0673
```

```
(fit_tukey<-TukeyHSD(fit, "tree_sp:rainfall_size:distance"))
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = throughfall ~ tree_sp * rainfall_size * distance, data = dados)
##
## $`tree_sp:rainfall_size:distance`
##                            diff          lwr         upr     p adj
## 2:1:100-1:1:100  -0.002962963  -2.36698556   2.3610596 1.0000000
## 1:2:100-1:1:100   2.310476190   0.03244702   4.5885054 0.0416337
## 2:2:100-1:1:100   2.209523810  -0.06850536   4.4875530 0.0724905
## 1:3:100-1:1:100   8.552380952   6.27435178  10.8304101 0.0000000
## 2:3:100-1:1:100   8.836190476   6.55816130  11.1142196 0.0000000
## 1:4:100-1:1:100  22.716296296  20.35227370  25.0803189 0.0000000
## 2:4:100-1:1:100  21.917037037  19.55301444  24.2810596 0.0000000
```

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## 1:5:100-1:1:100  40.418055556  37.07482274  43.7612884 0.0000000
## 2:5:100-1:1:100  37.666666667  34.32343385  41.0098995 0.0000000
## 1:1:250-1:1:100   0.137516340  -2.26101936   2.5360520 1.0000000
## 2:1:250-1:1:100   0.326837607  -2.25450587   2.9081811 1.0000000
## 1:2:250-1:1:100   2.293146592  -0.01559897   4.6018922 0.0544503
## 2:2:250-1:1:100   2.841123321   0.36915747   5.3130892 0.0059398
## 1:3:250-1:1:100   8.955667600   6.64692204  11.2644132 0.0000000
## 2:3:250-1:1:100  10.740463980   8.26849813  13.2124298 0.0000000
## 1:4:250-1:1:100  22.724183007  20.32564731  25.1227187 0.0000000
## 2:4:250-1:1:100  27.103247863  24.52190439  29.6845913 0.0000000
## 1:5:250-1:1:100  39.692810458  36.27662579  43.1089951 0.0000000
## 2:5:250-1:1:100  47.197606838  43.40268924  50.9925244 0.0000000
## 1:1:550-1:1:100   0.595555556  -4.69055967   5.8816708 1.0000000
## 2:1:550-1:1:100   0.416507937  -2.74255014   3.5755660 1.0000000
## 1:2:550-1:1:100   2.976507937  -1.95809852   7.9111144 0.9095683
## 2:2:550-1:1:100   3.523446712   0.53126192   6.5156315 0.0037834
## 1:3:550-1:1:100  10.616507937   5.68190148  15.5511144 0.0000000
## 2:3:550-1:1:100  11.100589569   8.10840478  14.0927744 0.0000000
## 1:4:550-1:1:100  24.415555556  19.12944033  29.7016708 0.0000000
## 2:4:550-1:1:100  27.353650794  24.19459272  30.5127089 0.0000000
## 1:5:550-1:1:100  40.002222222  31.15685962  48.8475848 0.0000000
## 2:5:550-1:1:100  44.805079365  39.87047291  49.7396858 0.0000000
## 1:2:100-2:1:100   2.313439153   0.03540998   4.5914683 0.0409341
## 2:2:100-2:1:100   2.212486772  -0.06554240   4.4905159 0.0713664
## 1:3:100-2:1:100   8.555343915   6.27731474  10.8333731 0.0000000
## 2:3:100-2:1:100   8.839153439   6.56112427  11.1171826 0.0000000
## 1:4:100-2:1:100  22.719259259  20.35523666  25.0832819 0.0000000
## 2:4:100-2:1:100  21.920000000  19.55597741  24.2840226 0.0000000
## 1:5:100-2:1:100  40.421018519  37.07778570  43.7642513 0.0000000
## 2:5:100-2:1:100  37.669629630  34.32639681  41.0128624 0.0000000
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## 1:2:250-2:1:100   2.296109555  -0.01263600   4.6048551 0.0535798
## 2:2:250-2:1:100   2.844086284   0.37212043   5.3160521 0.0058287
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## 2:4:250-2:1:100  27.106210826  24.52486735  29.6875543 0.0000000
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## 2:5:250-2:1:100  47.200569801  43.40565220  50.9954874 0.0000000
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## 2:1:550-2:1:100   0.419470899  -2.73958717   3.5785290 1.0000000
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## 2:4:550-2:1:100  27.356613757  24.19755568  30.5156718 0.0000000
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## 2:5:550-2:1:100  44.808042328  39.87343587  49.7426488 0.0000000
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## 1:3:100-1:2:100   6.241904762   4.05324513   8.4305644 0.0000000
## 2:3:100-1:2:100   6.525714286   4.33705465   8.7143739 0.0000000
## 1:4:100-1:2:100  20.405820106  18.12779093  22.6838493 0.0000000
```

```
## 2:4:100-1:2:100  19.606560847  17.32853167  21.8845900 0.0000000
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## 2:5:100-1:2:100  35.356190476  32.07320102  38.6391799 0.0000000
## 1:1:250-1:2:100  -2.172959851  -4.48678516   0.1408655 0.1037256
## 2:1:250-1:2:100  -1.983638584  -4.48646663   0.5191895 0.4041420
## 1:2:250-1:2:100  -0.017329599  -2.23794216   2.2032830 1.0000000
## 2:2:250-1:2:100   0.530647131  -1.85921254   2.9205068 1.0000000
## 1:3:250-1:2:100   6.645191410   4.42457885   8.8658040 0.0000000
## 2:3:250-1:2:100   8.429987790   6.04012812  10.8198475 0.0000000
## 1:4:250-1:2:100  20.413706816  18.09988150  22.7275321 0.0000000
## 2:4:250-1:2:100  24.792771673  22.28994363  27.2955997 0.0000000
## 1:5:250-1:2:100  37.382334267  34.02508364  40.7395849 0.0000000
## 2:5:250-1:2:100  44.887130647  41.14517746  48.6290838 0.0000000
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## 1:2:550-1:2:100   0.666031746  -4.22795998   5.5600235 1.0000000
## 2:2:550-1:2:100   1.212970522  -1.71174894   4.1376900 0.9995925
## 1:3:550-1:2:100   8.306031746   3.41204002  13.2000235 0.0000001
## 2:3:550-1:2:100   8.790113379   5.86539392  11.7148328 0.0000000
## 1:4:550-1:2:100  22.105079365  16.85685793  27.3533008 0.0000000
## 2:4:550-1:2:100  25.043174603  21.94794246  28.1384067 0.0000000
## 1:5:550-1:2:100  37.691746032  28.86897698  46.5145151 0.0000000
## 2:5:550-1:2:100  42.494603175  37.60061145  47.3885949 0.0000000
## 1:3:100-2:2:100   6.342857143   4.15419751   8.5315168 0.0000000
## 2:3:100-2:2:100   6.626666667   4.43800703   8.8153263 0.0000000
## 1:4:100-2:2:100  20.506772487  18.22874331  22.7848017 0.0000000
## 2:4:100-2:2:100  19.707513228  17.42948405  21.9855424 0.0000000
## 1:5:100-2:2:100  38.208531746  34.92554229  41.4915212 0.0000000
## 2:5:100-2:2:100  35.457142857  32.17415341  38.7401323 0.0000000
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## 2:4:250-2:2:100  24.893724054  22.39089601  27.3965521 0.0000000
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## 2:4:100-1:3:100  13.364656085  11.08662691  15.6426853 0.0000000
## 1:5:100-1:3:100  31.865674603  28.58268515  35.1486641 0.0000000
## 2:5:100-1:3:100  29.114285714  25.83129626  32.3972752 0.0000000
```

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## 1:2:250-1:3:100  -6.259234360  -8.47984692  -4.0386218 0.0000000
## 2:2:250-1:3:100  -5.711257631  -8.10111731  -3.3213980 0.0000000
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## 2:4:250-1:3:100  18.550866911  16.04803887  21.0536950 0.0000000
## 1:5:250-1:3:100  31.140429505  27.78317888  34.4976801 0.0000000
## 2:5:250-1:3:100  38.645225885  34.90327269  42.3871791 0.0000000
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## 2:2:250-2:3:100  -5.995067155  -8.38492683  -3.6052075 0.0000000
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```

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## 2:2:550-1:5:100 -36.894608844 -40.70797647 -33.0812412 0.0000000
## 1:3:550-1:5:100 -29.801547619 -35.27319670 -24.3298985 0.0000000
## 2:3:550-1:5:100 -29.317465986 -33.13083361 -25.5040984 0.0000000
## 1:4:550-1:5:100 -16.002500000 -21.79314910 -10.2118509 0.0000000
## 2:4:550-1:5:100 -13.064404762 -17.01006703  -9.1187425 0.0000000
```

```
## 1:5:550-1:5:100  -0.415833333  -9.57165347   8.7399868 1.0000000
## 2:5:550-1:5:100   4.387023810  -1.08462528   9.8586729 0.3778397
## 1:1:250-2:5:100 -37.529150327 -40.89687602 -34.1614246 0.0000000
## 2:1:250-2:5:100 -37.339829060 -40.84010576 -33.8395524 0.0000000
## 1:2:250-2:5:100 -35.373520075 -38.67789731 -32.0691428 0.0000000
## 2:2:250-2:5:100 -34.825543346 -38.24595531 -31.4051314 0.0000000
## 1:3:250-2:5:100 -28.710999066 -32.01537630 -25.4066218 0.0000000
## 2:3:250-2:5:100 -26.926202686 -30.34661465 -23.5057907 0.0000000
## 1:4:250-2:5:100 -14.942483660 -18.31020935 -11.5747580 0.0000000
## 2:4:250-2:5:100 -10.563418803 -14.06369550  -7.0631421 0.0000000
## 1:5:250-2:5:100   2.026143791  -2.12824190   6.1805295 0.9938770
## 2:5:250-2:5:100   9.530940171   5.05992212  14.0019582 0.0000000
## 1:1:550-2:5:100 -37.071111111 -42.86176021 -31.2804620 0.0000000
## 2:1:550-2:5:100 -37.250158730 -41.19582100 -33.3044965 0.0000000
## 1:2:550-2:5:100 -34.690158730 -40.16180782 -29.2185096 0.0000000
## 2:2:550-2:5:100 -34.143219955 -37.95658758 -30.3298523 0.0000000
## 1:3:550-2:5:100 -27.050158730 -32.52180782 -21.5785096 0.0000000
## 2:3:550-2:5:100 -26.566077098 -30.37944473 -22.7527095 0.0000000
## 1:4:550-2:5:100 -13.251111111 -19.04176021  -7.4604620 0.0000000
## 2:4:550-2:5:100 -10.313015873 -14.25867814  -6.3673536 0.0000000
## 1:5:550-2:5:100   2.335555556  -6.82026458  11.4913757 1.0000000
## 2:5:550-2:5:100   7.138412698   1.66676361  12.6100618 0.0004184
## 2:1:250-1:1:250   0.189321267  -2.42366645   2.8023090 1.0000000
## 1:2:250-1:1:250   2.155630252  -0.18844243   4.4997029 0.1285753
## 2:2:250-1:1:250   2.703606981   0.19861480   5.2085992 0.0170670
## 1:3:250-1:1:250   8.818151261   6.47407858  11.1622239 0.0000000
## 2:3:250-1:1:250  10.602947641   8.09795545  13.1079398 0.0000000
## 1:4:250-1:1:250  22.586666667  20.15410749  25.0192258 0.0000000
## 2:4:250-1:1:250  26.965731523  24.35274381  29.5787192 0.0000000
## 1:5:250-1:1:250  39.555294118  36.11513593  42.9954523 0.0000000
## 2:5:250-1:1:250  47.060090498  43.24357766  50.8766033 0.0000000
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## 2:1:550-1:1:250   0.278991597  -2.90597600   3.4639592 1.0000000
## 1:2:550-1:1:250   2.838991597  -2.11224174   7.7902249 0.9476102
## 2:2:550-1:1:250   3.385930372   0.36640384   6.4054569 0.0091589
## 1:3:550-1:1:250  10.478991597   5.52775826  15.4302249 0.0000000
## 2:3:550-1:1:250  10.963073229   7.94354669  13.9825998 0.0000000
## 1:4:550-1:1:250  24.278039216  18.97639939  29.5796790 0.0000000
## 2:4:550-1:1:250  27.216134454  24.03116686  30.4011020 0.0000000
## 1:5:550-1:1:250  39.864705882  31.01005681  48.7193550 0.0000000
## 2:5:550-1:1:250  44.667563025  39.71632969  49.6187964 0.0000000
## 1:2:250-2:1:250   1.966308985  -0.56450855   4.4971265 0.4502678
## 2:2:250-2:1:250   2.514285714  -0.16626395   5.1948354 0.1050704
## 1:3:250-2:1:250   8.628829994   6.09801246  11.1596475 0.0000000
## 2:3:250-2:1:250  10.413626374   7.73307671  13.0941760 0.0000000
## 1:4:250-2:1:250  22.397345400  19.78435768  25.0103331 0.0000000
## 2:4:250-2:1:250  26.776410256  23.99467241  29.5581481 0.0000000
## 1:5:250-2:1:250  39.365972851  35.79595198  42.9359937 0.0000000
## 2:5:250-2:1:250  46.870769231  42.93679784  50.8047406 0.0000000
## 1:1:550-2:1:250   0.268717949  -5.11809423   5.6555301 1.0000000
## 2:1:550-2:1:250   0.089670330  -3.23514233   3.4144830 1.0000000
## 1:2:550-2:1:250   2.649670330  -2.39265772   7.6919984 0.9822622
## 2:2:550-2:1:250   3.196609105   0.02992296   6.3632953 0.0443028
## 1:3:550-2:1:250  10.289670330   5.24734228  15.3319984 0.0000000
```

```
## 2:3:550-2:1:250  10.773751962   7.60706582  13.9404381 0.0000000
## 1:4:550-2:1:250  24.088717949  18.70190577  29.4755301 0.0000000
## 2:4:550-2:1:250  27.026813187  23.70200053  30.3516258 0.0000000
## 1:5:550-2:1:250  39.675384615  30.76947810  48.5812911 0.0000000
## 2:5:550-2:1:250  44.478241758  39.43591370  49.5205698 0.0000000
## 2:2:250-1:2:250   0.547976729  -1.87117982   2.9671333 1.0000000
## 1:3:250-1:2:250   6.662521008   4.41040882   8.9146332 0.0000000
## 2:3:250-1:2:250   8.447317388   6.02816084  10.8664739 0.0000000
## 1:4:250-1:2:250  20.431036415  18.08696373  22.7751091 0.0000000
## 2:4:250-1:2:250  24.810101271  22.27928374  27.3409188 0.0000000
## 1:5:250-1:2:250  37.399663866  34.02149559  40.7778321 0.0000000
## 2:5:250-1:2:250  44.904460246  41.14372856  48.6651919 0.0000000
## 1:1:550-1:2:250  -1.697591036  -6.95921791   3.5640358 0.9999975
## 2:1:550-1:2:250  -1.876638655  -4.99454679   1.2412695 0.9115346
## 1:2:550-1:2:250   0.683361345  -4.22500337   5.5917261 1.0000000
## 2:2:550-1:2:250   1.230300120  -1.71840690   4.1790071 0.9995453
## 1:3:550-1:2:250   8.323361345   3.41499663  13.2317261 0.0000001
## 2:3:550-1:2:250   8.807442977   5.85873596  11.7561500 0.0000000
## 1:4:550-1:2:250  22.122408964  16.86078209  27.3840358 0.0000000
## 2:4:550-1:2:250  25.060504202  21.94259607  28.1784123 0.0000000
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## 2:5:550-1:2:250  42.511932773  37.60356806  47.4202975 0.0000000
## 1:3:250-2:2:250   6.114544279   3.69538773   8.5337008 0.0000000
## 2:3:250-2:2:250   7.899340659   5.32395185  10.4747295 0.0000000
## 1:4:250-2:2:250  19.883059685  17.37806750  22.3880519 0.0000000
## 2:4:250-2:2:250  24.262124542  21.58157488  26.9426742 0.0000000
## 1:5:250-2:2:250  36.851687136  33.35993542  40.3434388 0.0000000
## 2:5:250-2:2:250  44.356483516  40.49340030  48.2195667 0.0000000
## 1:1:550-2:2:250  -2.245567766  -7.58083032   3.0896948 0.9994676
## 2:1:550-2:2:250  -2.424615385  -5.66524191   0.8160111 0.5386530
## 1:2:550-2:2:250   0.135384615  -4.85183437   5.1226036 1.0000000
## 2:2:550-2:2:250   0.682323391  -2.39585500   3.7605018 1.0000000
## 1:3:550-2:2:250   7.775384615   2.78816563  12.7626036 0.0000024
## 2:3:550-2:2:250   8.259466248   5.18128786  11.3376446 0.0000000
## 1:4:550-2:2:250  21.574432234  16.23916968  26.9096948 0.0000000
## 2:4:550-2:2:250  24.512527473  21.27190095  27.7531540 0.0000000
## 1:5:550-2:2:250  37.161098901  28.28627767  46.0359201 0.0000000
## 2:5:550-2:2:250  41.963956044  36.97673706  46.9511750 0.0000000
## 2:3:250-1:3:250   1.784796380  -0.63436017   4.2039529 0.5711337
## 1:4:250-1:3:250  13.768515406  11.42444273  16.1125881 0.0000000
## 2:4:250-1:3:250  18.147580263  15.61676273  20.6783978 0.0000000
## 1:5:250-1:3:250  30.737142857  27.35897458  34.1153111 0.0000000
## 2:5:250-1:3:250  38.241939237  34.48120755  42.0026709 0.0000000
## 1:1:550-1:3:250  -8.360112045 -13.62173892  -3.0984852 0.0000012
## 2:1:550-1:3:250  -8.539159664 -11.65706780  -5.4212515 0.0000000
## 1:2:550-1:3:250  -5.979159664 -10.88752437  -1.0707950 0.0019282
## 2:2:550-1:3:250  -5.432220888  -8.38092790  -2.4835139 0.0000000
## 1:3:550-1:3:250   1.660840336  -3.24752437   6.5692050 0.9999929
## 2:3:550-1:3:250   2.144921969  -0.80378505   5.0936290 0.6033573
## 1:4:550-1:3:250  15.459887955  10.19826108  20.7215148 0.0000000
## 2:4:550-1:3:250  18.397983193  15.28007506  21.5158913 0.0000000
## 1:5:550-1:3:250  31.046554622  22.21580478  39.8773045 0.0000000
## 2:5:550-1:3:250  35.849411765  30.94104706  40.7577765 0.0000000
## 1:4:250-2:3:250  11.983719026   9.47872684  14.4887112 0.0000000
```

```
## 2:4:250-2:3:250  16.362783883  13.68223422  19.0433335 0.0000000
## 1:5:250-2:3:250  28.952346477  25.46059476  32.4440982 0.0000000
## 2:5:250-2:3:250  36.457142857  32.59405964  40.3202261 0.0000000
## 1:1:550-2:3:250 -10.144908425 -15.48017098  -4.8096459 0.0000000
## 2:1:550-2:3:250 -10.323956044 -13.56458257  -7.0833295 0.0000000
## 1:2:550-2:3:250  -7.763956044 -12.75117503  -2.7767371 0.0000025
## 2:2:550-2:3:250  -7.217017268 -10.29519566  -4.1388389 0.0000000
## 1:3:550-2:3:250  -0.123956044  -5.11117503   4.8632629 1.0000000
## 2:3:550-2:3:250   0.360125589  -2.71805280   3.4383040 1.0000000
## 1:4:550-2:3:250  13.675091575   8.33982902  19.0103541 0.0000000
## 2:4:550-2:3:250  16.613186813  13.37256029  19.8538133 0.0000000
## 1:5:550-2:3:250  29.261758242  20.38693701  38.1365795 0.0000000
## 2:5:550-2:3:250  34.064615385  29.07739640  39.0518344 0.0000000
## 2:4:250-1:4:250   4.379064857   1.76607714   6.9920526 0.0000002
## 1:5:250-1:4:250  16.968627451  13.52846927  20.4087856 0.0000000
## 2:5:250-1:4:250  24.473423831  20.65691099  28.2899367 0.0000000
## 1:1:550-1:4:250 -22.128627451 -27.43026727 -16.8269876 0.0000000
## 2:1:550-1:4:250 -22.307675070 -25.49264266 -19.1227075 0.0000000
## 1:2:550-1:4:250 -19.747675070 -24.69890841 -14.7964417 0.0000000
## 2:2:550-1:4:250 -19.200736295 -22.22026283 -16.1812098 0.0000000
## 1:3:550-1:4:250 -12.107675070 -17.05890841  -7.1564417 0.0000000
## 2:3:550-1:4:250 -11.623593437 -14.64311997  -8.6040669 0.0000000
## 1:4:550-1:4:250   1.691372549  -3.61026727   6.9930124 0.9999980
## 2:4:550-1:4:250   4.629467787   1.44450019   7.8144354 0.0000229
## 1:5:550-1:4:250  17.278039216   8.42339014  26.1326883 0.0000000
## 2:5:550-1:4:250  22.080896359  17.12966302  27.0321297 0.0000000
## 1:5:250-2:4:250  12.589562594   9.01954173  16.1595835 0.0000000
## 2:5:250-2:4:250  20.094358974  16.16038758  24.0283304 0.0000000
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## 2:1:550-2:4:250 -26.686739927 -30.01155259 -23.3619273 0.0000000
## 1:2:550-2:4:250 -24.126739927 -29.16906798 -19.0844119 0.0000000
## 2:2:550-2:4:250 -23.579801151 -26.74648730 -20.4131150 0.0000000
## 1:3:550-2:4:250 -16.486739927 -21.52906798 -11.4444119 0.0000000
## 2:3:550-2:4:250 -16.002658294 -19.16934444 -12.8359721 0.0000000
## 1:4:550-2:4:250  -2.687692308  -8.07450449   2.6991199 0.9914190
## 2:4:550-2:4:250   0.250402930  -3.07440973   3.5752156 1.0000000
## 1:5:550-2:4:250  12.898974359   3.99306784  21.8048809 0.0000255
## 2:5:550-2:4:250  17.701831502  12.65950345  22.7441596 0.0000000
## 2:5:250-1:5:250   7.504796380   2.97896889  12.0306239 0.0000003
## 1:1:550-1:5:250 -39.097254902 -44.93032690 -33.2641829 0.0000000
## 2:1:550-1:5:250 -39.276302521 -43.28396552 -35.2686395 0.0000000
## 1:2:550-1:5:250 -36.716302521 -42.23282822 -31.1997768 0.0000000
## 2:2:550-1:5:250 -36.169363745 -40.04684807 -32.2918794 0.0000000
## 1:3:550-1:5:250 -29.076302521 -34.59282822 -23.5597768 0.0000000
## 2:3:550-1:5:250 -28.592220888 -32.46970521 -24.7147366 0.0000000
## 1:4:550-1:5:250 -15.277254902 -21.11032690  -9.4441829 0.0000000
## 2:4:550-1:5:250 -12.339159664 -16.34682267  -8.3314967 0.0000000
## 1:5:550-1:5:250   0.309411765  -8.87329777   9.4921213 1.0000000
## 2:5:550-1:5:250   5.112268908  -0.40425679  10.6287946 0.1190293
## 1:1:550-2:5:250 -46.602051282 -52.66470836 -40.5393942 0.0000000
## 2:1:550-2:5:250 -46.781098901 -51.11612424 -42.4460736 0.0000000
## 1:2:550-2:5:250 -44.221098901 -49.97984335 -38.4623544 0.0000000
## 2:2:550-2:5:250 -43.674160126 -47.88912947 -39.4591908 0.0000000
## 1:3:550-2:5:250 -36.581098901 -42.33984335 -30.8223544 0.0000000
```

```
## 2:3:550-2:5:250 -36.097017268 -40.31198662 -31.8820479 0.0000000
## 1:4:550-2:5:250 -22.782051282 -28.84470836 -16.7193942 0.0000000
## 2:4:550-2:5:250 -19.843956044 -24.17898138 -15.5089307 0.0000000
## 1:5:550-2:5:250  -7.195384615 -16.52561700   2.1348478 0.4676803
## 2:5:550-2:5:250  -2.392527473  -8.15127192   3.3662170 0.9995792
## 2:1:550-1:1:550  -0.179047619  -5.86535215   5.5072569 1.0000000
## 1:2:550-1:1:550   2.380952381  -4.45313514   9.2150399 0.9999869
## 2:2:550-1:1:550   2.927891156  -2.66742663   8.5232089 0.9832415
## 1:3:550-1:1:550  10.020952381   3.18686486  16.8550399 0.0000176
## 2:3:550-1:1:550  10.505034014   4.90971623  16.1003518 0.0000000
## 1:4:550-1:1:550  23.820000000  16.72793222  30.9120678 0.0000000
## 2:4:550-1:1:550  26.758095238  21.07179071  32.4443998 0.0000000
## 1:5:550-1:1:550  39.406666667  29.37696822  49.4363651 0.0000000
## 2:5:550-1:1:550  44.209523810  37.37543629  51.0436113 0.0000000
## 1:2:550-2:1:550   2.560000000  -2.80109932   7.9210993 0.9955684
## 2:2:550-2:1:550   3.106938776  -0.54603466   6.7599122 0.2537041
## 1:3:550-2:1:550  10.200000000   4.83890068  15.5610993 0.0000000
## 2:3:550-2:1:550  10.684081633   7.03110820  14.3370551 0.0000000
## 1:4:550-2:1:550  23.999047619  18.31274309  29.6853521 0.0000000
## 2:4:550-2:1:550  26.937142857  23.14627317  30.7280125 0.0000000
## 1:5:550-2:1:550  39.585714286  30.49552811  48.6759005 0.0000000
## 2:5:550-2:1:550  44.388571429  39.02747210  49.7496708 0.0000000
## 2:2:550-1:2:550   0.546938776  -4.71755625   5.8114338 1.0000000
## 1:3:550-1:2:550   7.640000000   1.07402110  14.2059789 0.0047392
## 2:3:550-1:2:550   8.124081633   2.85958660  13.3885767 0.0000034
## 1:4:550-1:2:550  21.439047619  14.60496010  28.2731351 0.0000000
## 2:4:550-1:2:550  24.377142857  19.01604353  29.7382422 0.0000000
## 1:5:550-1:2:550  37.025714286  27.17674593  46.8746826 0.0000000
## 2:5:550-1:2:550  41.828571429  35.26259253  48.3945503 0.0000000
## 1:3:550-2:2:550   7.093061224   1.82856620  12.3575563 0.0001882
## 2:3:550-2:2:550   7.577142857   4.06747951  11.0868062 0.0000000
## 1:4:550-2:2:550  20.892108844  15.29679106  26.4874266 0.0000000
## 2:4:550-2:2:550  23.830204082  20.17723065  27.4831775 0.0000000
## 1:5:550-2:2:550  36.478775510  27.44522656  45.5123245 0.0000000
## 2:5:550-2:2:550  41.281632653  36.01713763  46.5461277 0.0000000
## 2:3:550-1:3:550   0.484081633  -4.78041340   5.7485767 1.0000000
## 1:4:550-1:3:550  13.799047619   6.96496010  20.6331351 0.0000000
## 2:4:550-1:3:550  16.737142857  11.37604353  22.0982422 0.0000000
## 1:5:550-1:3:550  29.385714286  19.53674593  39.2346826 0.0000000
## 2:5:550-1:3:550  34.188571429  27.62259253  40.7545503 0.0000000
## 1:4:550-2:3:550  13.314965986   7.71964820  18.9102838 0.0000000
## 2:4:550-2:3:550  16.253061224  12.60008779  19.9060347 0.0000000
## 1:5:550-2:3:550  28.901632653  19.86808371  37.9351816 0.0000000
## 2:5:550-2:3:550  33.704489796  28.43999477  38.9689848 0.0000000
## 2:4:550-1:4:550   2.938095238  -2.74820929   8.6243998 0.9859020
## 1:5:550-1:4:550  15.586666667   5.55696822  25.6163651 0.0000027
## 2:5:550-1:4:550  20.389523810  13.55543629  27.2236113 0.0000000
## 1:5:550-2:4:550  12.648571429   3.55838526  21.7387576 0.0000801
## 2:5:550-2:4:550  17.451428571  12.09032925  22.8125279 0.0000000
## 2:5:550-1:5:550   4.802857143  -5.04611121  14.6518255 0.9938886
```

```
fit_plot <- aov(throughfall ~ tree_sp/(rainfall_size*distance), data = dados)
```

```r
summary(fit_plot, split=list("tree_sp:rainfall_size" = list("tree_sp1"= grep("tree_sp1", names(coef(fit
```

```
##                                     Df Sum Sq Mean Sq  F value   Pr(>F)
## tree_sp                              1    449     449   20.954 4.98e-06 ***
## tree_sp:rainfall_size                8 302424   37803 1765.294  < 2e-16 ***
##   tree_sp:rainfall_size: tree_sp1    4 140308   35077 1637.991  < 2e-16 ***
##   tree_sp:rainfall_size: tree_sp2    4 162117   40529 1892.597  < 2e-16 ***
## tree_sp:distance                     4   1800     450   21.009  < 2e-16 ***
##   tree_sp:distance: tree_sp1         2     66      33    1.551    0.212
##   tree_sp:distance: tree_sp2         2   1733     867   40.468  < 2e-16 ***
## tree_sp:rainfall_size:distance      16   1726     108    5.036 2.21e-10 ***
## Residuals                         2070  44328      21
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```