Assignment 1 Report of MT5762

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Contents

1 Introduction

A scientist has been planting the chemical constituents of the leaves of different soil types of cannabis plants. In particular, he shows the interest in if there is a difference between the plants of the potting mix purchased from the standard store and the plants in the general soil. It is believed that if the chemical composition of the plant differs depending on the type of soil, this will help those who prosecute the production and distribution of the drug. Therefore, to help study cannabis leaves in different soil types, this report will help prove this theory by analysing the chemical composition of cannabis leaves in different soil types. The focus of this study is on whether the chemical elements of cannabis cultivation are the same in different soil types.

2 Data

The dataset to be used in this study is from University of St. Andrews. The variables contained are:

- **Sample Name**: Number of every sample.
- **Group**: There are four soil types, including pm (potting mix) and three other types (bhb, mb and nth) in New Zealand, which represent Blockhouse Bay, Mission Bay and Northland respectively.
- **Elements**: Data of 38 chemistry elements from Mg to Th are collected.

As stated in the introduction, the primary aim is to study the correlation between different soil types and cannabis cultivation, in other words, the relationship between 'Group' and 'Elements'. Thus, sample name will not be the main interest in this analysis.

R Studio [5.0] is the main software to be used to implement this analysis. The code used to analyse the data will display in Appendix.

3 Analysis & Results

3 1 Basic information

Due to the fact that the number of elements is 38, which is a relatively large number of factors if needed to be researched, after comparing the coefficient of variation (CV) in Appendix 1, four elements (Ti, Ga, Rb and Ta) were chosen to be analysed and paired. Plus, after dropping the null data, the summary of data is showed in Appendix 2.

By drawing a scatter plot and observing the difference between a pair of elements in different soil types, the plots of three special pairs of elements and descriptions are presented below in Figure 1, 2 and 3. The other scatter diagrams that indicate the relationship of these pairs can also be found in Appendix 3.

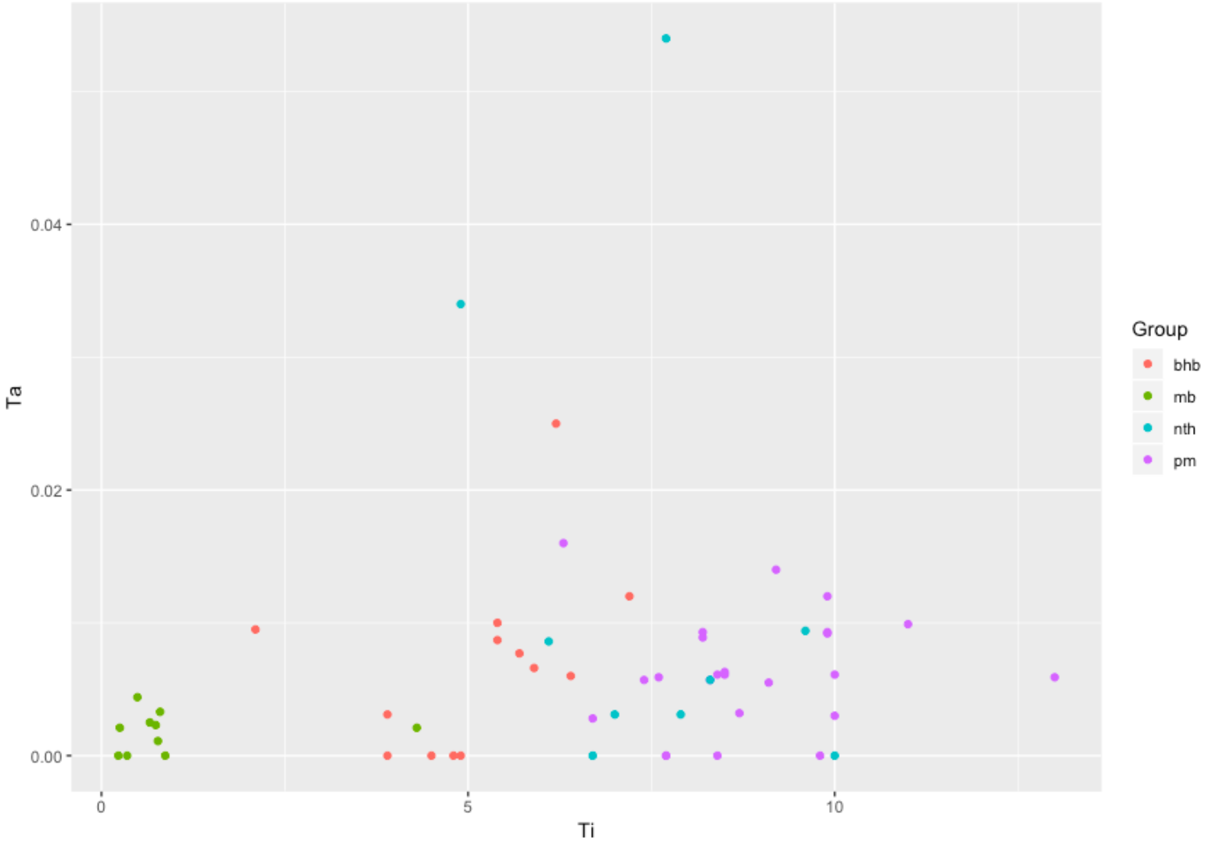


Figure 1 Scatter plot of Ti & Ta by Group

As can be seen in Figure 1, except for data of mb, the points of all soil types almost lie in the lower middle area. Thus, it is quite hard to distinguish if data of pm has any differences with the data in other two soil types.

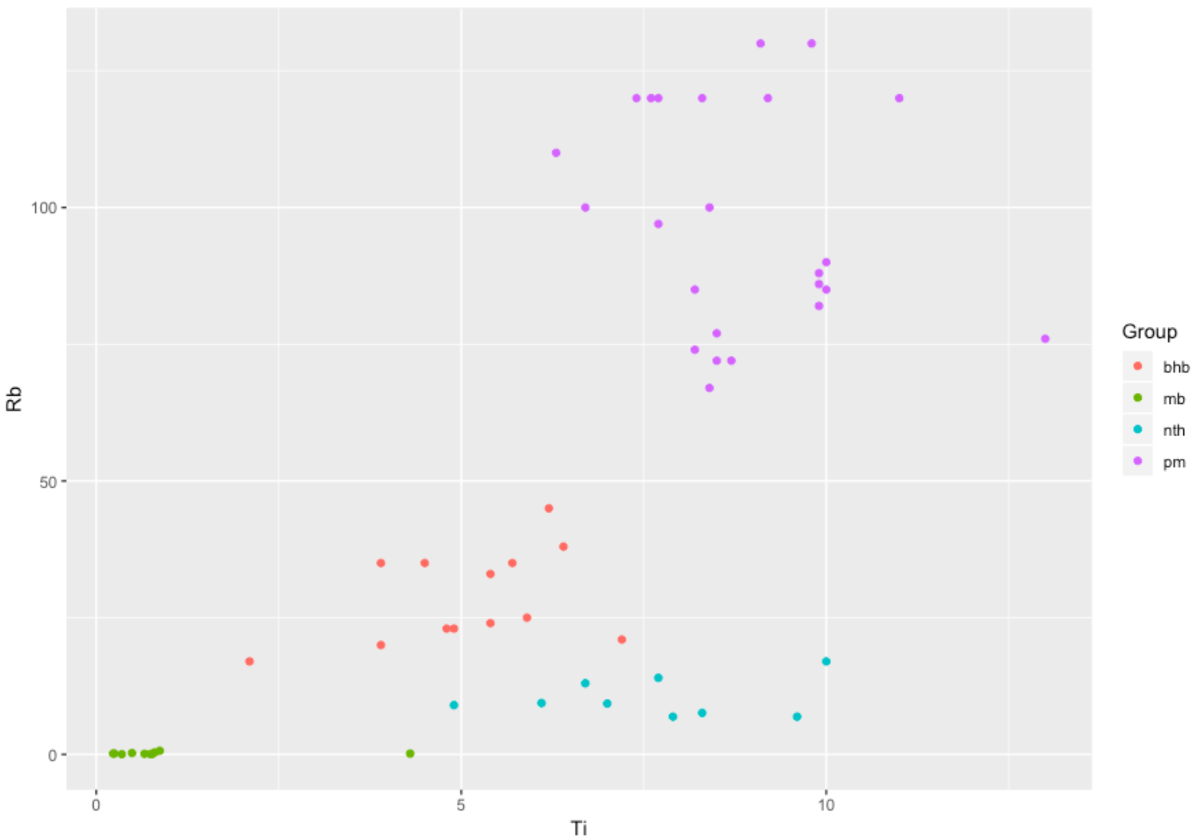


Figure 2 Scatter plot of Ti & Rb by Group

Nevertheless, Figure 2 demonstrates completely different situation that the green points lie in lower left and are close to 0 on both axes. In the contrary, purple points, which represent pm, comprise a large range in the middle and upper middle areas. The blue ones and orange ones also not mix together, but not very clear.

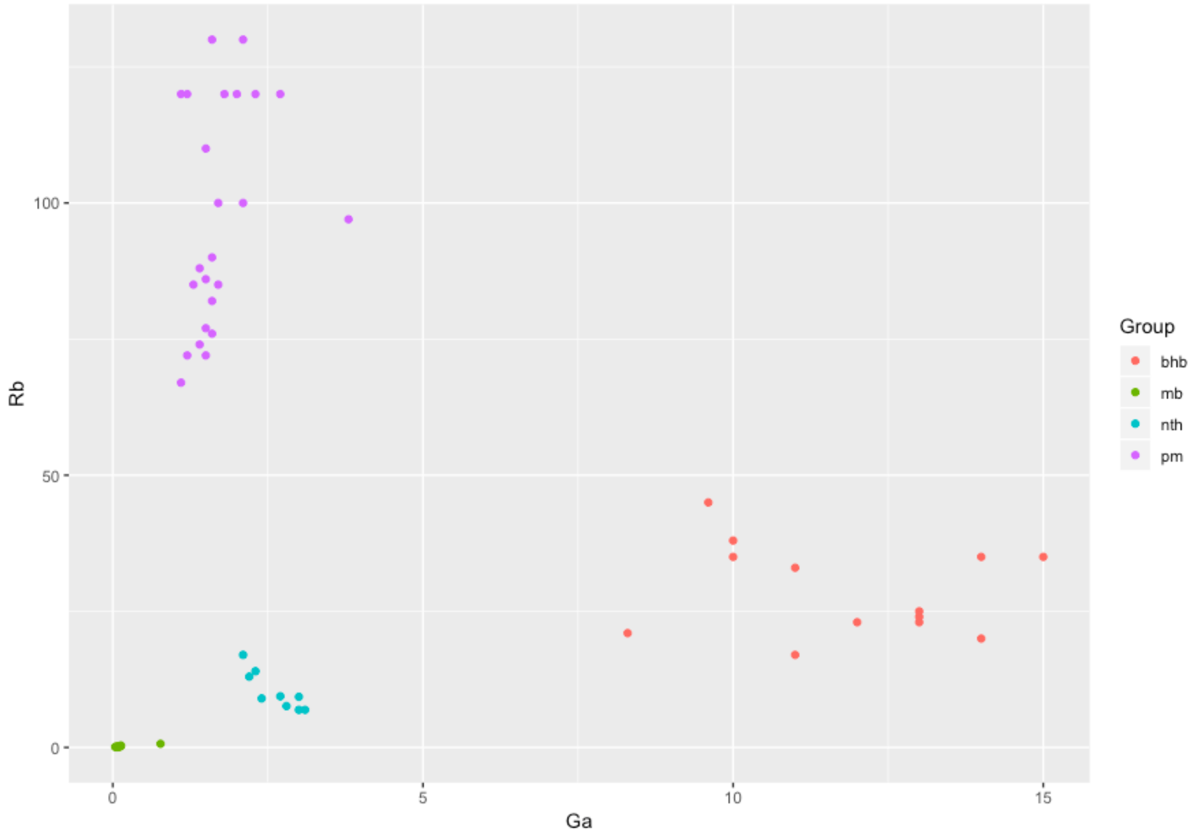


Figure 3 Scatter plot of Ga & Rb by Group

If Figure 2 cannot show that plants grew up in different location does not have similar content of elements, Figure 3 displays that vividly by showing elements of bhb and nth separately in the scatter plots.

All in all, although Figure 2 and 3 almost can answer the question that the chemical composition of plants are specific to the soil types, Figure 1 still leaves the answer in doubt. Thus, in the following section, parametric tests will be used to further investigate this problem.

3 2 Parametric Tests

3 2 1 Element Ti

First, by showing the boxplot of element Ti in Figure 4, it is obvious that plants grew up in mb separate from other three places.

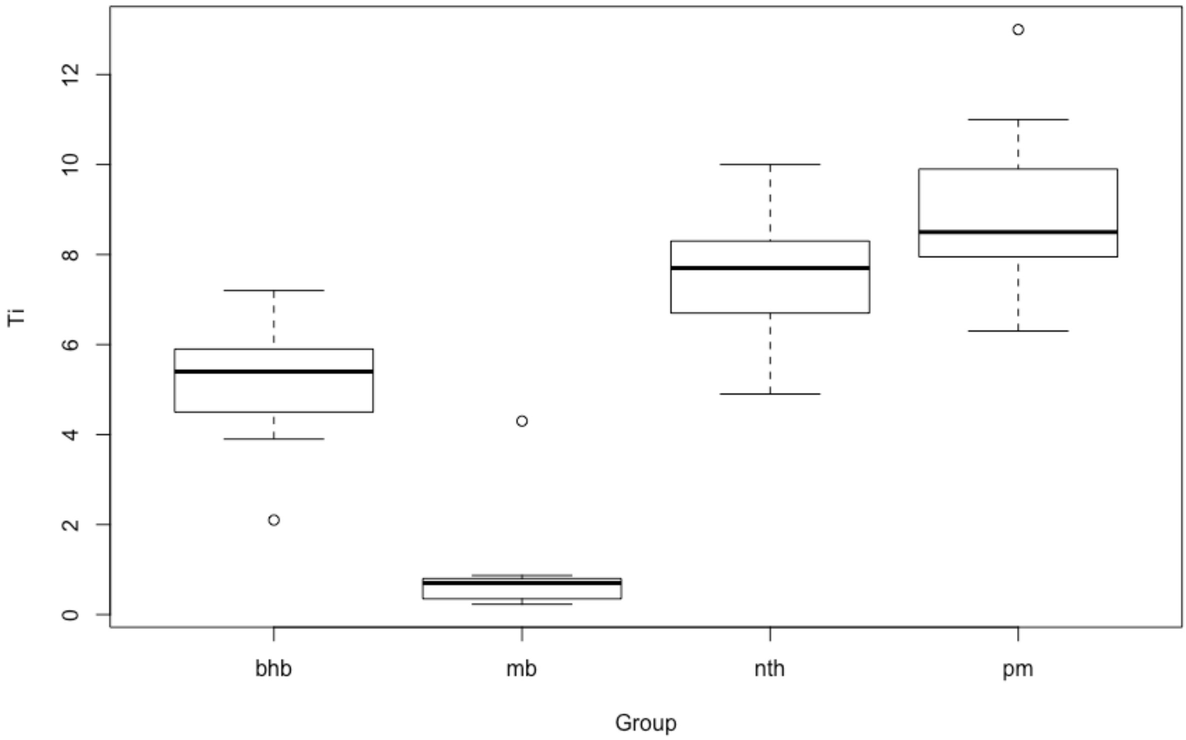


Figure 4 Boxplot of Ti by Group

Then, by operating one-way test and summary of Analysis of Variance (aov) Model for hypothesis testing to the data, the following data displayed as below in Figure 5.

```
        One-way analysis of means (not assuming equal variances)

data:  potplants$Ti and factor(potplants$Group)
F = 89.378, num df = 3.000, denom df = 22.261, p-value = 1.44e-12

                        Df Sum Sq Mean Sq F value Pr(>F)    
 factor(potplants$Group)  3  475.9  158.63   80.05 <2e-16 ***
 Residuals              52  103.0    1.98                   
 ---
 Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Figure 5 One-way test and aov of Ti

From the one-way test, it can be seen that F is 89.378 and P-value is 1.44e-12 which is much smaller than 0.05. And in the aov summary the significance is close to 0, which means to reject H_0, in other words, different soil types do not show same quantity of Ti.

Also, qqPlot is used to conduct normality test of Ti and plot indicates that the data pass the normality test in Figure 6.

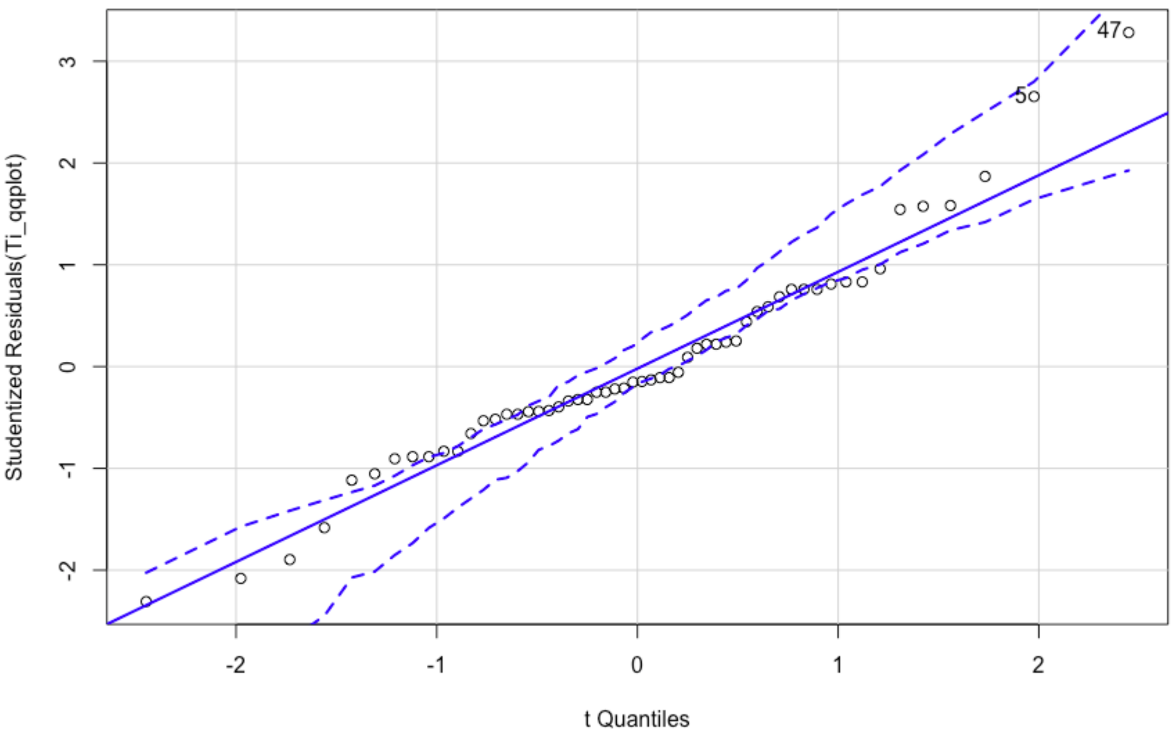


Figure 6 qqPlot of Ti

And then, the Bartlett test can continue conduct homogeneity test of variances as in Figure 8. P-value is 0.8343, which is larger than 0.05, meaning that the variances of data has almost no difference.

```
        Bartlett test of homogeneity of variances

data:  potplants$Ti by factor(potplants$Group)
Bartlett's K-squared = 0.86317, df = 3, p-value = 0.8343
```

Figure 7 Bartlett test of homogeneity of variance of Ti

Last but not least, TurkeyHSD can be used as a post-hoc test as below in Figure 8. The figure verifies that apart from pm and nth that have little correlation, other soil types cannot be grew up with same element.

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

Fit: aov(formula = potplants$Ti ~ factor(potplants$Group))

$`factor(potplants$Group)`
             diff        lwr       upr     p adj
mb-bhb  -4.154000 -5.7255426 -2.582457 0.0000000
nth-bhb  2.477778  0.8576386  4.097917 0.0009308
pm-bhb   3.750000  2.4633587  5.036641 0.0000000
nth-mb   6.631778  4.9150973  8.348458 0.0000000
pm-mb    7.904000  6.4977331  9.310267 0.0000000
pm-nth   1.272222 -0.1881515  2.732596 0.1083757
```

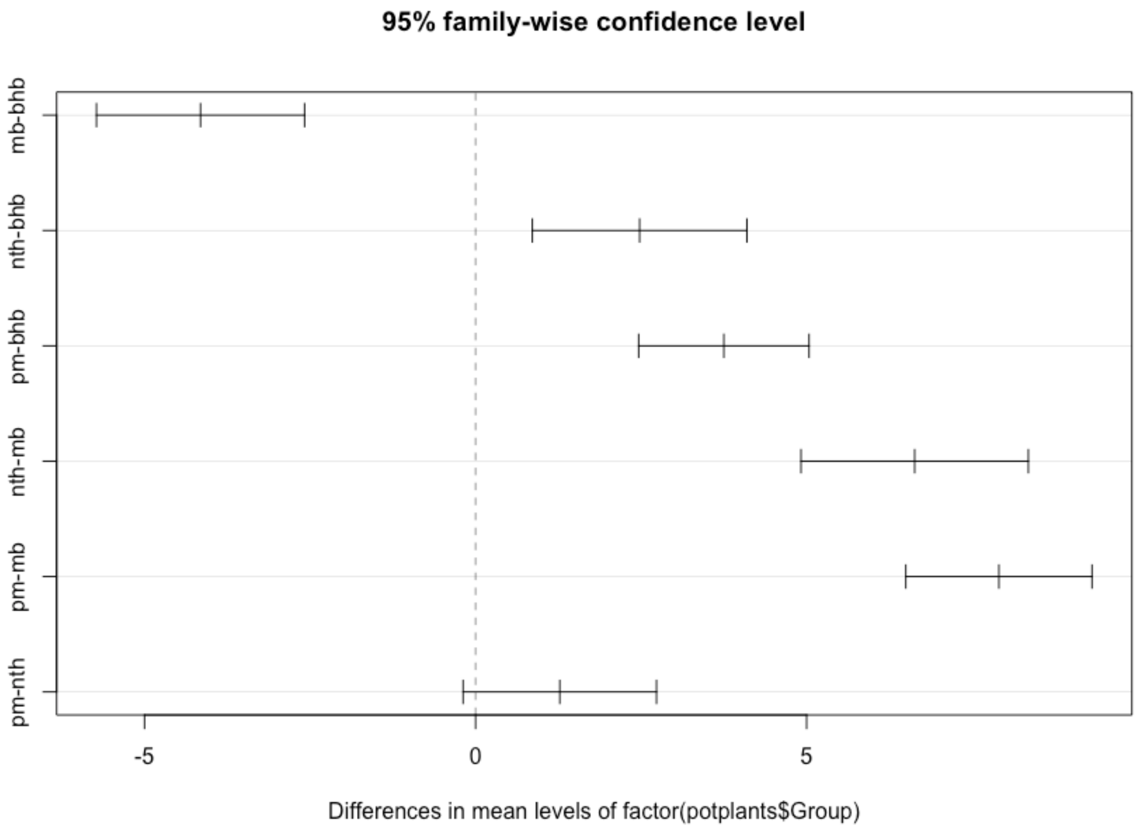


Figure 8 TurkeyHSD of Ti

3 2 2 Element Ga

The boxplot of Ga in Figure 9 vividly shows the discrepancy of Ga of bhb and other three groups. Not only the median, but the whole of data in bhb is much larger than others.

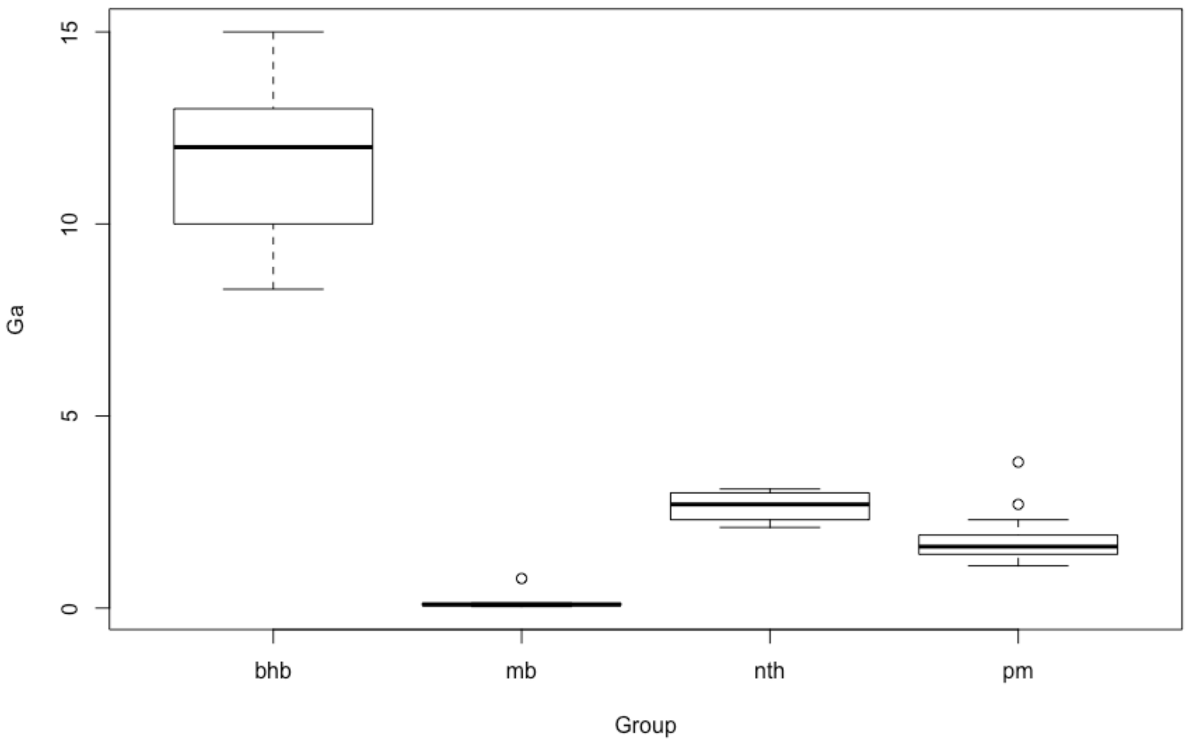


Figure 9 Boxplot of Ga

From the One-way test and aov in Appendix 6 5, F of Ga is 228.12 and P-value is even smaller than 2.2e-16 as well as the significance is almost 0. So, H_0: different soil types can be cultivated plants with similar elements is rejected. But the qqPlot still indicated the data pass normality test while Bartlett Test gives P-value smaller than 8.466e-12 in Appendix 6 6 and 6 7. However, it is worth saying that similar to TurkeyHSD of Ti, the soil type in pm and nth share some correlation in Appendix 6 8.

3 2 3 Element Rb

Figure 11 displays the boxplot of element Rb, which can argue that plants grew up in potting mix (pm) has large differences with other three with Rb.

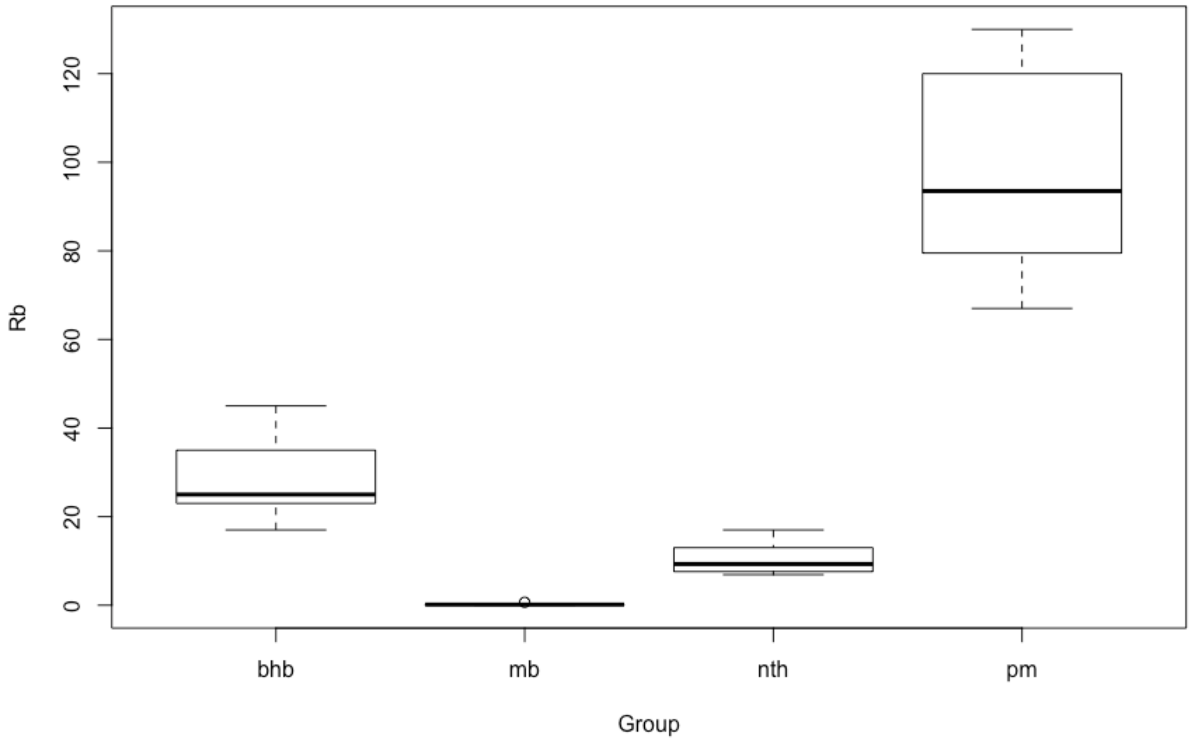


Figure 10 Boxplot of Rb

Also, the One-way Test reveals that F is 235.37 and P-value is 1.023e-15. In addition, aov shows that the significance is almost 0 too in Appendix 6 5. And qqPlot in Appendix 6 6 also passes the normality test. Then, the Bartlett Test in Appendix 6 7 has P-value smaller than 2.2e-16. Thus, the conclusion of Rb can also reject H_0. And in TurkeyHSD in Appendix 6 8, only soil type nth and mb has some similarity.

3 2 4 Element Ta

The last element is Ta, whose boxplot is in Figure 11. Being different from the above three boxplots, the quantity of Ta in different locations seems not have much discrepancy.

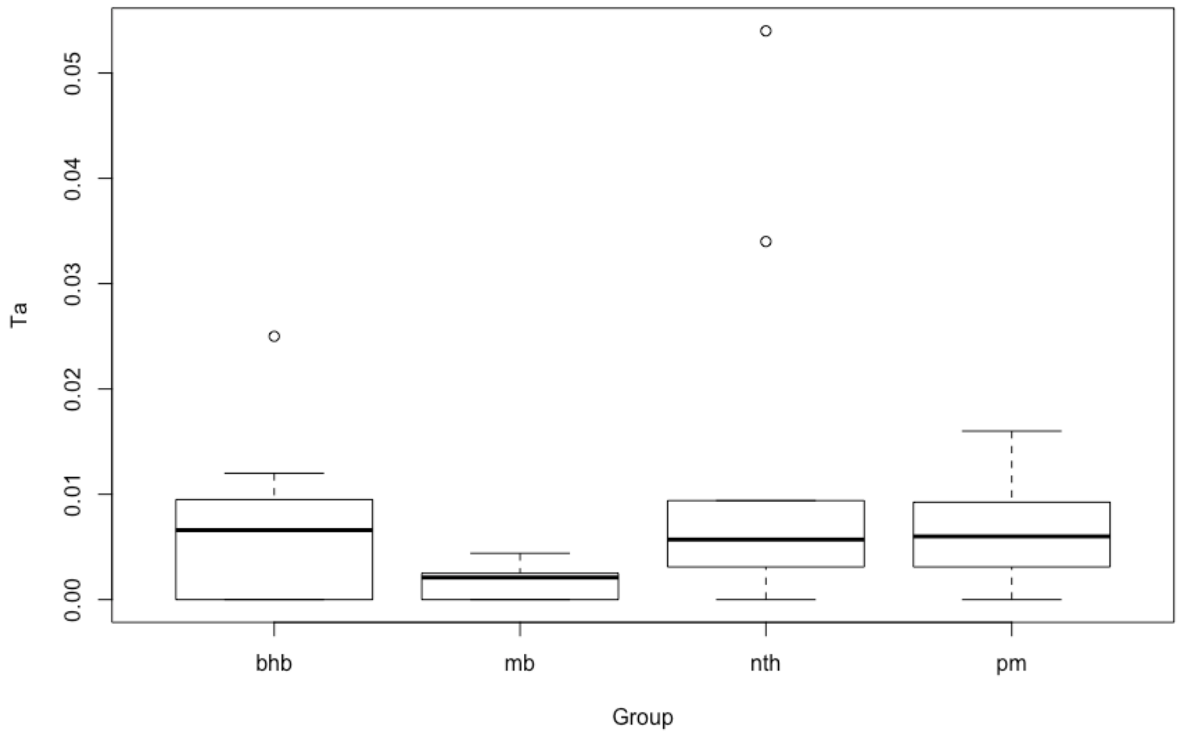


Figure 11 Boxplot of Ta

In order to conduct further research, One-way Test and aov also be used in Appendix 6 5, which has F = 8.5566, P-value = 0.00063 and significance close to 0.01. Despite that compared with the One-way Test and aov of above three elements, these data is much close to the number to accept H_0, it should still be rejected. Also, in Figure 12, the qqPlot of Ta shows that it does not pass the normality test. Therefore, Leneve's Test was used in this case in Appendix 6 7, which shows the significance of variance also close to 0.01. But in the TurkeyHSD, the result shows that only nth and mb do not have correlation, which is interesting in that the result of Rb shows only nth and mb have correlation. However, it proves that chemical compositions are special to soil types.

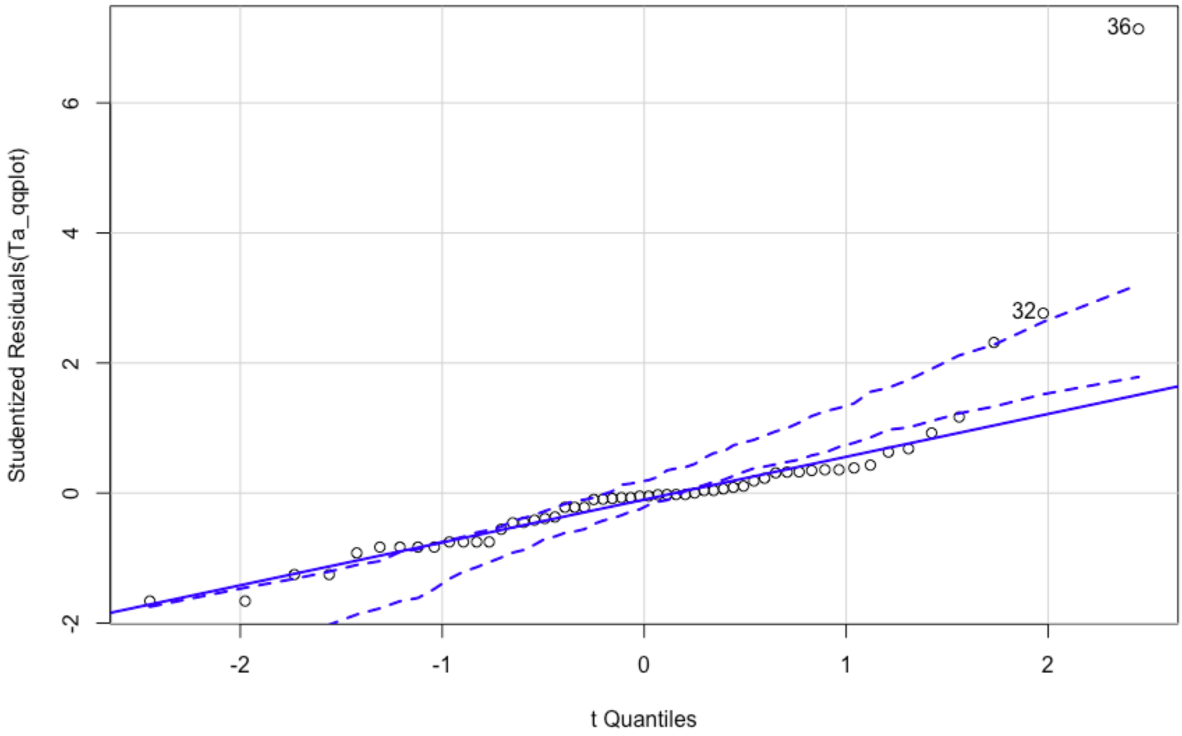


Figure 12 qqPlot of Ta

4 Conclusion

The data do indicate differences in the elemental composition of Cannabis leaves grown in different soil types. Especially, the elemental Ti, Ga and Rb composition indicates differences the elemental composition of Cannabis leaves grown in different soil types very well. Some of the elements do appear to be related to one another in terms of their levels in the sampled leaves. For example, the cannabis leaves with more Ti will also contains more Ta.

From my point of view, the results of this experiment will not ultimately allow the determination of what soil the plants were grown in, just from the elemental composition of the leaves. Because, firstly, this experiment only considers the Cannabis leaves, others plants are not studied yet. Secondly, only 163 samples are studied in this experiment, the result is not enough even to generalised to all the cannabis leaves. Thirdly, no control experiment are designed. Hence, more experiments need be designed on more samples and more plants to ultimately allow the determination of what soil the plants were grown in, just from the elemental composition of the leaves.

5 References

Smith, N. (2000) Criminal may rue pot from this plot. *New Zealand Herald*.

R Core Team. (2015) *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing.

6 Appendix

6 1 CV of data

	Group	Sample.Name	Mg	Al	K	Ca	Sc	Ti	Mn	Fe
1	bhb	NA	0.20894547	0.27725548	0.22729387	0.18214001	0.14308655	0.25852131	0.25941139	0.13057193
2	mb	NA	0.77658978	0.41490943	0.19615105	0.55659026	0.16968667	1.2700562	0.8992204	0.2953103
3	nth	NA	0.05813426	0.16182429	0.06514012	0.16974019	0.09893041	0.21409005	0.20035239	0.07800237
4	pm	NA	0.11856008	0.17048134	0.25361996	0.30023761	0.10553054	0.16347293	0.55121302	0.16183436

	Group	Sample.Name	Ni	Cu	Zn	Ga	Ge	Se	Br	Rb
1	bhb	NA	0.16548143	0.1458956	0.24906305	0.17088442	0.35259285	0.23395405	0.27893245	0.29465394
2	mb	NA	0.24092029	0.41702193	0.29642692	1.41311114	0.41586684	0.35388579	0.13916499	0.9070409
3	nth	NA	0.13548333	0.59439821	0.11993925	0.14493755	0.25458262	0.35670361	0.32786932	0.34137435
4	pm	NA	0.72846835	0.74635268	0.18652522	0.34142564	0.3954666	0.37414669	0.40231341	0.21179332

	Group	Sample.Name	Sr	Y	Mo	Pd	I	Ba	La	Ce
1	bhb	NA	0.16927699	0.28093974	0.38586662	0.23190397	0.17080545	0.14313718	0.39367606	0.41181571
2	mb	NA	0.75066337	0.26506215	0.44034326	0.63218706	0.37260168	0.46327625	0.33595446	0.18437215
3	nth	NA	0.15156886	0.20202881	0.1717282	0.35354521	0.14406042	0.11957338	0.25010151	0.47313285
4	pm	NA	0.27938677	0.25562648	0.37878668	0.52334905	0.36235884	0.21761891	0.15106483	0.31948746

	Group	Sample.Name	Pr	Nd	Sm	Eu	Gd	Tb	Dy
1	bhb	NA	0.42576429	0.35825354	0.31101229	0.18329975	0.28947302	0.29868165	0.39404106
2	mb	NA	0.46015685	0.40509055	0.3422257	0.4156735	0.40127192	0.61943704	0.32828085
3	nth	NA	0.13024503	0.19706482	0.22680451	0.21725422	0.38761112	0.29694852	0.20804458
4	pm	NA	0.15890921	0.22211151	0.29801318	0.27656896	0.2286051	0.27885864	0.25034136

	Group	Sample.Name	Ho	Er	Tm	Yb	Lu	Ta	Th
1	bhb	NA	0.2578084	0.34108678	0.38008414	0.34688514	0.39196215	1.01968741	0.83004991
2	mb	NA	0.53533181	0.33083415	0.4299654	0.22884615	0.368816	0.84032125	0.86255382
3	nth	NA	0.22023715	0.1692508	0.32209978	0.33541499	0.21690966	1.41312638	0.59160798
4	pm	NA	0.22486465	0.30427303	0.23718509	0.27931333	0.2646942	0.68392577	0.61692355

6 2 Summary of potplants

Sample.Na	Group	Mg	Al	K	Ca	Sc	Ti	Mn	Fe
R1 H2 PMC :	bhb:13	Min. : 4	Min. : 8.6	Min. : 85	Min. : 28	Min. :0.1900	Min. : 0.230	Min. : 0.36	Min. : 35.0
R1 H3 BHBC/M	mb :10	1st Qu.:19000	1st Qu.:25.0	1st Qu.:16000	1st Qu.:21500	1st Qu.:0.6475	1st Qu.: 4.725	1st Qu.: 240.00	1st Qu.:385.0
R1 H3 PMC/M/	nth: 9	Median :26500	Median :29.0	Median :19500	Median :35000	Median :0.7300	Median : 7.100	Median : 315.00	Median :435.0
R1 H4 BHB2/M	pm :24	Mean :23791	Mean :32.6	Mean :18896	Mean :36426	Mean :0.6593	Mean : 6.364	Mean : 399.67	Mean :406.2
R1 H4 BHB5/M	NA	3rd Qu.:30250	3rd Qu.:37.5	3rd Qu.:27250	3rd Qu.:56500	3rd Qu.:0.7825	3rd Qu.: 8.500	3rd Qu.: 440.00	3rd Qu.:532.5
R1 H4 PM2/M	NA	Max. :56000	Max. :83.0	Max. :36000	Max. :81000	Max. :1.0000	Max. :13.000	Max. :1200.00	Max. :640.0

Sample.Na	Group	Ni	Cu	Zn	Ga	Ge	Se	Br	Rb
R1 H2 PMC :	bhb:13	Min. : 0.530	Min. : 1.00	Min. : 2.6	Min. : 0.040	Min. :0.0580	Min. : 1.400	Min. : 6.40	Min. : 0.040
R1 H3 BHBC/M	mb :10	1st Qu.: 1.775	1st Qu.: 33.00	1st Qu.: 277.5	1st Qu.: 1.275	1st Qu.:0.3025	1st Qu.: 3.875	1st Qu.:21.00	1st Qu.: 9.225
R1 H3 PMC/M/	nth: 9	Median : 2.100	Median : 44.00	Median : 380.0	Median : 1.900	Median :0.4550	Median : 5.800	Median :25.50	Median : 35.000
R1 H4 BHB2/M	pm :24	Mean : 2.259	Mean : 44.18	Mean : 523.1	Mean : 3.935	Mean :0.4478	Mean : 5.752	Mean :27.29	Mean : 50.182
R1 H4 BHB5/M	NA	3rd Qu.: 2.700	3rd Qu.: 51.25	3rd Qu.: 512.5	3rd Qu.: 3.275	3rd Qu.:0.5975	3rd Qu.: 7.300	3rd Qu.:33.00	3rd Qu.: 86.500
R1 H4 PM2/M	NA	Max. :10.000	Max. :240.00	Max. :1900.0	Max. :15.000	Max. :1.2000	Max. :14.000	Max. :63.00	Max. :130.000

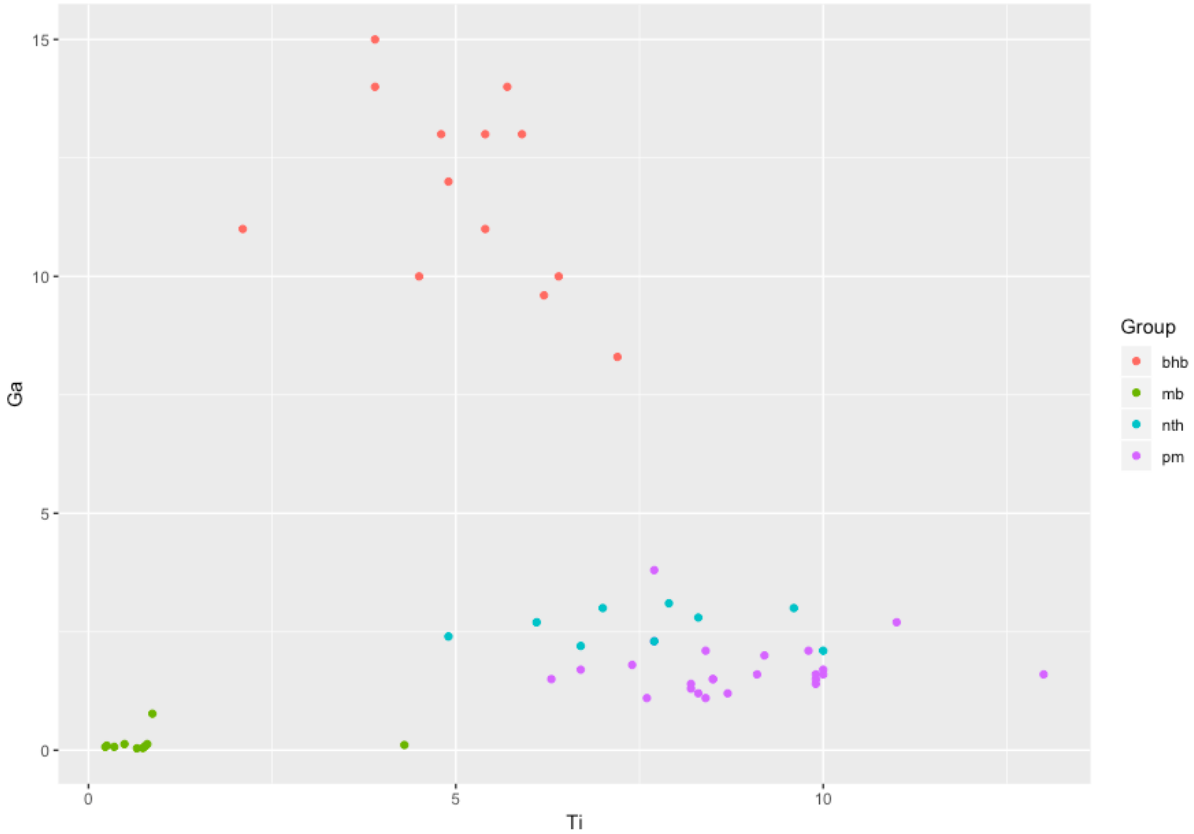
Sample.Na	Group	Sr	Y	Mo	Pd	I	Ba	La	Ce
R1 H2 PMC :	bhb:13	Min. : 0.1	Min. :0.01100	Min. : 0.072	Min. :0.00000	Min. : 0.420	Min. : 0.37	Min. :0.00340	Min. :0.0230
R1 H3 BHBC/M	mb :10	1st Qu.:217.5	1st Qu.:0.04300	1st Qu.: 0.585	1st Qu.:0.05175	1st Qu.: 6.300	1st Qu.: 58.25	1st Qu.:0.07400	1st Qu.:0.0865
R1 H3 PMC/M/	nth: 9	Median :340.0	Median :0.06100	Median : 1.950	Median :0.10500	Median : 9.850	Median : 79.00	Median :0.09400	Median :0.1100
R1 H4 BHB2/M	pm :24	Mean :380.7	Mean :0.06032	Mean : 3.438	Mean :0.12330	Mean : 9.037	Mean :161.84	Mean :0.08339	Mean :0.1123
R1 H4 BHB5/M	NA	3rd Qu.:557.5	3rd Qu.:0.08425	3rd Qu.: 5.500	3rd Qu.:0.18500	3rd Qu.:12.250	3rd Qu.:130.00	3rd Qu.:0.10250	3rd Qu.:0.1400
R1 H4 PM2/M	NA	Max. :910.0	Max. :0.11000	Max. :11.000	Max. :0.32000	Max. :20.000	Max. :580.00	Max. :0.22000	Max. :0.3200

Sample.Na	Group	Pr	Nd	Sm	Eu	Gd	Tb	Dy	
R1 H2 PMC :	bhb:13	Min. :0.00100	Min. :0.00280	Min. :0.00480	Min. :0.00120	Min. :0.00450	Min. :0.000700	Min. :0.00340	
R1 H3 BHBC/M	mb :10	1st Qu.:0.01175	1st Qu.:0.04575	1st Qu.:0.02900	1st Qu.:0.01300	1st Qu.:0.02700	1st Qu.:0.004075	1st Qu.:0.01875	
R1 H3 PMC/M/	nth: 9	Median :0.01700	Median :0.06350	Median :0.04200	Median :0.01900	Median :0.04300	Median :0.006150	Median :0.02900	
R1 H4 BHB2/M	pm :24	Mean :0.01507	Mean :0.05834	Mean :0.03848	Mean :0.02252	Mean :0.03891	Mean :0.005698	Mean :0.02739	
R1 H4 BHB5/M	NA	3rd Qu.:0.02000	3rd Qu.:0.08050	3rd Qu.:0.05225	3rd Qu.:0.02825	3rd Qu.:0.05125	3rd Qu.:0.007525	3rd Qu.:0.03725	
R1 H4 PM2/M	NA	Max. :0.03100	Max. :0.10000	Max. :0.07200	Max. :0.06300	Max. :0.08600	Max. :0.010000	Max. :0.05100	

Sample.Na	Group	Ho	Er	Tm	Yb	Lu	Ta	Th	
R1 H2 PMC :	bhb:13	Min. :0.00100	Min. :0.00300	Min. :0.000900	Min. :0.00540	Min. :0.001000	Min. :0.000000	Min. :0.00000	
R1 H3 BHBC/M	mb :10	1st Qu.:0.00645	1st Qu.:0.01500	1st Qu.:0.004025	1st Qu.:0.02100	1st Qu.:0.005550	1st Qu.:0.001850	1st Qu.:0.01045	
R1 H3 PMC/M/	nth: 9	Median :0.00790	Median :0.02050	Median :0.006350	Median :0.02950	Median :0.007550	Median :0.005700	Median :0.01750	
R1 H4 BHB2/M	pm :24	Mean :0.00738	Mean :0.01954	Mean :0.005989	Mean :0.03012	Mean :0.007039	Mean :0.006700	Mean :0.02094	
R1 H4 BHB5/M	NA	3rd Qu.:0.00945	3rd Qu.:0.02625	3rd Qu.:0.008025	3rd Qu.:0.03925	3rd Qu.:0.008775	3rd Qu.:0.008975	3rd Qu.:0.03100	
R1 H4 PM2/M	NA	Max. :0.01400	Max. :0.03900	Max. :0.011000	Max. :0.06000	Max. :0.016000	Max. :0.054000	Max. :0.07000	

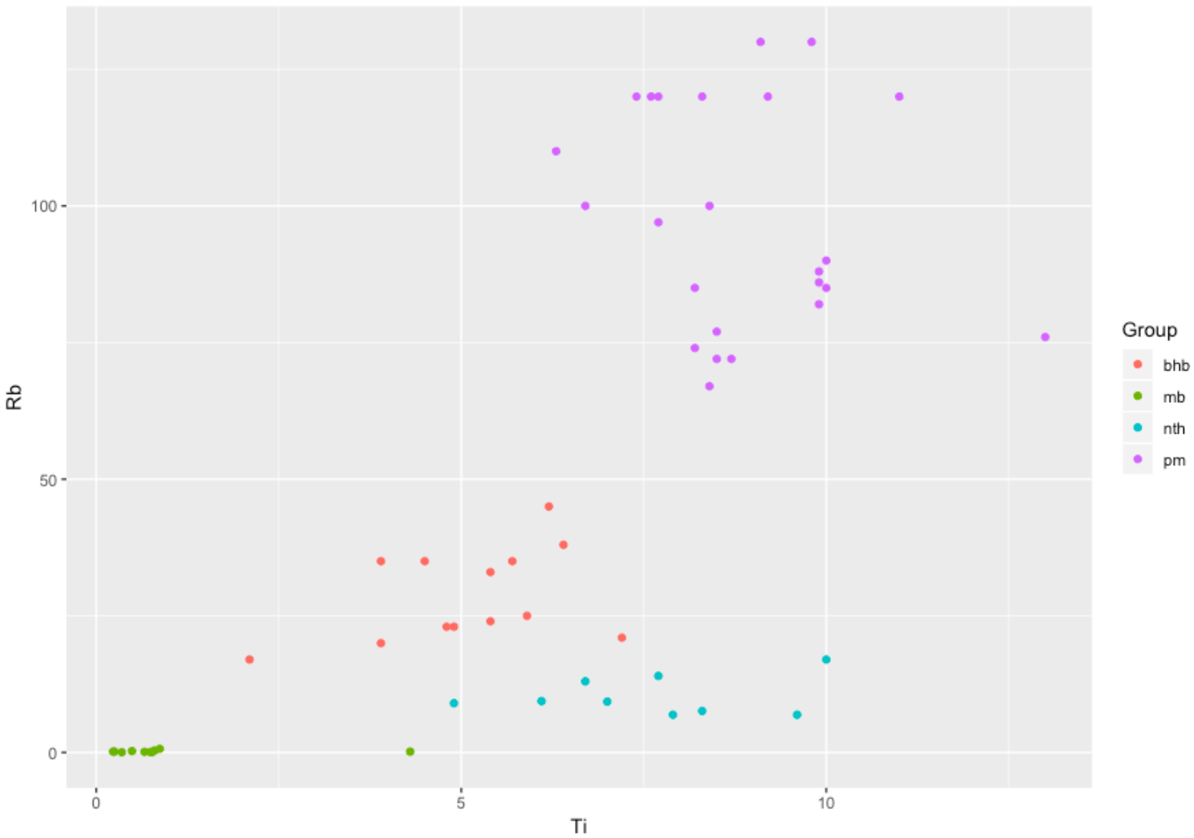
6 3 Scatter plots of pairs of elements by Group

6 3 1 Ti_Ga



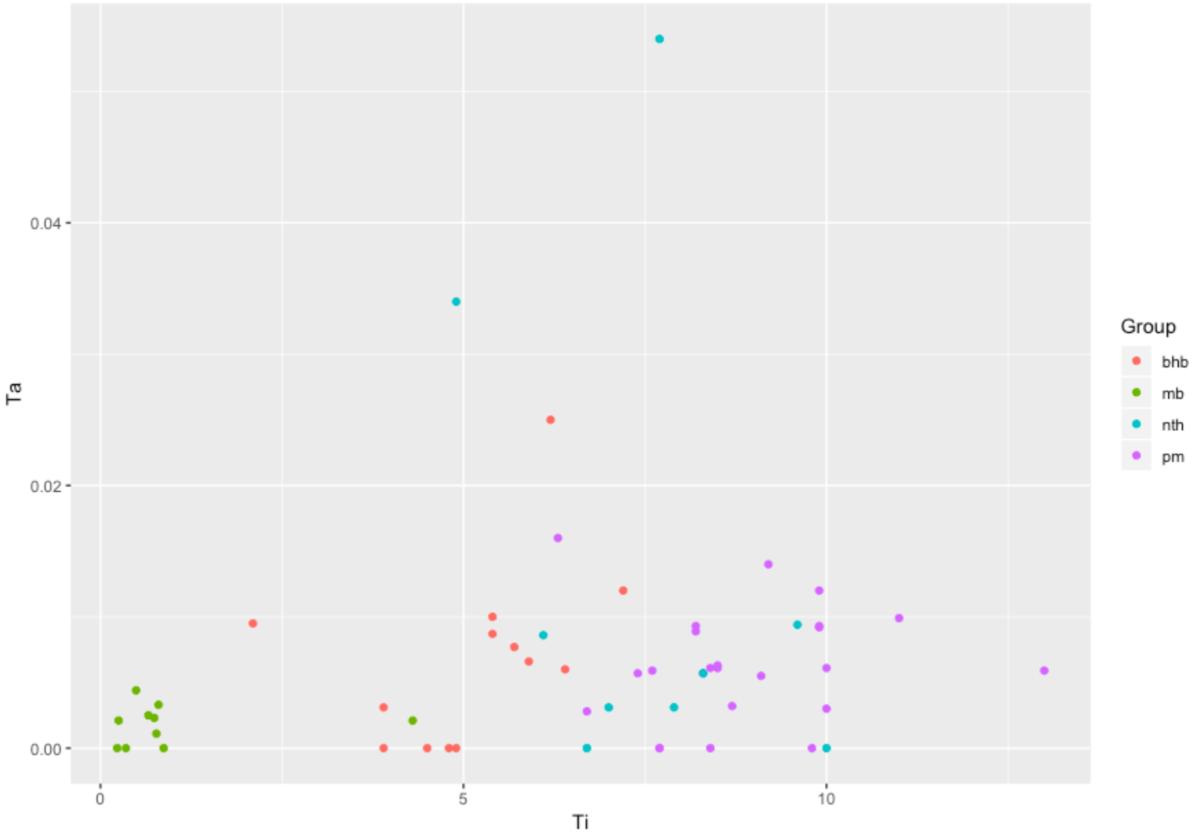
15
10
5
0
Ga
0
5
10
Ti
Group
bhb
mb
nth
pm

6 3 2 Ti_Rb

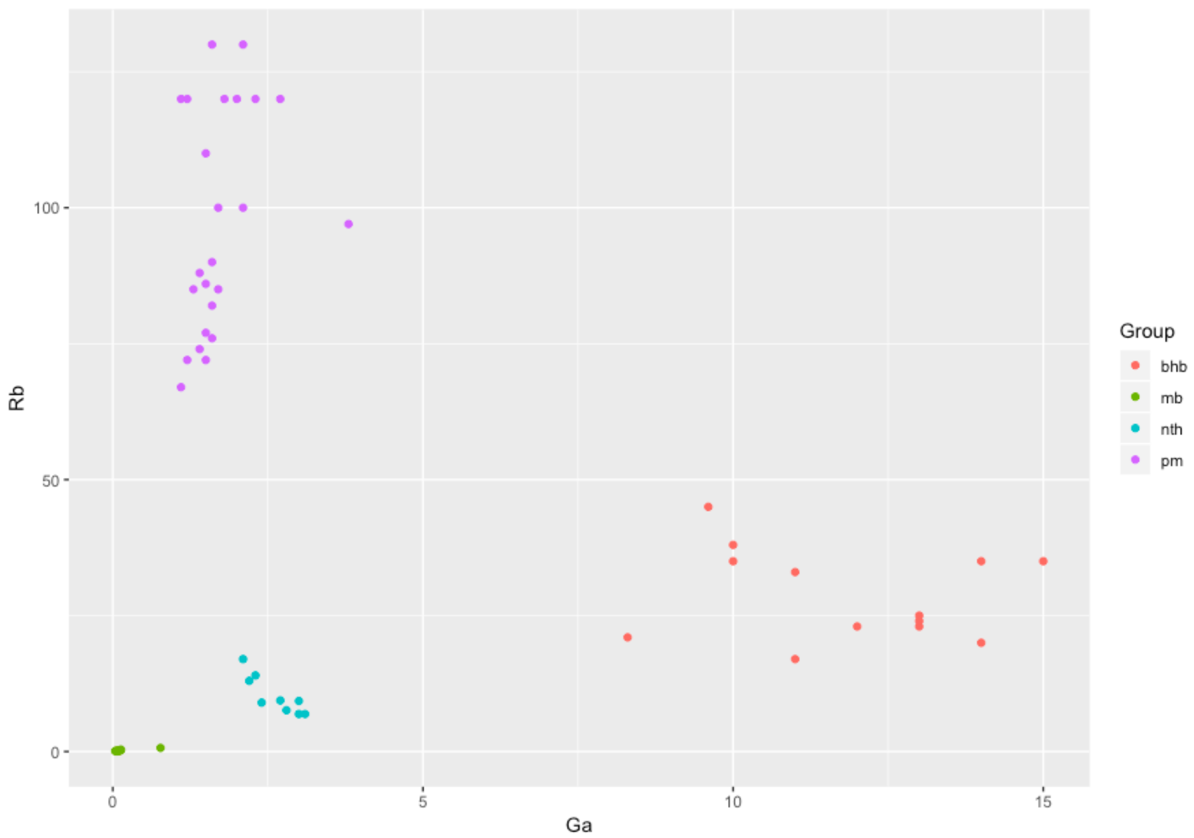


100
50
0
Rb
0
5
10
Ti
Group
bhb
mb
nth
pm

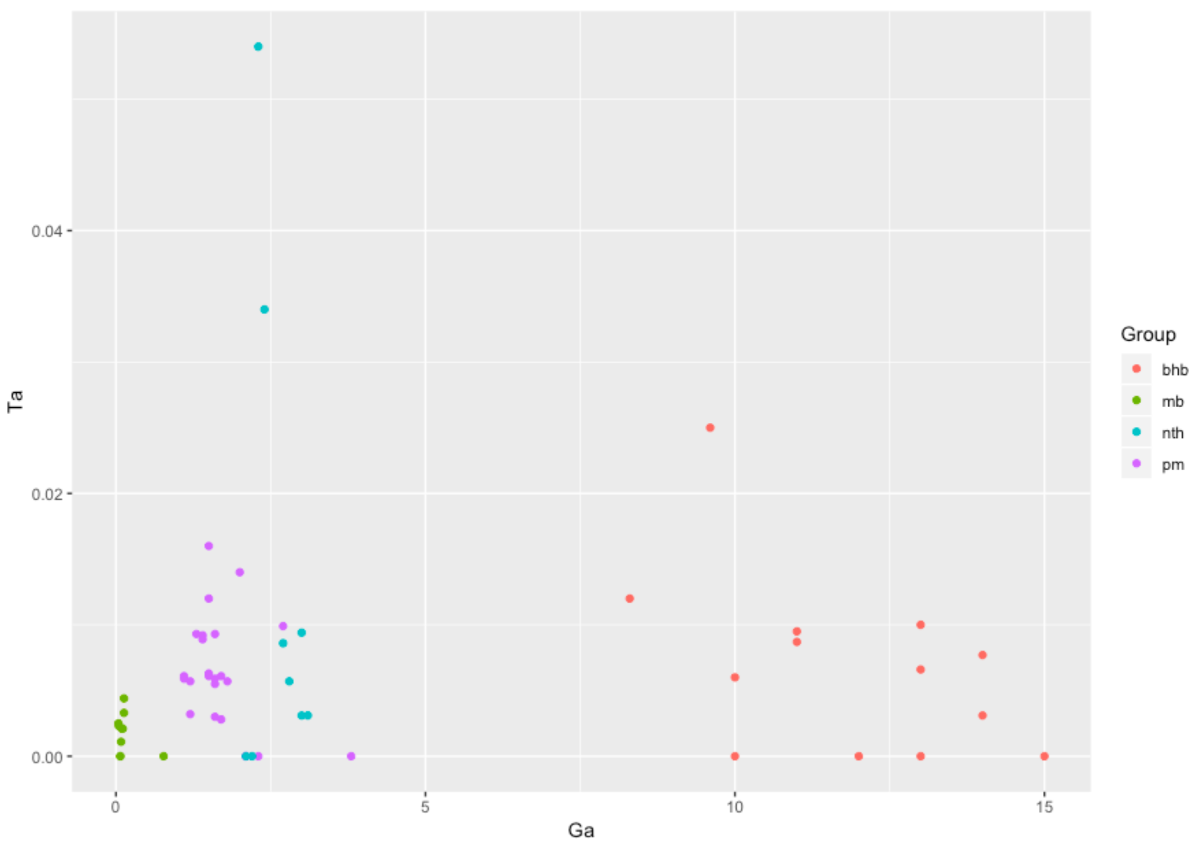
6 3 3 Ti_Ta



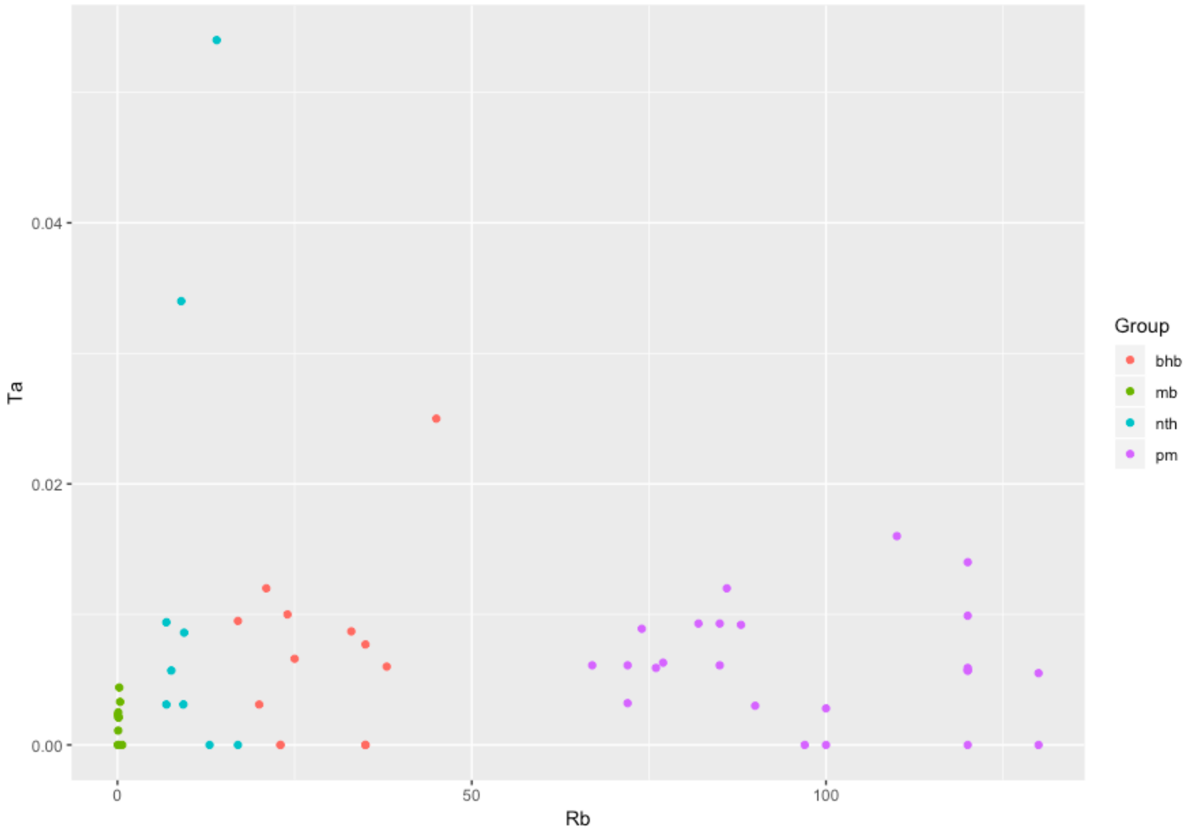
6 3 4 Ga_Rb


Rb
100
50
0
0
5
10
15
Ga
Group
bhb
mb
nth
pm

6 3 5 Ga_Ta

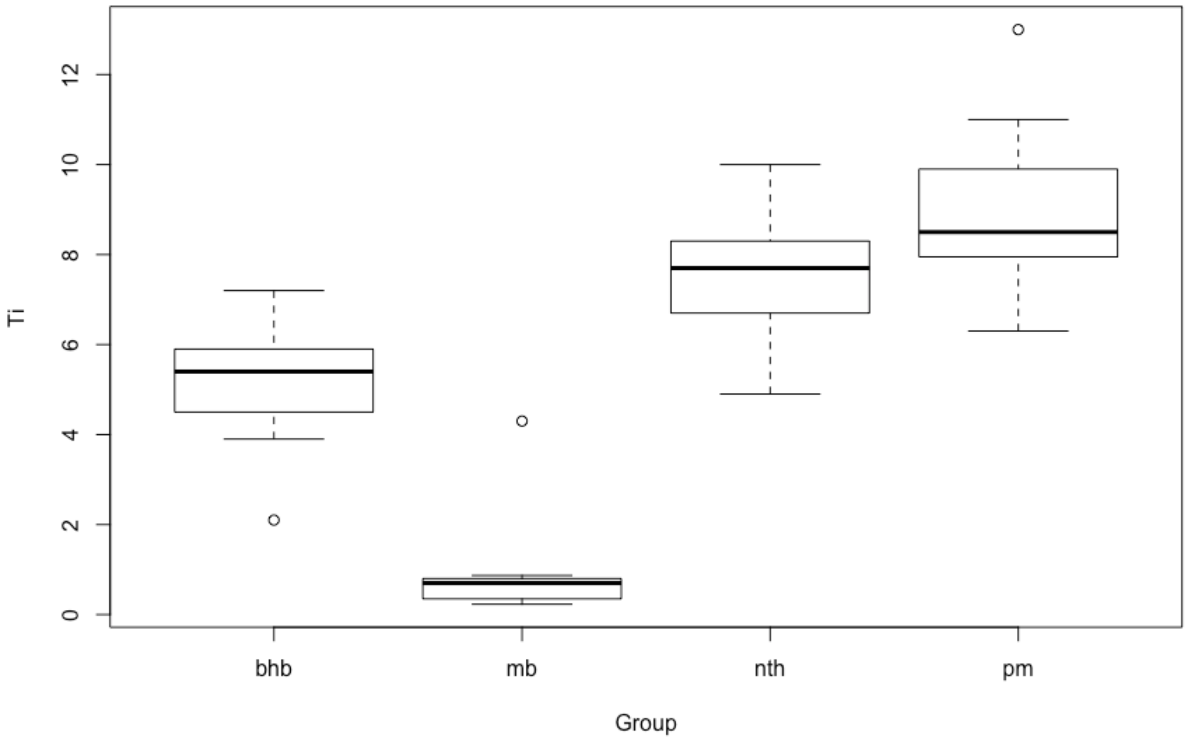

Ta
0.04
0.02
0.00
0
5
10
15
Ga
Group
bhb
mb
nth
pm

6 3 6 Rb_Ta

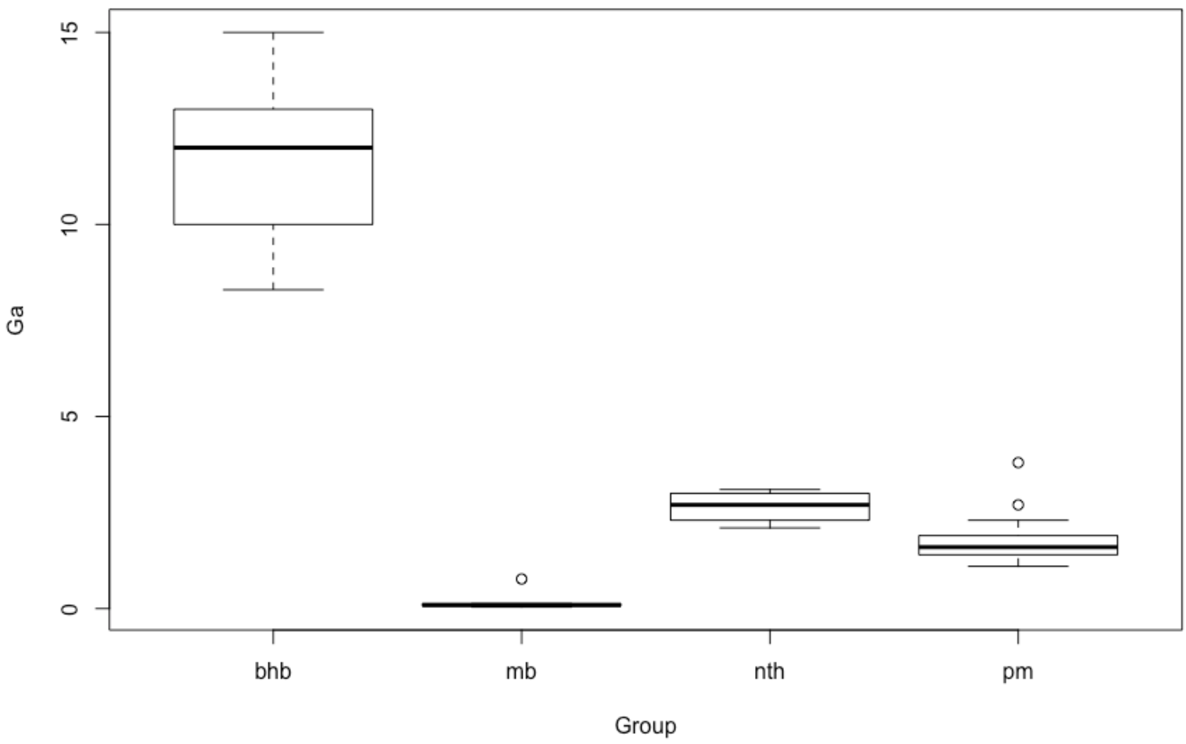


6 4 Boxplot

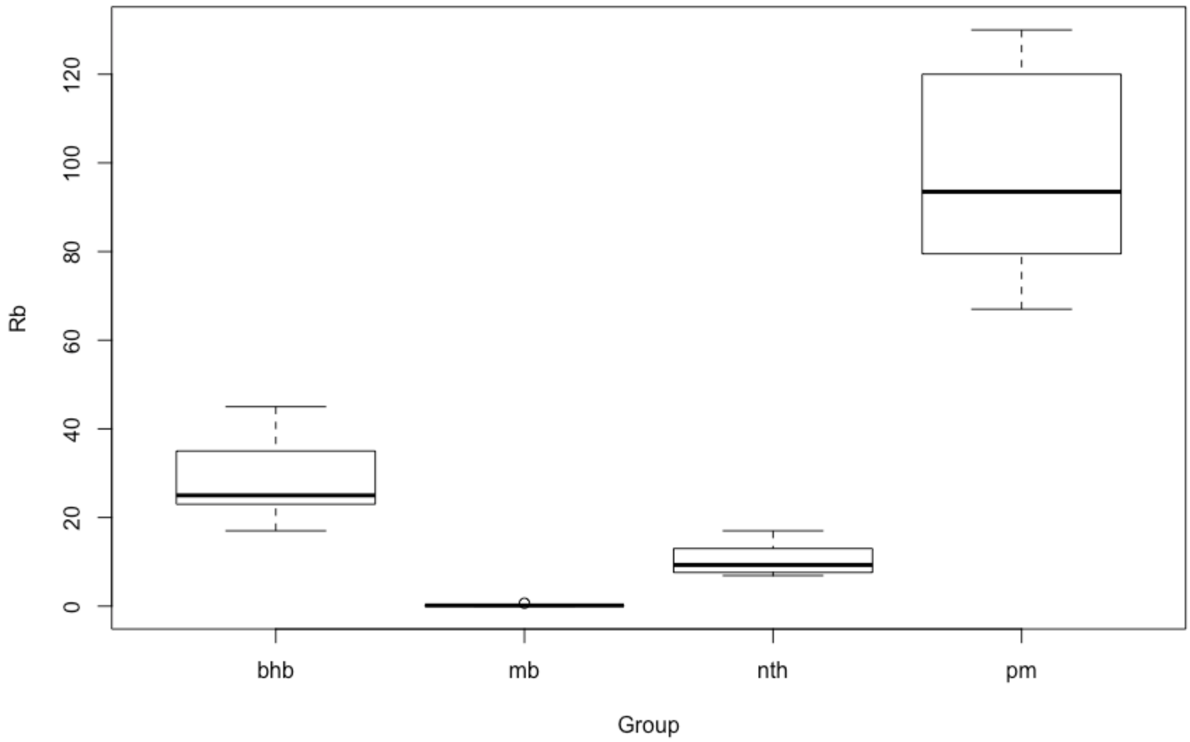
6 4 1 Boxplot of Ti



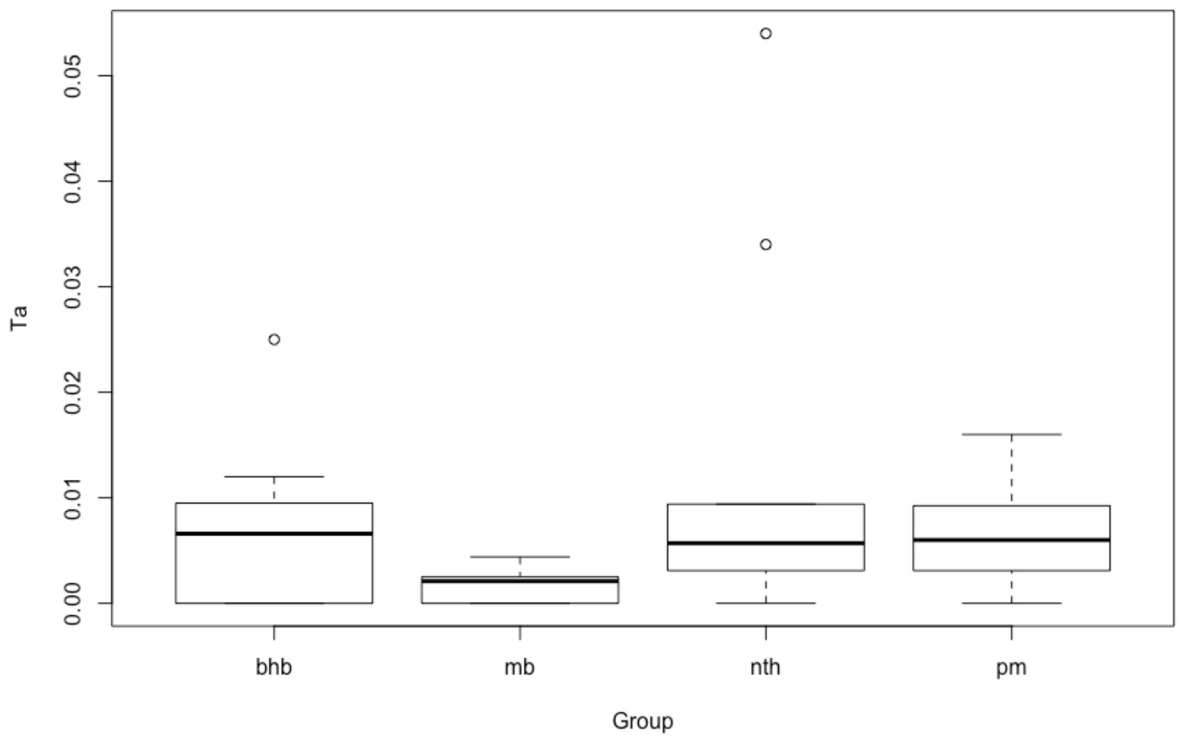
6 4 2 Boxplot of Ga



6 4 3 Boxplot of Rb



6 4 4 Boxplot of Ta



6 5 One-way Test and aov

6 5 1 One-way Test and aov of Ti

```
        One-way analysis of means (not assuming equal variances)

data:  potplants$Ti and factor(potplants$Group)
F = 89.378, num df = 3.000, denom df = 22.261, p-value = 1.44e-12

                         Df Sum Sq Mean Sq F value Pr(>F)    
factor(potplants$Group)  3  475.9  158.63   80.05 <2e-16 ***
Residuals               52  103.0    1.98                   
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

6 5 2 One-way Test and aov of Ga

```
        One-way analysis of means (not assuming equal variances)

data:  potplants$Ga and factor(potplants$Group)
F = 228.12, num df = 3.000, denom df = 23.759, p-value <
2.2e-16

                         Df Sum Sq Mean Sq F value Pr(>F)    
factor(potplants$Group)  3 1088.1   362.7   321.7 <2e-16 ***
Residuals               52   58.6     1.1                   
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

6 5 3 One-way Test and aov of Rb

```
        One-way analysis of means (not assuming equal variances)

data:  potplants$Rb and factor(potplants$Group)
F = 235.37, num df = 3.000, denom df = 19.916, p-value =
1.023e-15
```

```
                           Df Sum Sq Mean Sq F value Pr(>F)    
factor(potplants$Group)  3  99049   33016   159.3 <2e-16 ***
Residuals               52  10778     207                   
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

6 5 4 One-way Test and aov of Ta

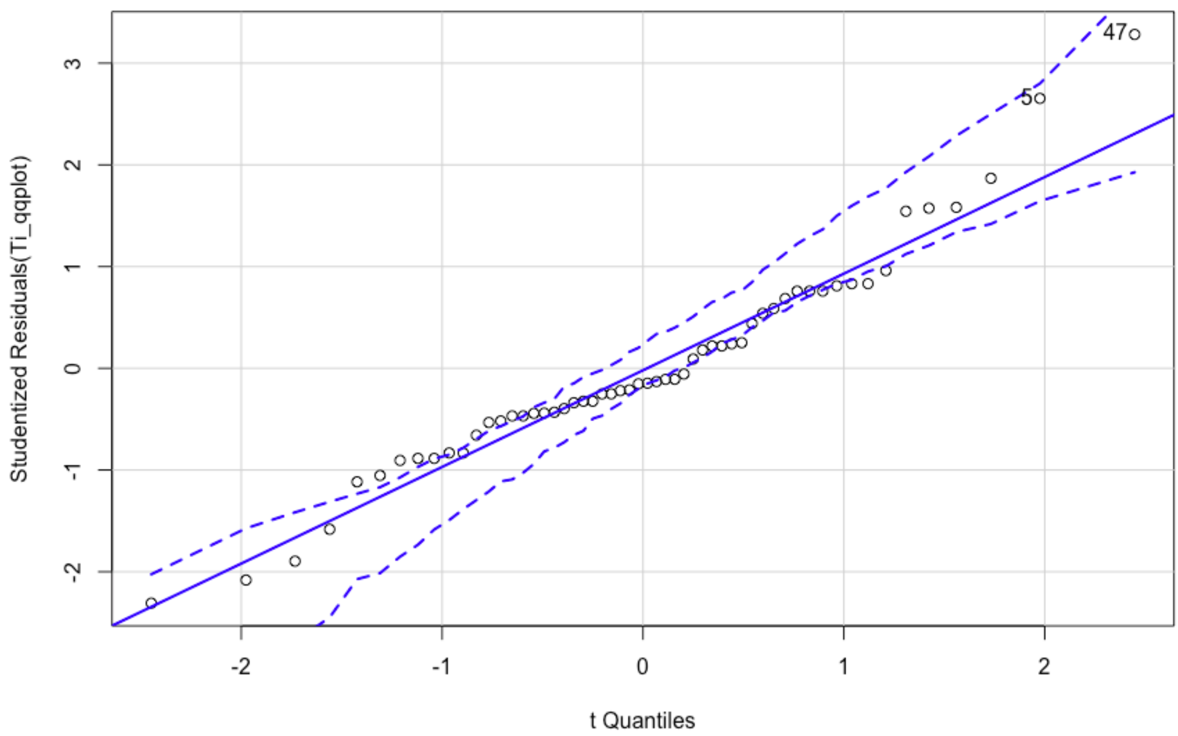
```
        One-way analysis of means (not assuming equal variances)

data:  potplants$Ta and factor(potplants$Group)
F = 8.5566, num df = 3.000, denom df = 21.318, p-value =
0.0006398
```

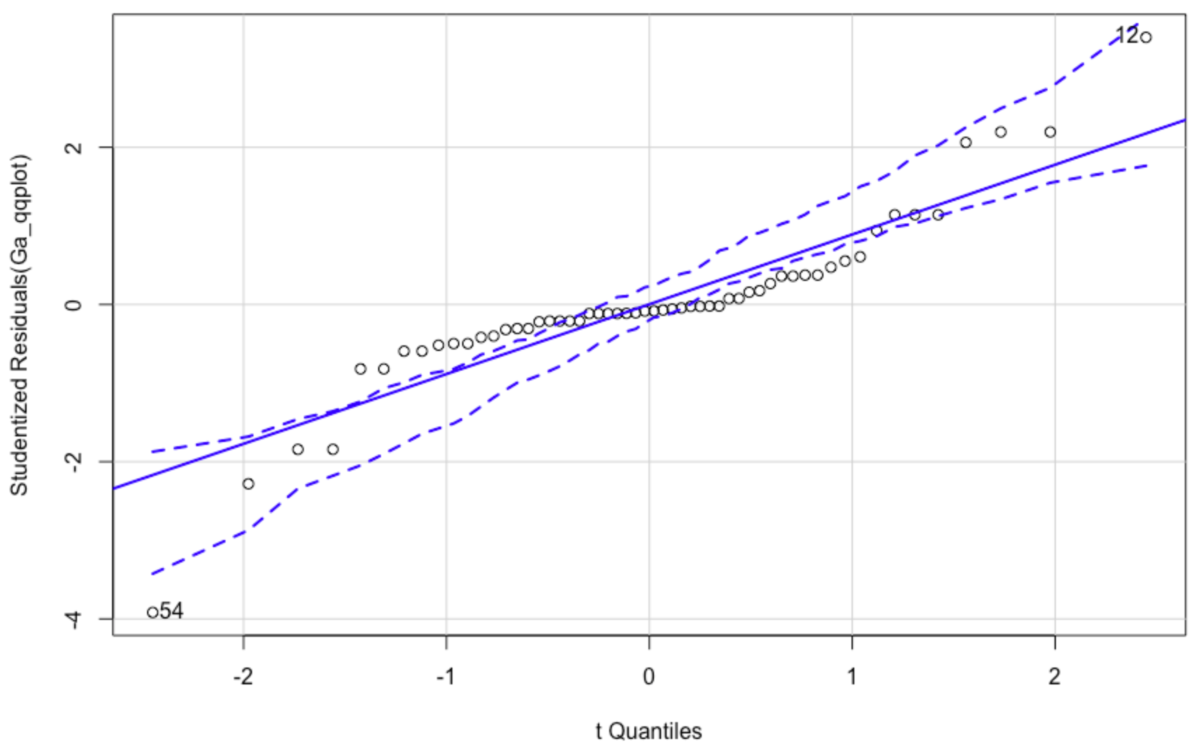
```
                           Df   Sum Sq   Mean Sq F value Pr(>F)  
factor(potplants$Group)  3 0.000615 2.050e-04    2.83 0.0473 *
Residuals               52 0.003767 7.243e-05                 
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

6 6 qqPlot

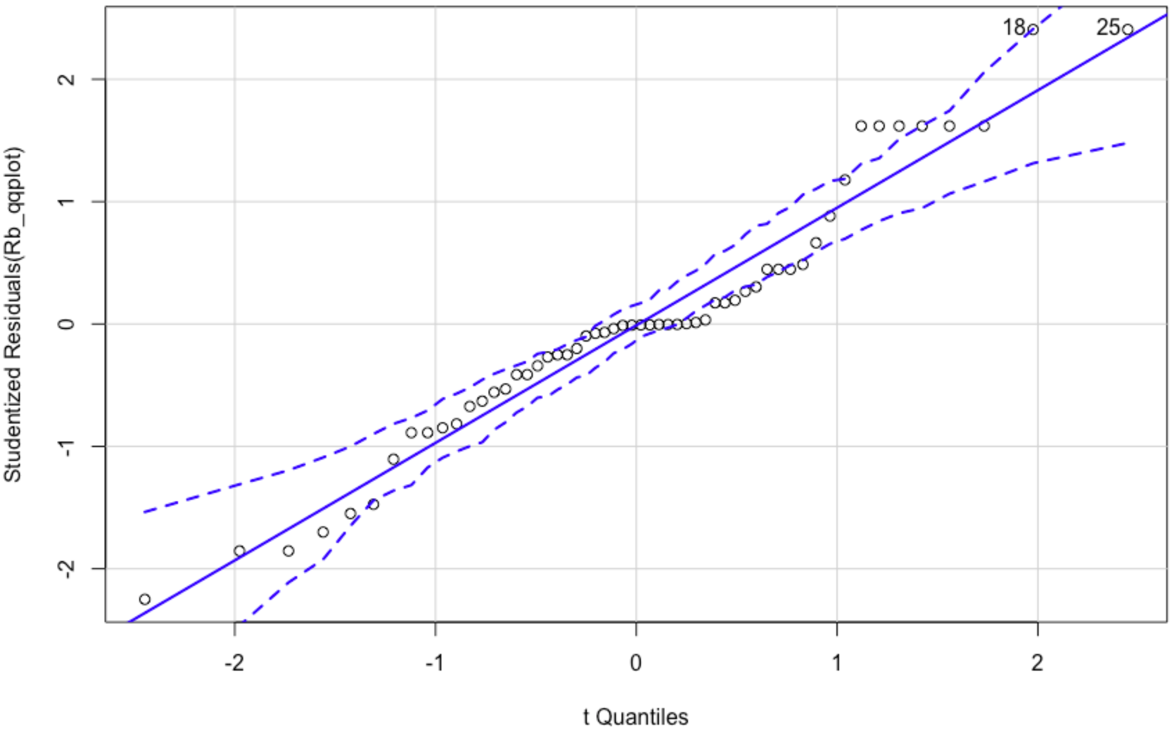
6 6 1 qqPlot of Ti



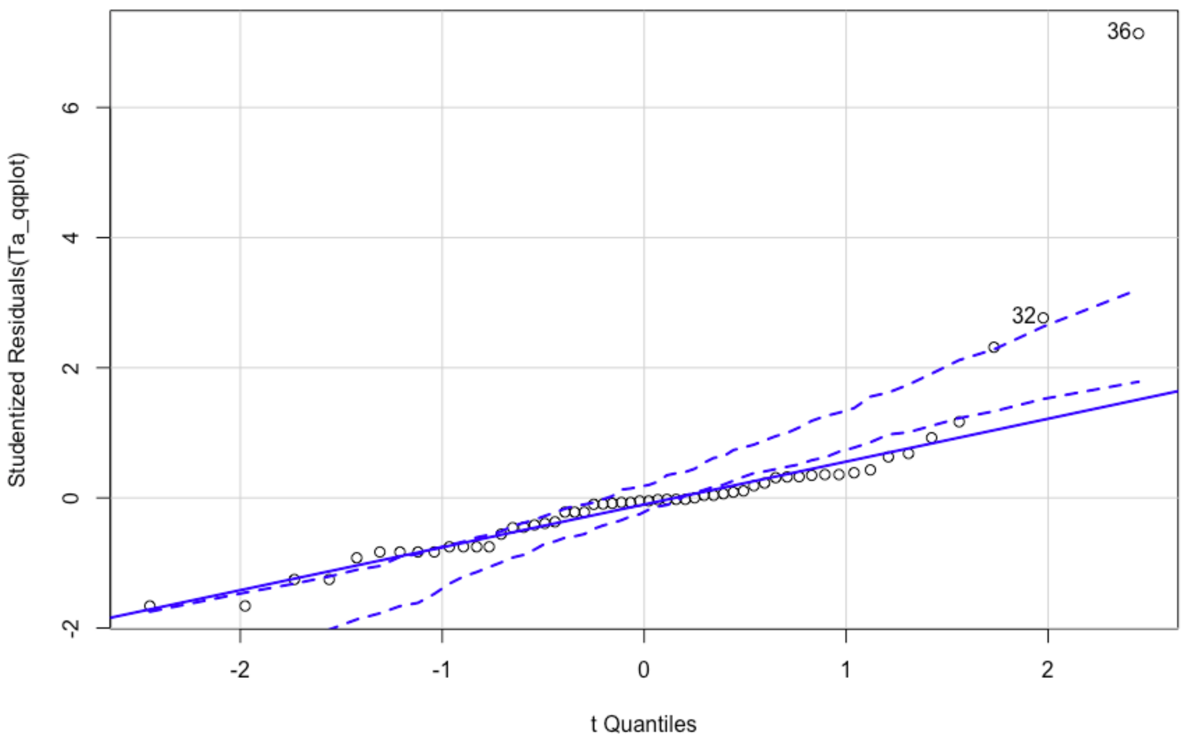
6 6 2 qqPlot of Ga



6 6 3 qqPlot of Rb



6 6 4 qqPlot of Ta



6 7 Bartlett Test/ Levene's Test

6 7 1 Bartlett Test of Ti

```
        Bartlett test of homogeneity of variances

data:  potplants$Ti by factor(potplants$Group)
Bartlett's K-squared = 0.86317, df = 3, p-value = 0.8343
```

6 7 2 Bartlett Test of Ga

```
        Bartlett test of homogeneity of variances

data:  potplants$Ga by factor(potplants$Group)
Bartlett's K-squared = 54.573, df = 3, p-value = 8.466e-12
```

6 7 3 Bartlett Test of Rb

```
        Bartlett test of homogeneity of variances

data:  potplants$Rb by factor(potplants$Group)
Bartlett's K-squared = 93.118, df = 3, p-value < 2.2e-16
```

6 7 4 Levene's Test of Ta

```
Levene's Test for Homogeneity of Variance (center = median)
      Df F value  Pr(>F)
group  3  3.6753 0.01779 *
      52
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

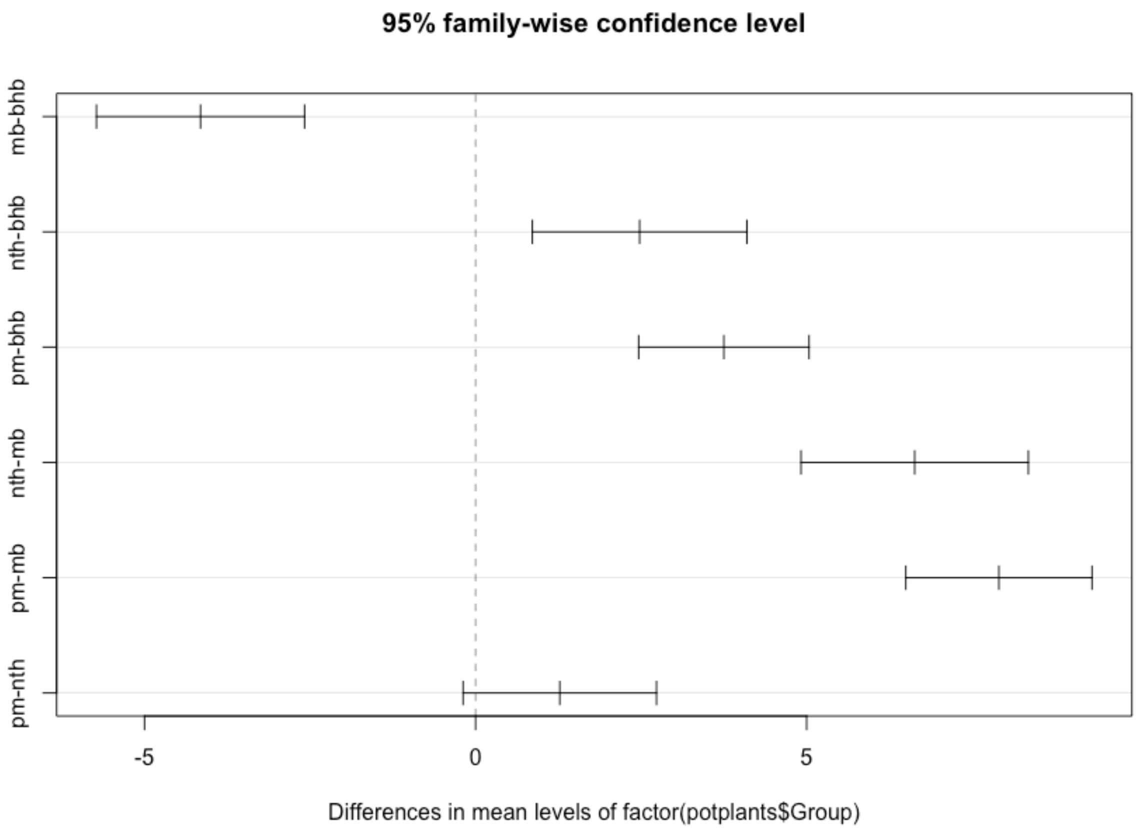
6 8 TurkeyHSD

6 8 1 TurkeyHSD of Ti

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

Fit: aov(formula = potplants$Ti ~ factor(potplants$Group))

$`factor(potplants$Group)`
             diff        lwr       upr     p adj
mb-bhb  -4.154000 -5.7255426 -2.582457 0.0000000
nth-bhb  2.477778  0.8576386  4.097917 0.0009308
pm-bhb   3.750000  2.4633587  5.036641 0.0000000
nth-mb   6.631778  4.9150973  8.348458 0.0000000
pm-mb    7.904000  6.4977331  9.310267 0.0000000
pm-nth   1.272222 -0.1881515  2.732596 0.1083757
```

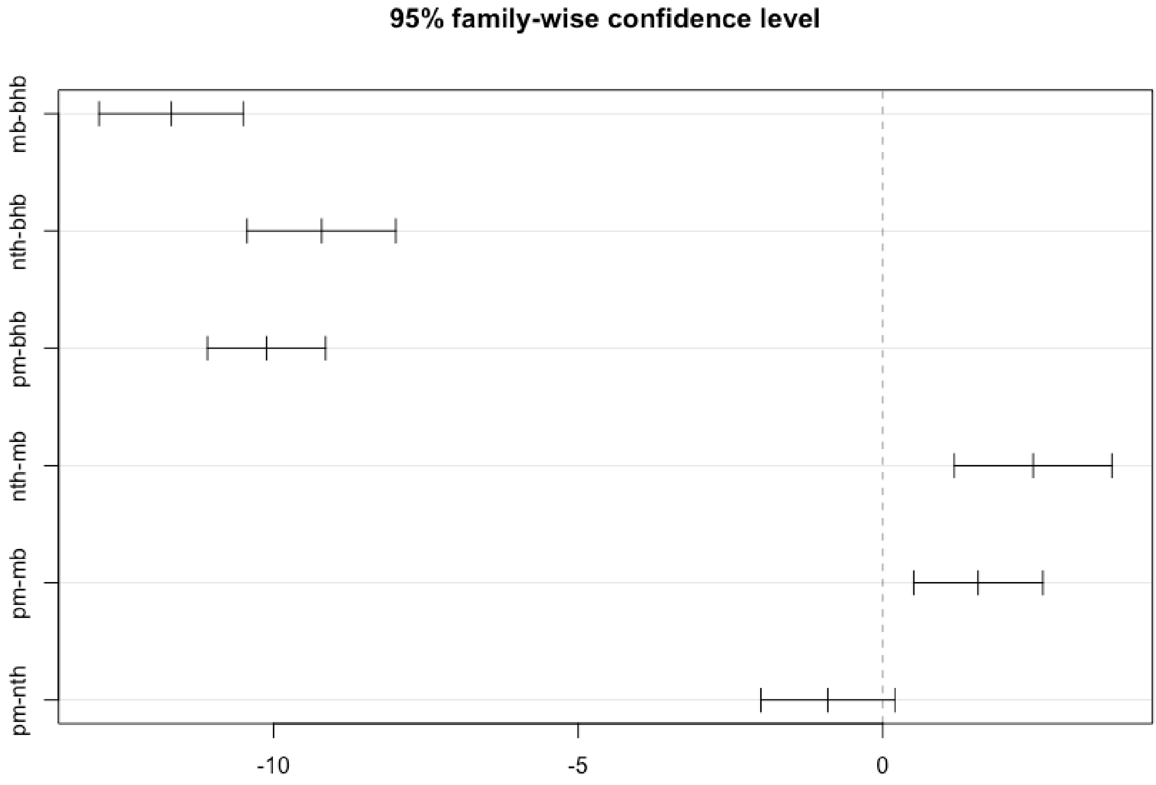


6 8 2 TurkeyHSD of Ga

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

Fit: aov(formula = potplants$Ga ~ factor(potplants$Group))

$`factor(potplants$Group)`
               diff         lwr         upr     p adj
mb-bhb  -11.6838615 -12.8693240 -10.4983990 0.0000000
nth-bhb  -9.2162393 -10.4383597  -7.9941189 0.0000000
pm-bhb  -10.1176282 -11.0881810  -9.1470755 0.0000000
nth-mb    2.4676222   1.1726778   3.7625666 0.0000327
pm-mb     1.5662333   0.5054433   2.6270233 0.0014505
pm-nth   -0.9013889  -2.0029933   0.2002155 0.1447324
```

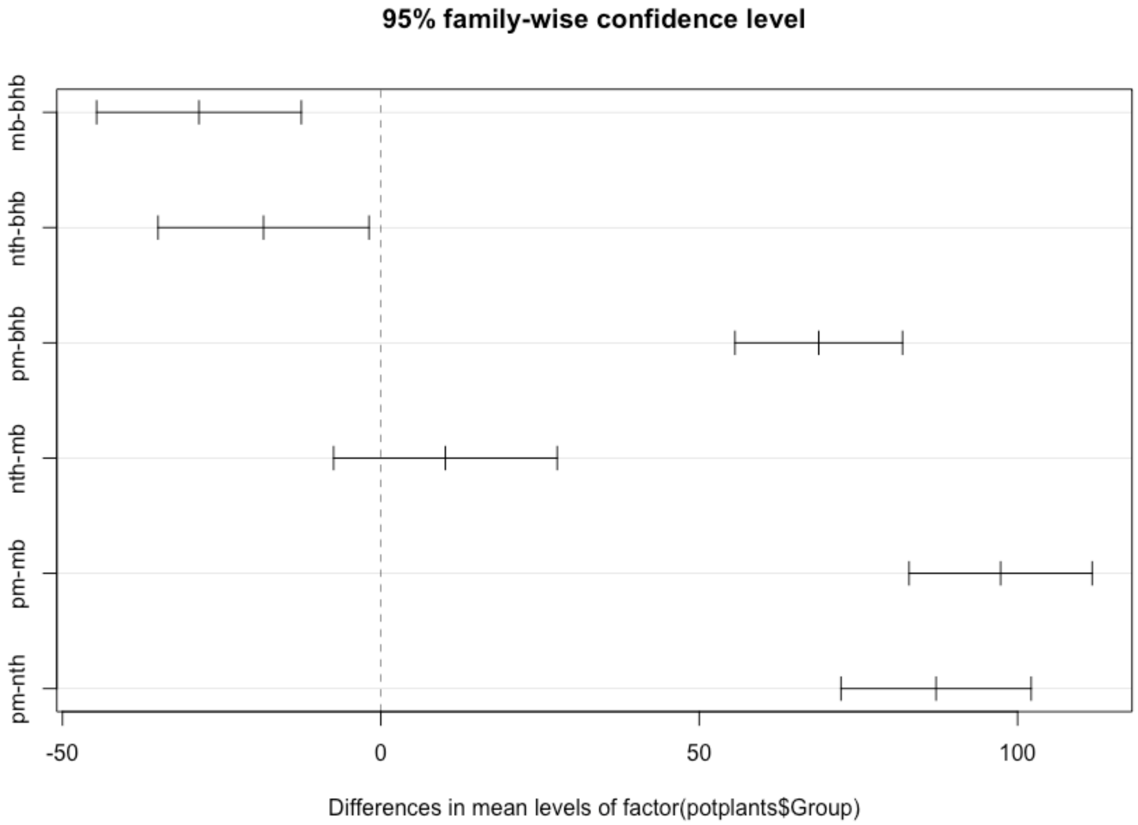


6 8 3 TurkeyHSD of Rb

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

Fit: aov(formula = potplants$Rb ~ factor(potplants$Group))

$`factor(potplants$Group)`
             diff        lwr        upr     p adj
mb-bhb  -28.56193 -44.634442 -12.489420 0.0001061
nth-bhb -18.42479 -34.994305  -1.855268 0.0237501
pm-bhb   68.77244  55.613673  81.931199 0.0000000
nth-mb   10.13714  -7.419723  27.694012 0.4259023
pm-mb    97.33437  82.952167 111.716567 0.0000000
pm-nth   87.19722  72.261660 102.132785 0.0000000
```

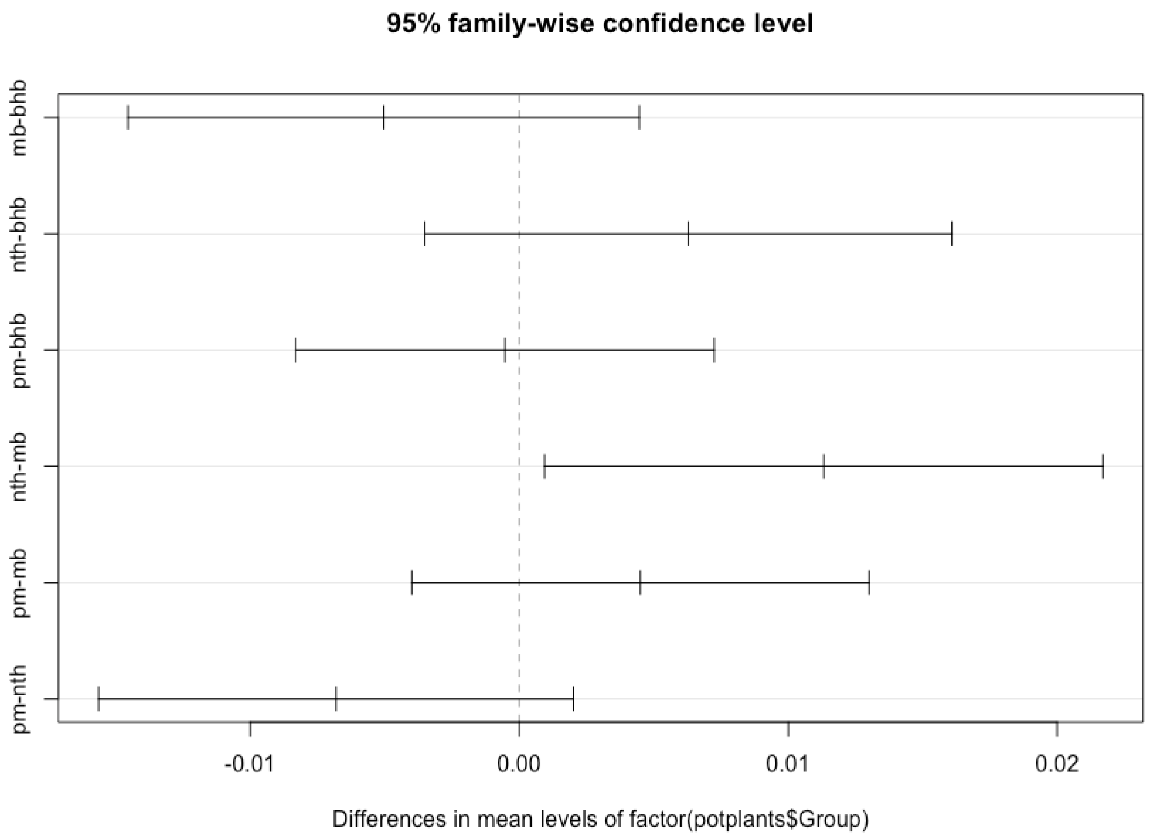


6 8 4 TurkeyHSD of Ta

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

Fit: aov(formula = potplants$Ta ~ factor(potplants$Group))

$`factor(potplants$Group)`
                 diff           lwr         upr     p adj
mb-bhb  -0.0050353846 -0.0145365943 0.004465825 0.5010263
nth-bhb  0.0062846154 -0.0035103988 0.016079630 0.3325835
pm-bhb  -0.0005278846 -0.0083066420 0.007250873 0.9978984
nth-mb   0.0113200000  0.0009413179 0.021698682 0.0274889
pm-mb    0.0045075000 -0.0039944882 0.013009488 0.5007062
pm-nth  -0.0068125000 -0.0156416065 0.002016607 0.1840523
```



7 Programming Code

```
#Read the data into R
potplants<-read.csv("Desktop/MT5762/Assignment 1/potplants_MT5762.csv")
head(potplants)
#Drop NA in the data
potplants<-na.omit(potplants)
dim(potplants)
#Summarise the data
##install.packages("dplyr")
library(dplyr)
potplants_sum<-summary(potplants)
write.csv(potplants_sum, file = "Desktop/MT5762/Assignment 1/potplants_sum.csv")
```

```
potplants_sd<-summarise_all(group_by(potplants,Group),sd)
potplants_mean<-summarise_all(group_by(potplants,Group),mean)
cv<-summarise_all(group_by(potplants,Group),funs(sd(.)/mean(.)))
write.csv(cv, file = "Desktop/MT5762/Assignment 1/cv.csv")
#Plot the data
#install.packages("ggplot2")
library(ggplot2)
Ti_Ga<-ggplot(potplants) + geom_point(mapping = aes(x = Ti, y = Ga, color =
Group))
ggsave("potplants_Ti_Ga", Ti_Ga, "pdf")
Ti_Ga
Ti_Rb<-ggplot(potplants) + geom_point(mapping = aes(x = Ti, y = Rb, color =
Group))
ggsave("potplants_Ti_Rb", Ti_Rb, "pdf")
Ti_Rb
Ti_Ta<-ggplot(potplants) + geom_point(mapping = aes(x = Ti, y = Ta, color =
Group))
ggsave("potplants_Ti_Ta", Ti_Ta, "pdf")
Ti_Ta
Ga_Rb<-ggplot(potplants) + geom_point(mapping = aes(x = Ga, y = Rb, color =
Group))
ggsave("potplants_Ga_Rb", Ga_Rb, "pdf")
Ga_Rb
Ga_Ta<-ggplot(potplants) + geom_point(mapping = aes(x = Ga, y = Ta, color =
Group))
ggsave("potplants_Ga_Ta", Ga_Ta, "pdf")
Ga_Ta
Rb_Ta<-ggplot(potplants) + geom_point(mapping = aes(x = Rb, y = Ta, color =
Group))
```

```
ggsave("potplants_Rb_Ta", Rb_Ta, "pdf")
Rb_Ta

#Anova
library(stats)
#1 Ti
boxplot(potplants$Ti~factor(potplants$Group), xlab = "Group", ylab = "Ti")
#Oneway Test
oneway.test(potplants$Ti~factor(potplants$Group))
potplants_Ti.aov=aov(potplants$Ti~factor(potplants$Group))
summary(potplants_Ti.aov)
#Normality test
##qqPlot
Ti_qqplot<-lm(potplants$Ti~potplants$Group, data=potplants)
qqPlot(Ti_qqplot)
#Bartlett Test
bartlett.test(potplants$Ti~factor(potplants$Group))
#Post-hoc (TurkeyHSD)
potplants_Ti_posthoc=TukeyHSD(potplants_Ti.aov)
potplants_Ti_posthoc
plot(potplants_Ti_posthoc)

#2 Ga
boxplot(potplants$Ga~factor(potplants$Group), xlab = "Group", ylab = "Ga")
#Oneway Test
oneway.test(potplants$Ga~factor(potplants$Group))
potplants_Ga.aov=aov(potplants$Ga~factor(potplants$Group))
summary(potplants_Ga.aov)
#Normality test (qqPlot)
```

```
Ga_qqplot<-lm(potplants$Ga~potplants$Group, data=potplants)
qqPlot(Ga_qqplot)
#Bartlett Test
bartlett.test(potplants$Ga~factor(potplants$Group))
#Post-hoc (TurkeyHSD)
potplants_Ga_posthoc=TukeyHSD(potplants_Ga.aov)
potplants_Ga_posthoc
plot(potplants_Ga_posthoc)

#3 Rb
boxplot(potplants$Rb~factor(potplants$Group), xlab = "Group", ylab = "Rb")
#Oneway Test
oneway.test(potplants$Rb~factor(potplants$Group))
potplants_Rb.aov=aov(potplants$Rb~factor(potplants$Group))
summary(potplants_Rb.aov)
#Normality test (qqPlot)
Rb_qqplot<-lm(potplants$Rb~potplants$Group, data=potplants)
qqPlot(Rb_qqplot)
#Bartlett Test
bartlett.test(potplants$Rb~factor(potplants$Group))
#Post-hoc (TurkeyHSD)
potplants_Rb_posthoc=TukeyHSD(potplants_Rb.aov)
potplants_Rb_posthoc
plot(potplants_Rb_posthoc)

#4 Ta
boxplot(potplants$Ta~factor(potplants$Group), xlab = "Group", ylab = "Ta")
#Oneway Test
oneway.test(potplants$Ta~factor(potplants$Group))
```

```
potplants_Ta.aov=aov(potplants$Ta~factor(potplants$Group))
summary(potplants_Ta.aov)
#Normality test (qqPlot)
Ta_qqplot<-lm(potplants$Ta~potplants$Group, data=potplants)
qqPlot(Ta_qqplot)
#Bartlett Test
leveneTest(potplants$Ta~factor(potplants$Group))
#Post-hoc (TurkeyHSD)
potplants_Ta_posthoc=TukeyHSD(potplants_Ta.aov)
potplants_Ta_posthoc
plot(potplants_Ta_posthoc)
```