Appendix – Martin Roe Bachelors thesis

Physical properties of biochar (appendix 1):

vlastnost, veličina	jednotka	vzorek	EBC standard		ÚKZÚZ Pomocná půdní	ČSN 46 5735 Průmyslové komposty
			základní	prémium		
frakce > 5 mm	%	13,9	-	-	-	-
frakce 2 – 5 mm	%	26,3	-	-	-	-
frakce 0,5 – 2 mm	%	30,2	-	-	-	-
frakce < 0,5 mm	%	29,6	-	-	-	-
sypná hmotnost	g·dm^{-3}	163	deklarace		-	-
zdánlivá hustota, ρ_{Hg}	g·cm^{-3}	0,346	-	-	-	-
skeletální hustota, ρ_{He}	g·cm^{-3}	1,95	-	-	-	-
porozita, ε	–	0,823	-	-	-	-
specifický povrch, S_{BET}	m^2/g	564	deklarace, nejlépe > 150		-	-
specifický povrch mesopórů, S_{meso}	m^2/g	258	-	-	-	-
specifický celkový objem pórů, V_{tot}	mm$^3_{liq}$/g	443	-	-	-	-
specifický objem mikropórů, V_{micro}	mm$^3_{liq}$/g	162	-	-	-	-
specifický intruzní objem, V_{intr}	cm^3/g	2,17	-	-	-	-
pH	–	11,2	deklarace		-	od 6,0 do 8,5
vodivost, EC	µS/cm	1400	deklarace		-	-
vlhkost, W	% hm.	0,00	deklarace		-	závisí na obsahu spalitelných látek
popel, A^d	% hm.	10,6	deklarace		-	-
hořlavina, h^d	% hm.	89,4	-	-	-	min. 25
prchavá hořlavina, V^d	% hm.	1,30	deklarace		-	-
fixní uhlík, FC^d	% hm.	88,1				
spalné teplo, Q_s^d	MJ.kg^{-1}	28,2	-	-	-	-
výhřevnost, Q_i^d	MJ.kg^{-1}	28,0	-	-	-	-
obsah uhlíku, C^d	% hm.	87,0	≥ 50%		-	-
obsah organického uhlíku, C_{org}^d	% hm.	81,7	-	-	-	-
obsah vodíku, H^d	% hm.	0,911	-	-	-	-
obsah dusíku, N^d	% hm.	0,359	deklarace		-	min. 0,60
obsah kyslíku, O^d	% hm.	0,908	-	-	-	-
H/C$_{org}$	–	0,133	H/C$_{org}$ < 0,7		-	-
H/C	–	0,125	-		-	-
O/C	–	0,00783	O/C < 0,4		-	-
C/N	–	283	-	-	-	C/N ≤ 30
obsah celkové síry, S1^d	% hm.	0,231	-	-	-	-
obsah spalitelné síry, S2^d	mg.kg^{-1}	2170	-	-	-	-
obsah chloru, Cl^d	mg.kg^{-1}	997	-	-	-	-
obsah fluoru, F^d	mg.kg^{-1}	289	-	-	-	-
Suma 12 PAH	mg kg^{-1}	< 0,5	-	-	< 20	-
Suma 16 PAH	mg kg^{-1}	< 0,5	< 12	< 4	-	-

Chemical properties of biochar (appendix 2):

složka	jednotka	vzorek	EBC standard		ÚKZÚZ Pomocná půdní látka	ČSN 46 5735 Průmyslové komposty
			základní	prémium		
N[d]	mg/kg	3590	deklarace		-	min. 0,60
P	mg/kg	890	deklarace		-	-
K	mg/kg	3900	deklarace		-	-
Ca	mg/kg	16400	deklarace		-	-
Mg	mg/kg	2850	deklarace		-	-
As	mg/kg	<0,50	13	13	20	10
Cd	mg/kg	0,16	1,5	1	1	2
Cr	mg/kg	18,1	90	80	50	100
Cu	mg/kg	30,0	100	100	-	100
Hg	mg/kg	0,022	1	1	1	1,0
Mo	mg/kg	<0,50	-	-	-	5
Ni	mg/kg	21,0	50	30	-	50
Pb	mg/kg	8,30	150	120	10	100
Zn	mg/kg	429	400	400	-	300
naftalen	mg/kg	< 0,05				
acenafthen	mg/kg	< 0,05				
acenaftylen	mg/kg	< 0,2				
fluoren	mg/kg	< 0,05				
fenanthren	mg/kg	< 0,05				
anthracen	mg/kg	< 0,005				
fluoranthen	mg/kg	< 0,05				
pyren	mg/kg	< 0,1				
benzo(a)anthracen	mg/kg	< 0,05				
chrysen	mg/kg	< 0,005				
benzo(b)fluoranthen	mg/kg	< 0,05				
benzo(k)fluoranthen	mg/kg	< 0,02				
benzo(a)pyren	mg/kg	< 0,05				
benzo(g,h,i)perylen	mg/kg	< 0,1				
dibenzo(a,h)anthracen	mg/kg	< 0,1				
indeno(1,2,3-c,d)pyren	mg/kg	< 0,1				

HOAGLAND fertiliser (appendix 3):

1. Makroelementy, objem roztoku konečného roztoku 1000 ml, (300X)

složení	Konečná koncentrace roztoku		Koncentrace zásobního roztoku		Celkové množství zásobního roztoku
	g/L	mmol/L	g/L	mmol/L	
$Ca(NO_3)_2 \cdot 4 H_2O$	0.945	4	283.5	1200	1L (Macro A)
KNO_3	0.607	6	182.1	1800	
$NH_4H_2PO_4$	0.115	1	34.5	300	1L (Macro B)
$MgSO_4 7H_2O$	0.493	2	147.9	600	

2. Mikroelementy, (1000X)

složení	Konečná koncentrace roztoku		Koncentrace zásobního roztoku		Celkové množství zásobního roztoku
	mg/L	µmol/L	mg/L	mmol/L	
H_3BO_3	2.86	46.2	2860	46.2	1L
$MnCl_2 \cdot 4H_2O$	1.81	9.1	1810	9.1	
$ZnSO_4 \cdot 7H_2O$,	0.22	0.8	220	0.8	
$CuSO_4 \cdot 5H_2O$	0.08	0.3	80	0.3	

3. FeNa EDTA, (1000X)

složení	Konečná koncentrace roztoku		Koncentrace zásobního roztoku		Celkové množství zásobního roztoku
	mg/L	µM	g	mM	
FeNa EDTA	36,71	100	18.35	100	500

4. $(NH_4)_6Mo_7O_{24} \cdot 4H_2O$

| složení	Konečná koncentrace roztoku		Koncentrace zásobního roztoku		Celkové množství zásobního roztoku
	mg/L	µM	mg/L	mM	
$(NH_4)_6Mo_7O_{24} \cdot 4 H_2O$	0.18	1.0 µM for Mo	180	1.0	1L
		50nM	9	50 µM	1L

The individual components were weighed on a laboratory balance and dissolved using distilled water. The calculated amount was then measured from the stock solutions to the total required fertilizer amount of 40 L (8 weeks supply) according to the prescribed formulas for the macro-elements.
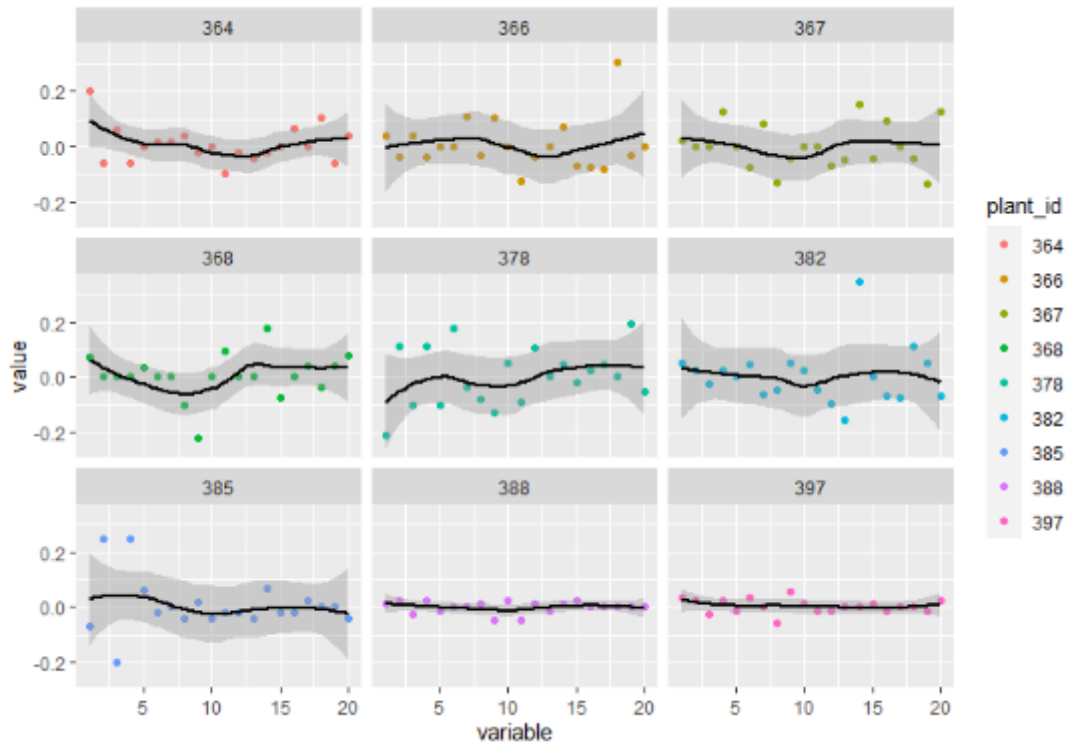
Results:

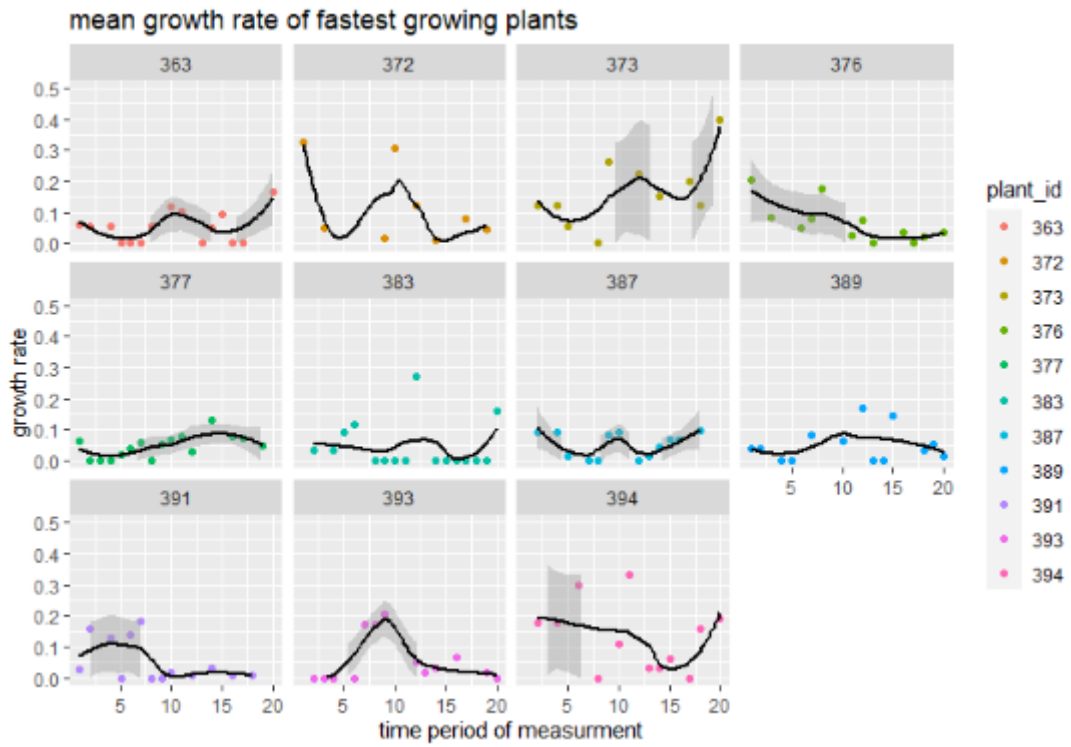Plant height over time (appendix 4):
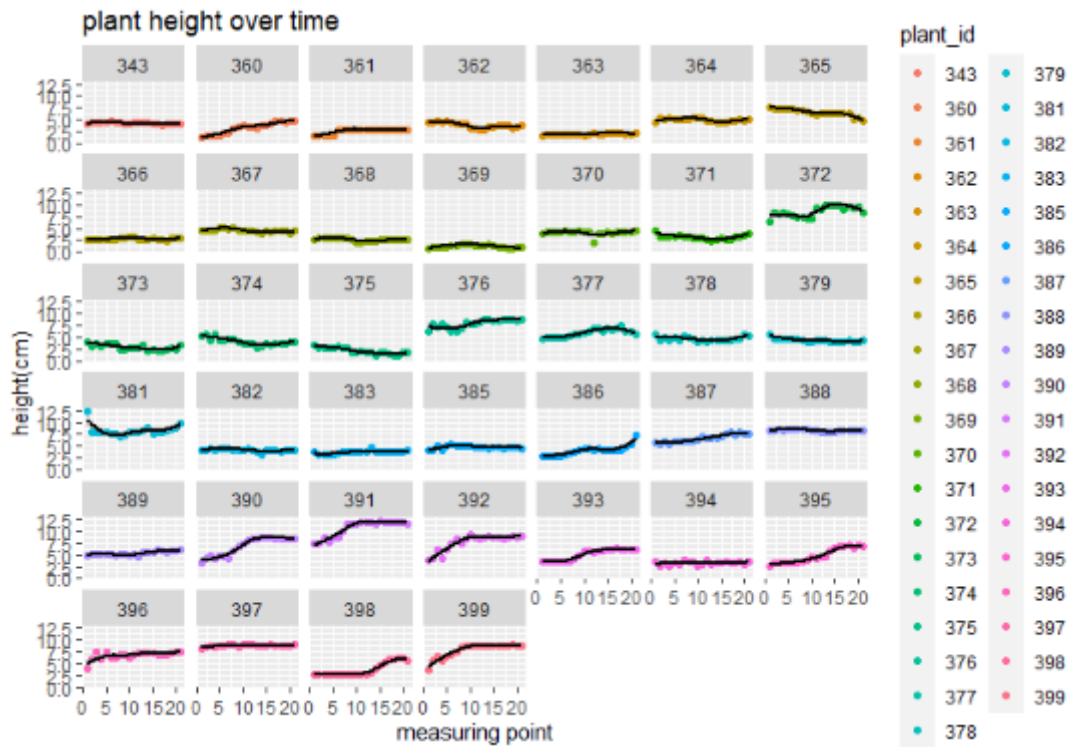
Plants with negative growth rate (appendix 5):
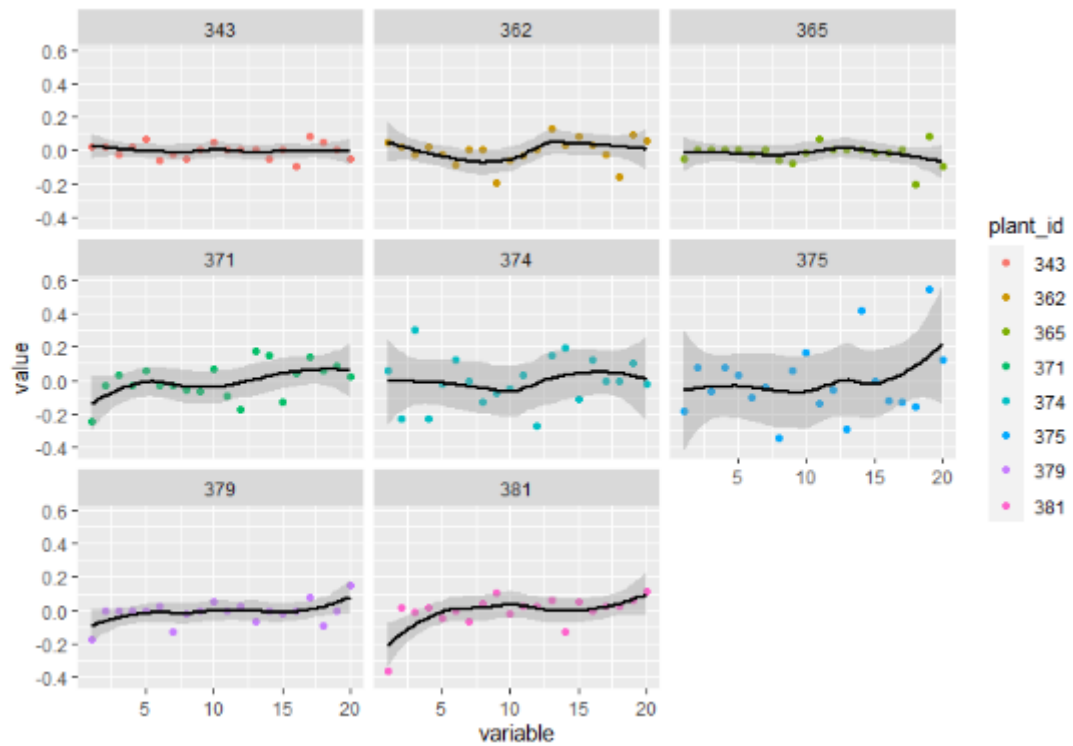
Plants with low growth rate (appendix 6):

Plants with medium growth rate (appendix 7):

Statistical values of medium plant growth rates (appendix 8):

	plant_id	mean	max	min	sd	median	COF	skew	mean max ratio	mean min ratio	range	species
1	343	0.00	0.08	-0.10	0.05	0.00	-31.08	-0.10	-0.02	0.01	0.18	S. byzatina
2	360	0.09	0.52	-0.07	0.17	0.06	1.90	0.55	0.17	-1.33	0.59	G.Macrorrhizum
3	361	0.04	0.76	-0.07	0.18	0.00	4.96	0.61	0.05	-0.53	0.83	G.Macrorrhizum
4	362	0.00	0.13	-0.20	0.08	0.00	-18.12	-0.17	-0.03	0.02	0.33	G.Macrorrhizum
5	363	0.01	0.17	-0.17	0.08	0.00	5.97	0.50	0.08	-0.08	0.34	G.Macrorrhizum
6	364	0.01	0.20	-0.09	0.07	0.00	7.10	0.42	0.05	-0.10	0.30	G.Macrorrhizum
7	365	-0.02	0.08	-0.21	0.06	0.00	-2.88	-1.04	-0.26	0.10	0.29	G.Macrorrhizum
8	366	0.01	0.30	-0.13	0.09	0.00	12.69	0.24	0.02	-0.06	0.43	G.Macrorrhizum
9	367	0.00	0.15	-0.13	0.08	0.00	91.49	0.03	0.01	-0.01	0.29	G.Macrorrhizum
10	368	0.00	0.17	-0.22	0.08	0.00	15.98	0.19	0.03	-0.02	0.40	G.Macrorrhizum
11	369	0.04	0.71	-0.33	0.24	0.00	5.75	0.52	0.06	-0.12	1.05	G.Macrorrhizum
12	370	0.03	0.90	-0.51	0.24	0.01	7.70	0.24	0.03	-0.06	1.42	G.Macrorrhizum
13	371	0.00	0.17	-0.24	0.11	0.00	-42.50	-0.05	-0.01	0.01	0.42	G.Macrorrhizum
14	372	0.02	0.33	-0.12	0.12	-0.02	5.82	0.98	0.06	-0.16	0.45	G.Macrorrhizum
15	373	0.01	0.40	-0.39	0.20	-0.01	15.69	0.39	0.03	-0.03	0.79	G.Macrorrhizum
16	374	0.00	0.30	-0.27	0.15	0.00	-44.02	-0.07	-0.01	0.01	0.57	G.Macrorrhizum
17	375	-0.01	0.55	-0.35	0.21	-0.05	-29.69	0.55	-0.01	0.02	0.89	G.Macrorrhizum
18	376	0.02	0.20	-0.14	0.08	0.01	4.10	0.30	0.10	-0.14	0.34	G.Macrorrhizum
19	377	0.01	0.13	-0.19	0.08	0.03	7.26	-0.85	0.09	-0.06	0.32	G.Macrorrhizum
20	378	0.00	0.19	-0.21	0.11	0.00	63.15	0.05	0.01	-0.01	0.40	G.Macrorrhizum
21	379	-0.01	0.15	-0.18	0.07	0.00	-7.41	-0.41	-0.06	0.05	0.33	G.Macrorrhizum
22	381	0.00	0.11	-0.37	0.10	0.02	-23.46	-0.67	-0.04	0.01	0.48	A.maritima
23	382	0.00	0.34	-0.16	0.10	0.00	31.07	0.10	0.01	-0.02	0.50	A.maritima
24	383	0.01	0.27	-0.21	0.10	0.00	8.19	0.37	0.05	-0.06	0.48	A.maritima
25	385	0.01	0.25	-0.20	0.10	-0.02	14.83	0.80	0.03	-0.03	0.45	A.maritima
26	386	0.05	0.31	-0.05	0.09	0.04	1.67	0.54	0.17	-1.11	0.36	A.maritima
27	387	0.02	0.10	-0.10	0.06	0.01	3.97	0.40	0.16	-0.16	0.19	A.maritima
28	388	0.00	0.02	-0.05	0.02	0.00	99.99	0.03	0.01	0.00	0.07	A.maritima
29	389	0.01	0.17	-0.10	0.07	0.00	5.22	0.57	0.08	-0.14	0.27	A.maritima
30	390	0.06	0.33	-0.18	0.13	0.01	2.26	1.04	0.17	-0.31	0.51	A.maritima
31	391	0.03	0.18	-0.11	0.07	0.00	2.74	0.92	0.14	-0.23	0.30	A.maritima
32	392	0.06	0.49	-0.33	0.18	0.02	3.24	0.54	0.11	-0.17	0.82	A.maritima
33	393	0.03	0.21	-0.05	0.07	0.00	2.55	1.18	0.14	-0.62	0.25	A.maritima

34	394	0.02	0.33	-0.27	0.17	0.02	10.23	0.02	0.05	-0.06	0.60	A.maritima
35	395	0.05	0.21	-0.09	0.09	0.05	1.81	0.09	0.23	-0.56	0.30	A.maritima
36	396	0.04	0.50	-0.19	0.15	0.01	3.54	0.55	0.08	-0.22	0.69	A.maritima
37	397	0.00	0.06	-0.06	0.02	0.00	5.70	0.53	0.07	-0.08	0.11	A.maritima
38	398	0.04	0.26	-0.13	0.09	0.02	2.34	0.73	0.15	-0.30	0.39	A.maritima
39	399	0.05	0.54	-0.15	0.14	0.01	2.61	0.90	0.10	-0.35	0.69	A.maritima

3-way ANOVA table – updated since Biochar: Greywater: species was not a significant effect (appendix 9)

```
                 Df   Sum Sq   Mean Sq F value Pr(>F)
species   1 0.001694 0.0016942   3.699 0.0637 .
biochar   1 0.000349 0.0003490   0.762 0.3894
greywater   1 0.000250 0.0002496   0.545 0.4660
species:biochar   1 0.002799 0.0027988   6.111 0.0191 *
species:greywater 1 0.000015 0.0000153   0.033 0.8560
biochar:greywater 1 0.000252 0.0002519   0.550 0.4639
Residuals   31 0.014199 0.0004580

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```



Residuals vs Fitted

aov(mean ~ species + biochar + greywater + species:biochar + species:greywa ...

Normal Q-Q

aov(mean ~ species + biochar + greywater + species:biochar + species:greywa ...



Scale-Location

aov(mean ~ species + biochar + greywater + species:biochar + species:greywa ...

Residuals vs Leverage

aov(mean ~ species + biochar + greywater + species:biochar + species:greywa ...
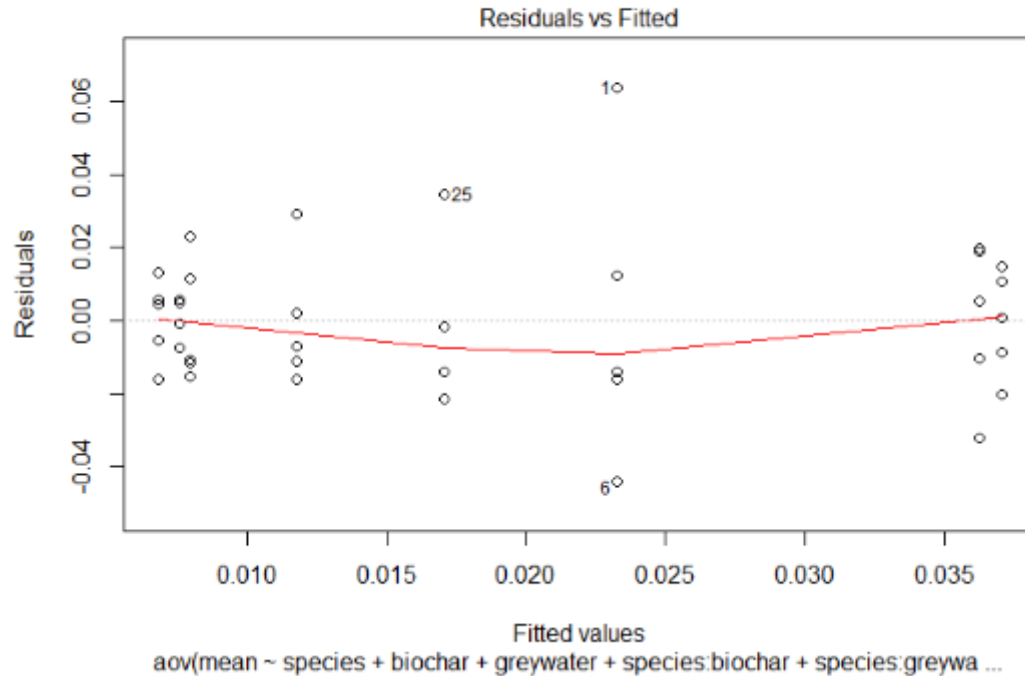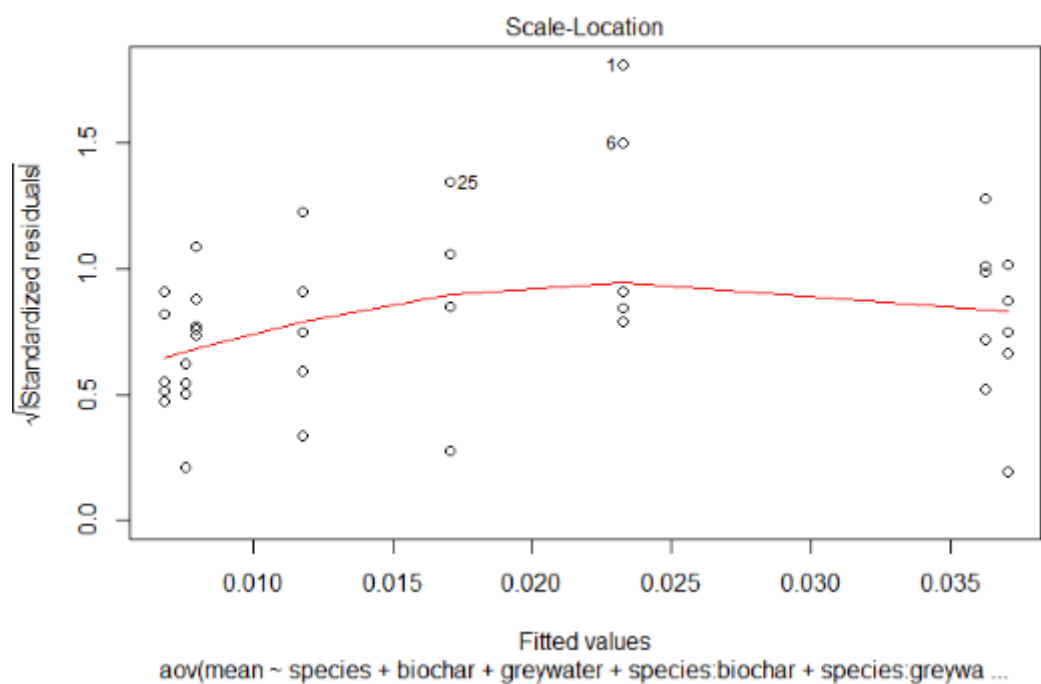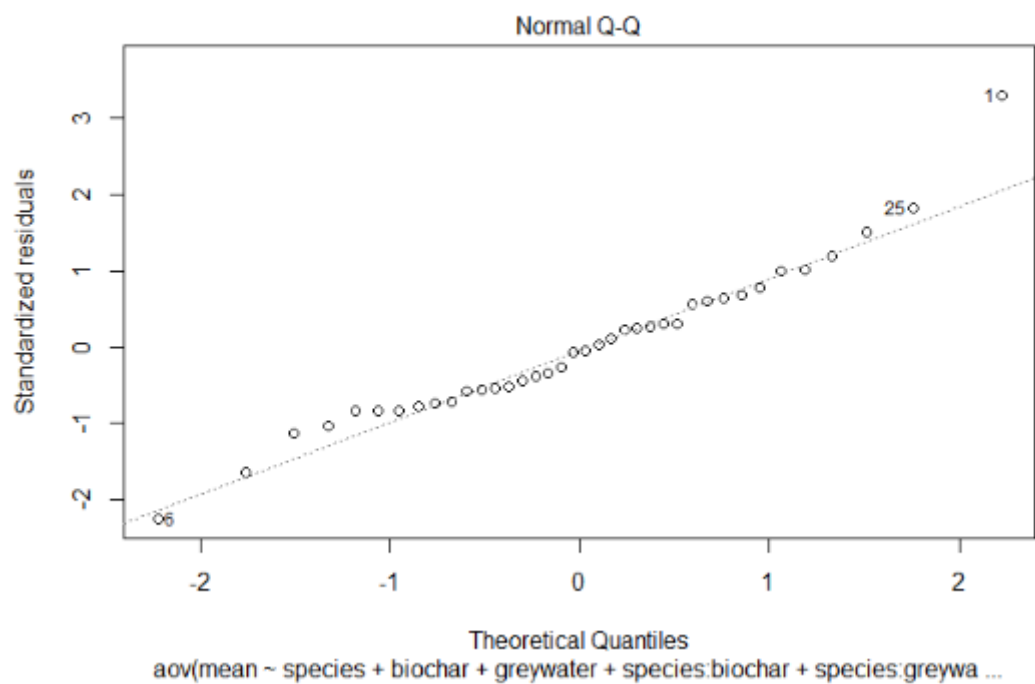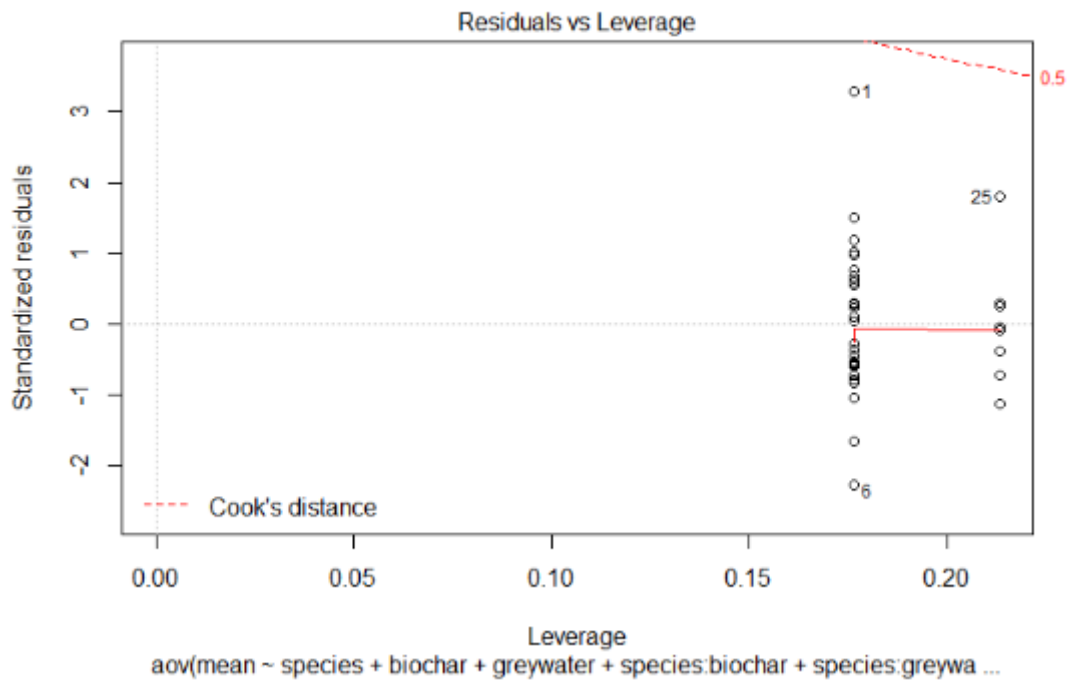
Poisson general linear model for number of leaves in *G. macrorrhizum* (appendix 10)

```
Coefficients:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)          2.21297    0.03227  68.566   <2e-16 ***
biochary             0.03782    0.04522   0.836    0.403
greywatery          -0.52481    0.05294  -9.914   <2e-16 ***
biochary:greywatery  0.83457    0.06739  12.385   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 2226.3  on 419  degrees of freedom
Residual deviance: 1890.9  on 416  degrees of freedom
AIC: 3418.9

Number of Fisher Scoring iterations: 5
```

9

Residuals vs Fitted

Predicted values
glm(value ~ biochar * greywater)

Normal Q-Q

Theoretical Quantiles
glm(value ~ biochar * greywater)

Scale-Location

glm(value ~ biochar * greywater)
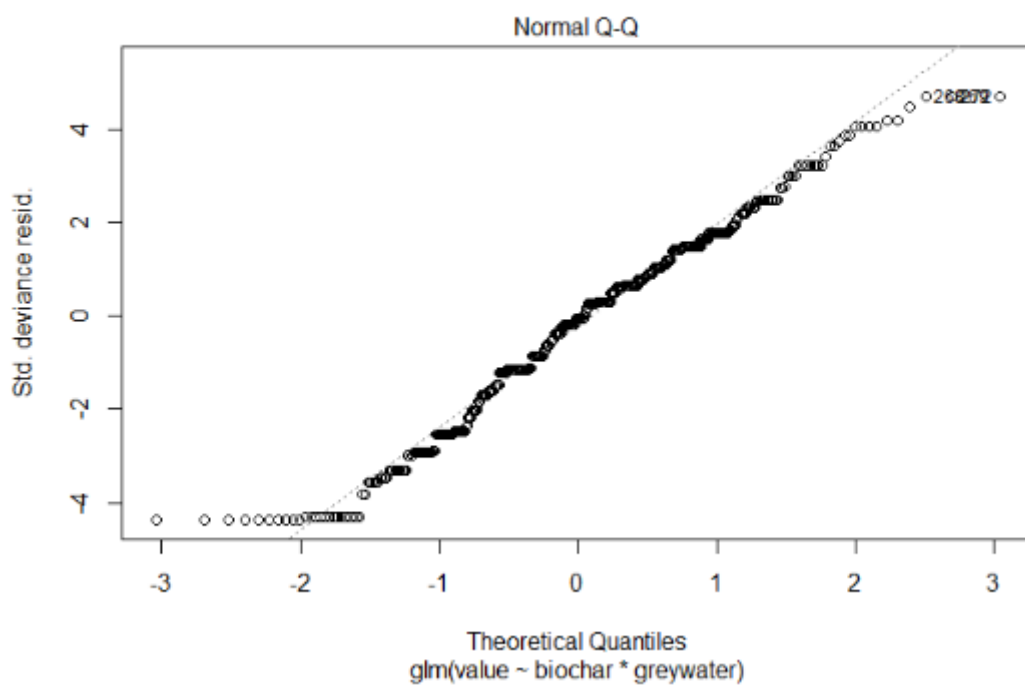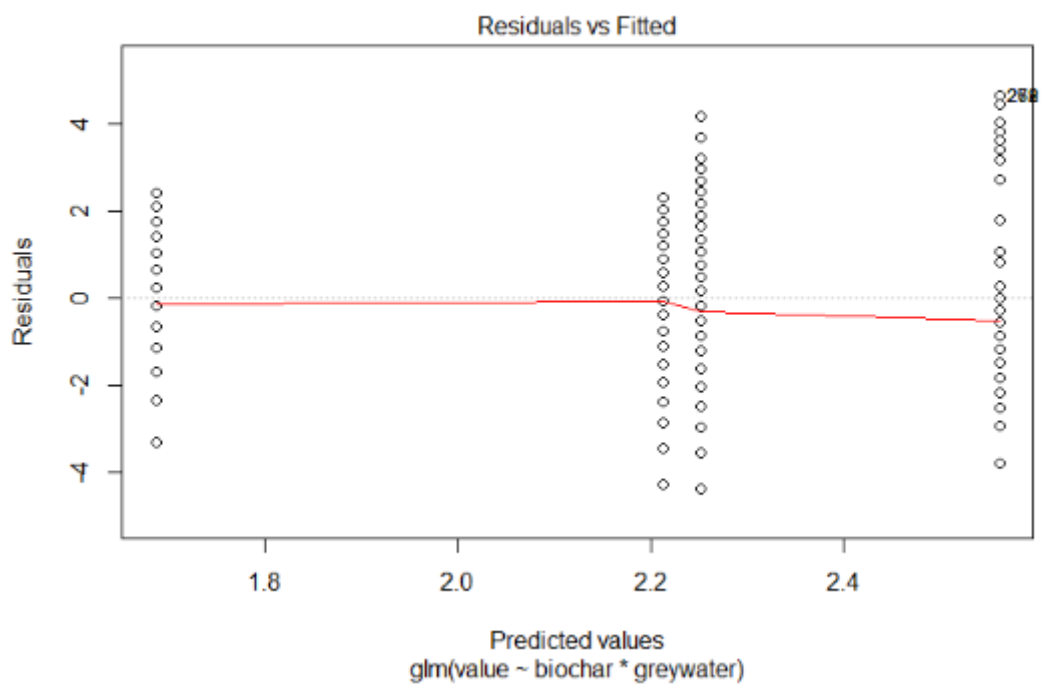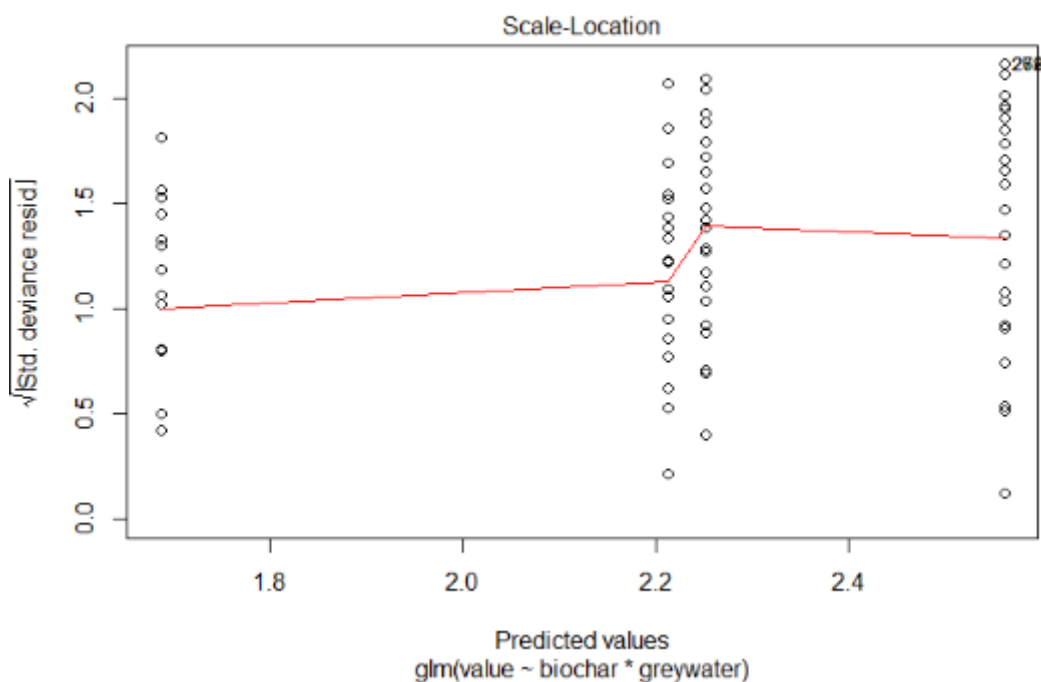
Poisson general linear model for number of flowers in *A. maritina* (appendix 11)
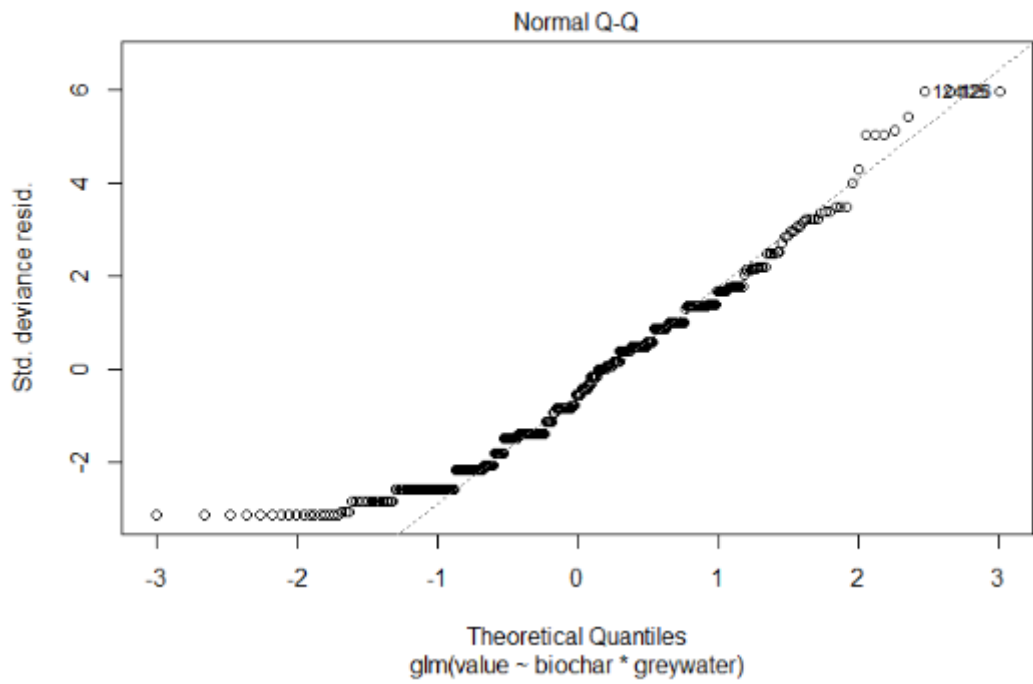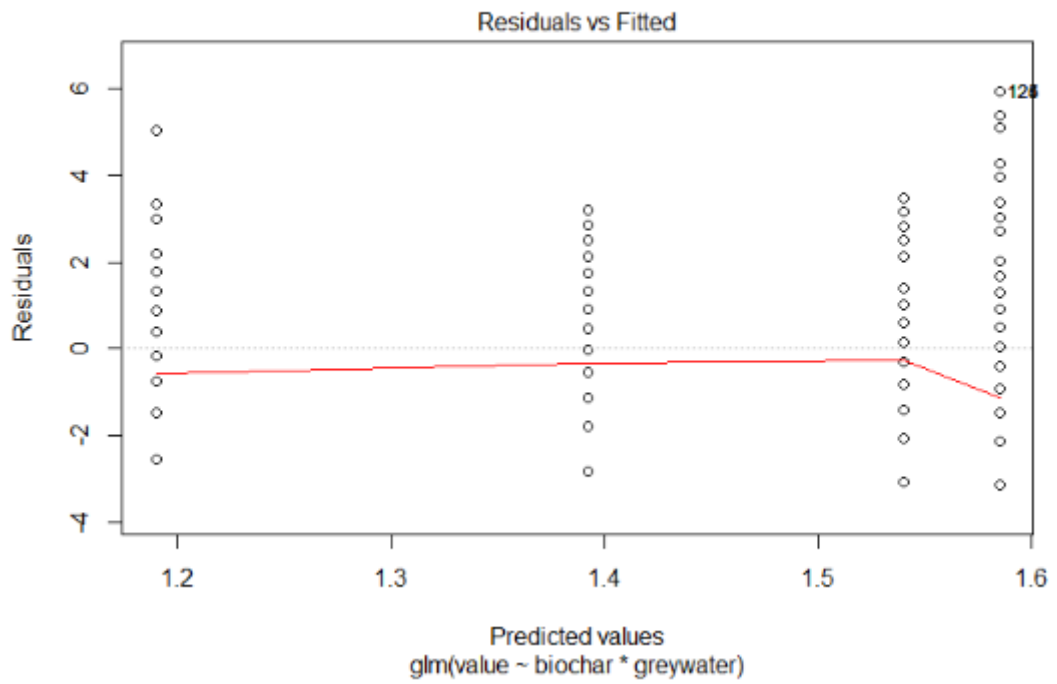
```
Coefficients:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)          1.58534    0.04938  32.102  < 2e-16 ***
biochary            -0.04490    0.06693  -0.671  0.50236
greywatery          -0.19311    0.07347  -2.629  0.00858 **
biochary:greywatery -0.15775    0.10167  -1.552  0.12076
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 1543.6  on 377  degrees of freedom
Residual deviance: 1506.4  on 374  degrees of freedom
AIC: 2503.6

Number of Fisher Scoring iterations: 5
```
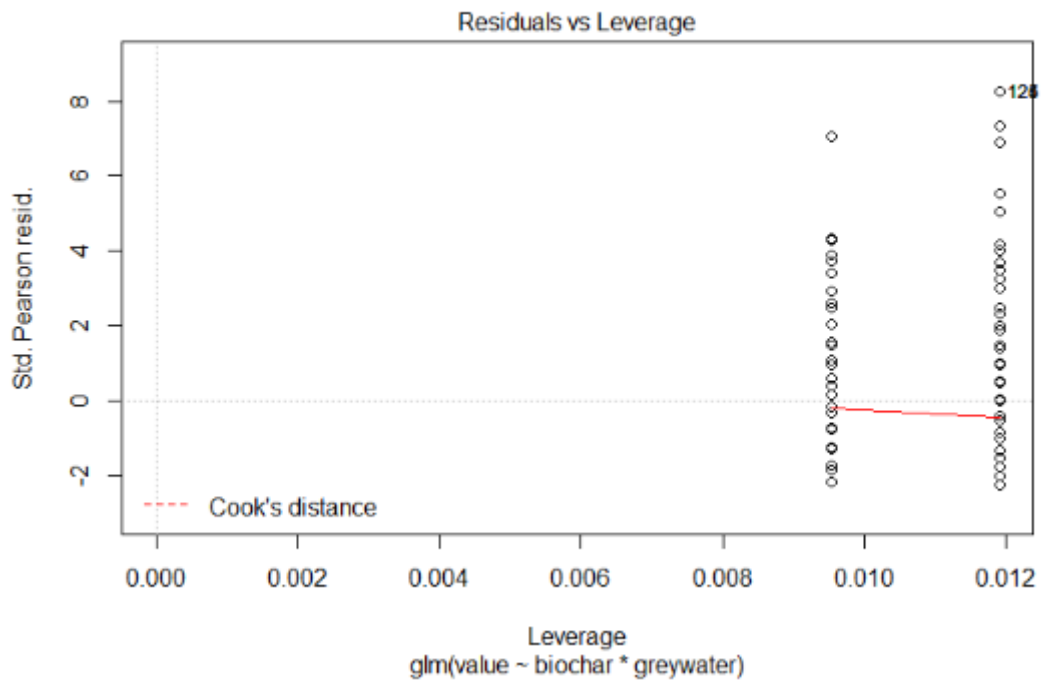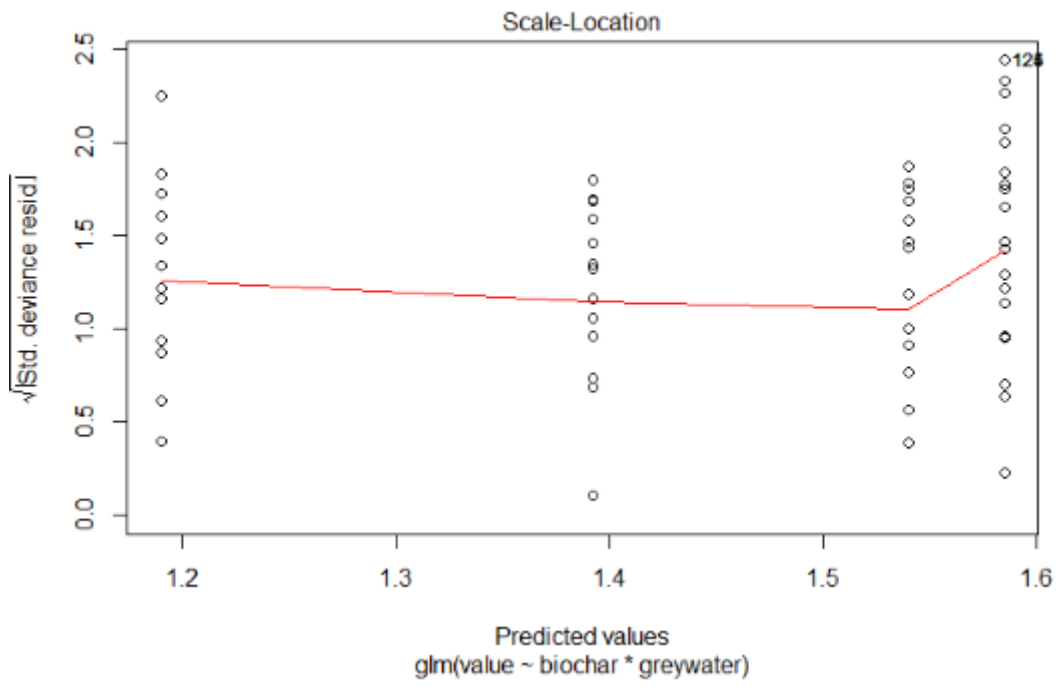
Residuals vs Fitted

Predicted values
glm(value ~ biochar * greywater)

Normal Q-Q

Theoretical Quantiles
glm(value ~ biochar * greywater)

Scale-Location

√|Std. deviance resid|

Predicted values
glm(value ~ biochar * greywater)

Residuals vs Leverage

Std. Pearson resid.

Cook's distance

Leverage
glm(value ~ biochar * greywater)

13

Correlation analysis between number of leaves and weight of dry biomass in *G. Macrorrhizum* (appendix 12)

```
        Spearman's rank correlation rho

data:  all$Dry_biomass_sixty_degrees_after_one_day and all$M21_no_L
S = 309.93, p-value = 3.982e-05
alternative hypothesis: true rho is greater than 0
sample estimates:
      rho
0.7669718
```

Correlation analysis between number of leaves and weight of dry biomass in *A. maritima* (appendix 13)
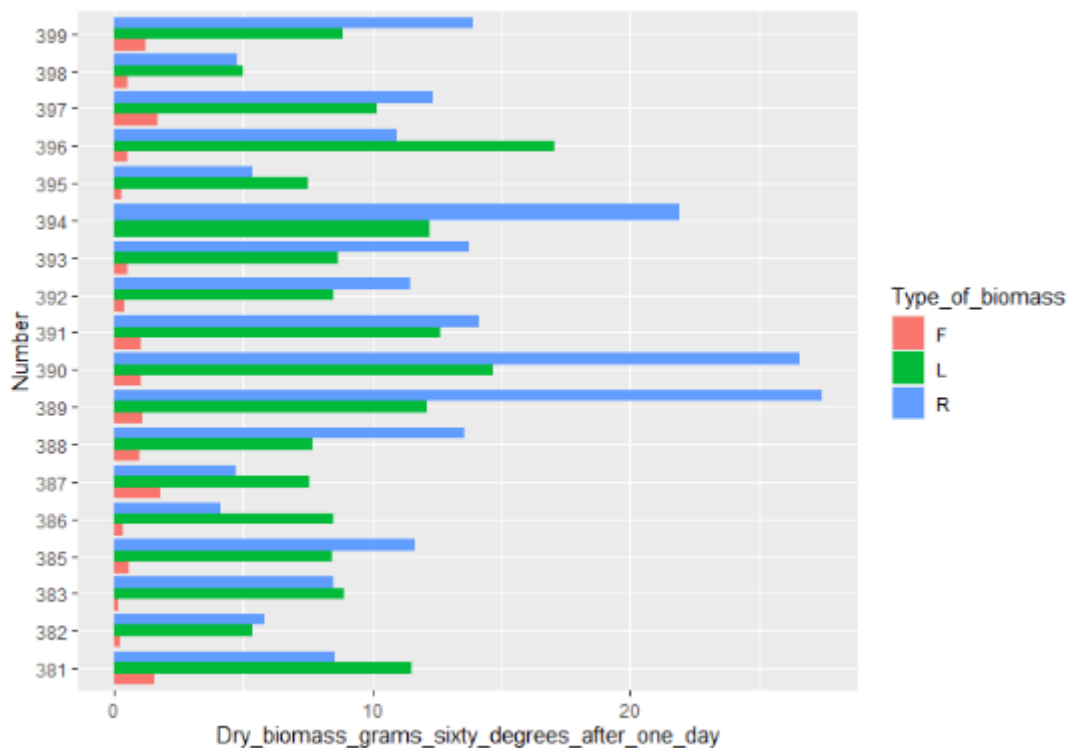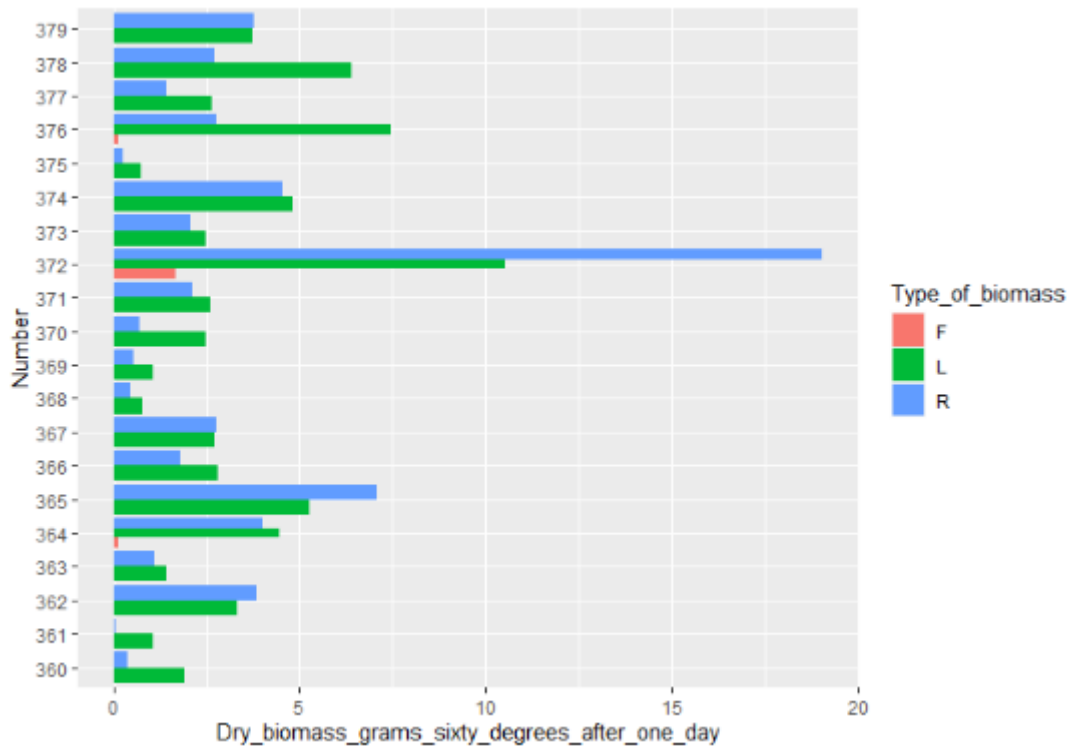
```
        Spearman's rank correlation rho

data:  all_2$Dry_biomass_sixty_degrees_after_one_day and all_2$M21_no_L
S = 584.83, p-value = 0.05167
alternative hypothesis: true rho is greater than 0
sample estimates:
      rho
0.3964567
```
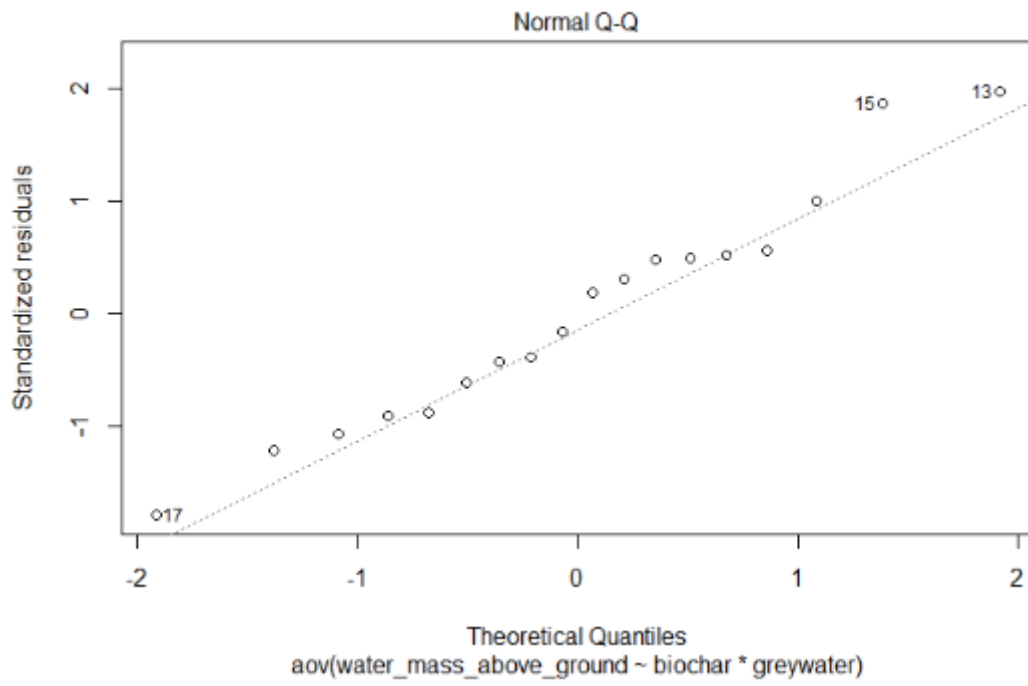
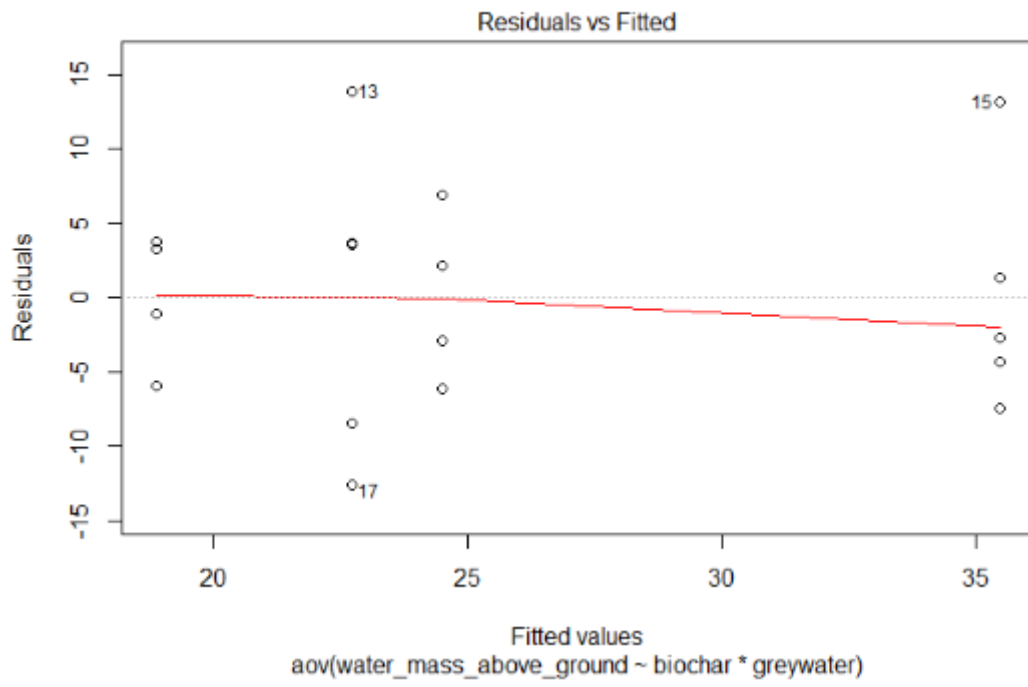Type and weight of biomass in *A. maritima* (appendix 14)

Type and weight of biomass in *G. Macrorrhizum* (appendix 15)
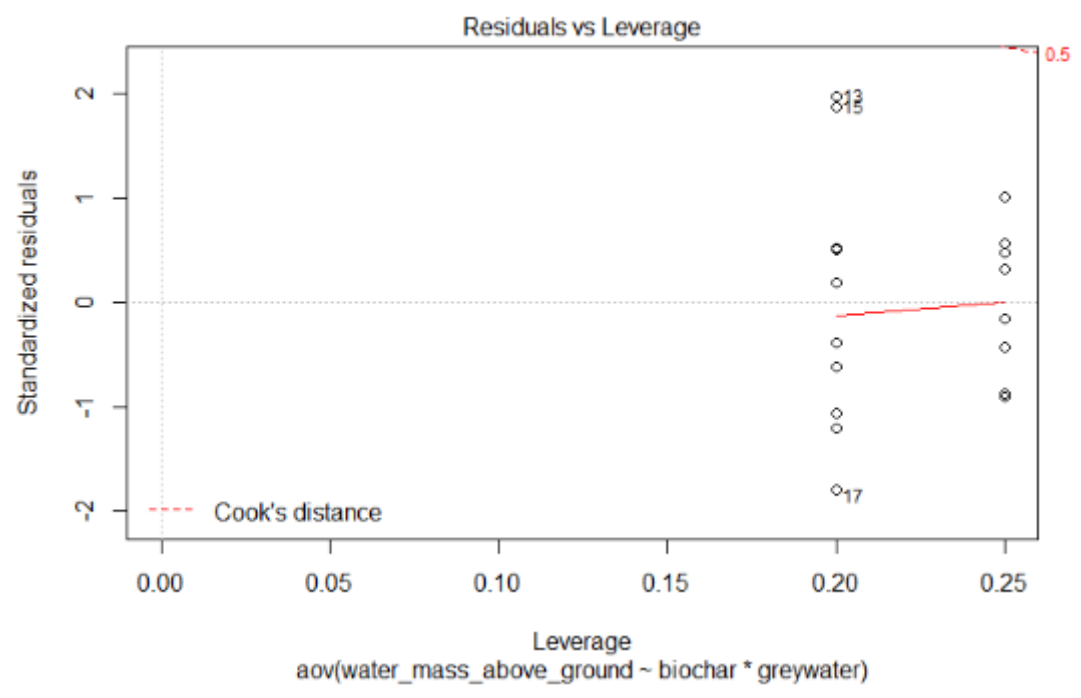

2-way ANOVA, for water mass above ground for *A. maritima* (appendix 16)

```
                 Df Sum Sq Mean Sq F value Pr(>F)
biochar           1  243.2   243.2   3.952 0.0667 .
greywater         1   94.3    94.3   1.532 0.2362
biochar:greywater 1  375.6   375.6   6.103 0.0270 *
Residuals        14  861.6    61.5
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Residuals vs Fitted

aov(water_mass_above_ground ~ biochar * greywater)

Normal Q-Q

aov(water_mass_above_ground ~ biochar * greywater)

Scale-Location

Fitted values
aov(water_mass_above_ground ~ biochar * greywater)

Residuals vs Leverage

Cook's distance

Leverage
aov(water_mass_above_ground ~ biochar * greywater)

17
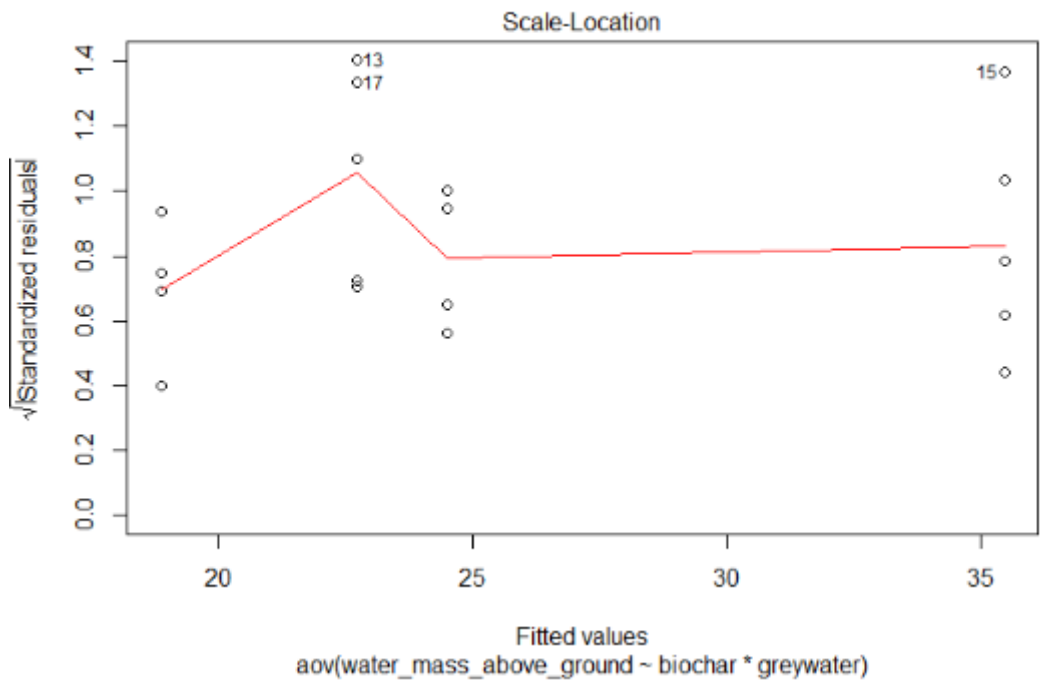
2-way ANOVA, for water mass below ground for *A. maritima* (appendix 17)

```
> summary(fit)
            Df Sum Sq Mean Sq F value Pr(>F)
biochar      1   35.1   35.07   0.183  0.675
greywater    1   37.4   37.39   0.195  0.665
Residuals   15 2873.0  191.53
>
```

2-way ANOVA, for water mass above ground for *G. Macrorrhizum* (appendix 18)

```
                  Df Sum Sq Mean Sq F value Pr(>F)
biochar            1  25.38  25.380   4.696 0.0457 *
greywater          1   2.13   2.132   0.394 0.5388
biochar:greywater  1   2.05   2.054   0.380 0.5462
Residuals         16  86.47   5.405
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
>
```
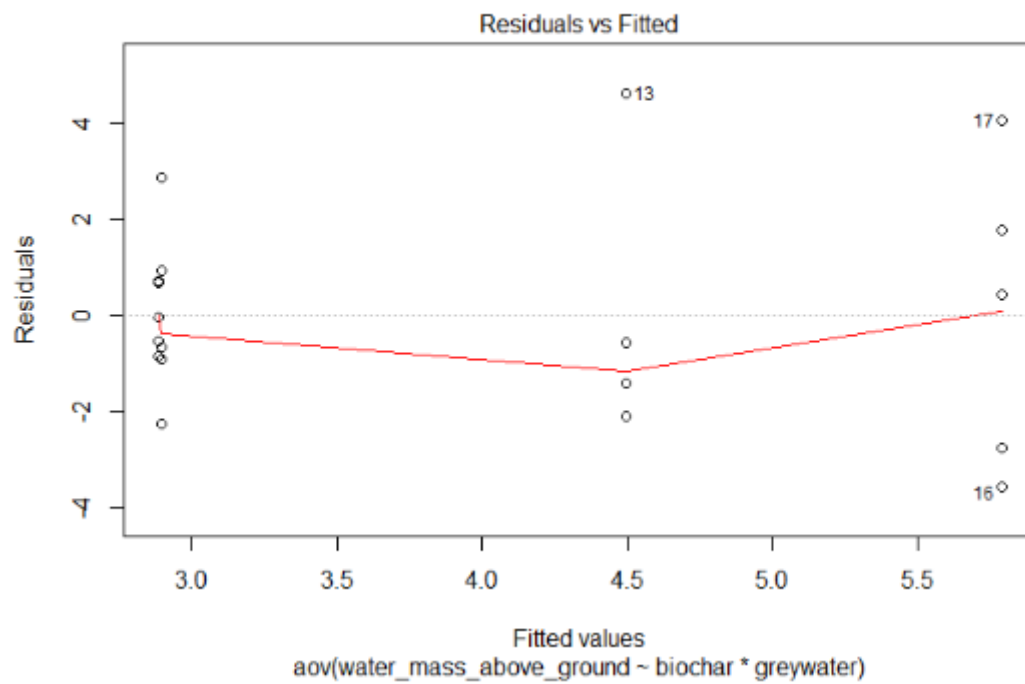

Residuals vs Fitted
Fitted values
aov(water_mass_above_ground ~ biochar * greywater)

Normal Q-Q

aov(water_mass_above_ground ~ biochar * greywater)

Scale-Location

aov(water_mass_above_ground ~ biochar * greywater)
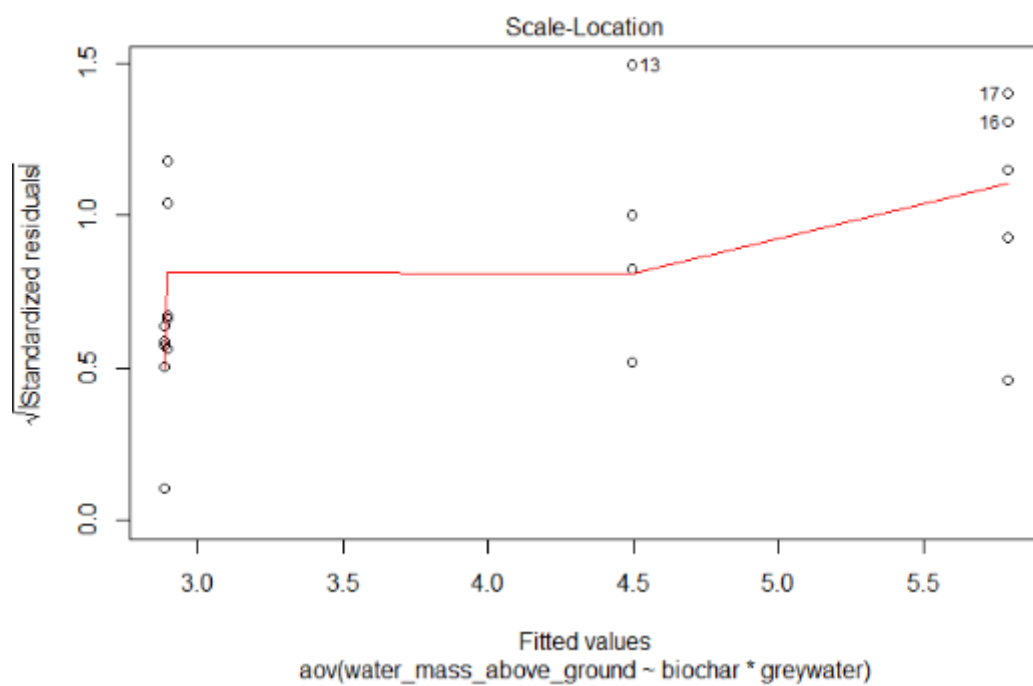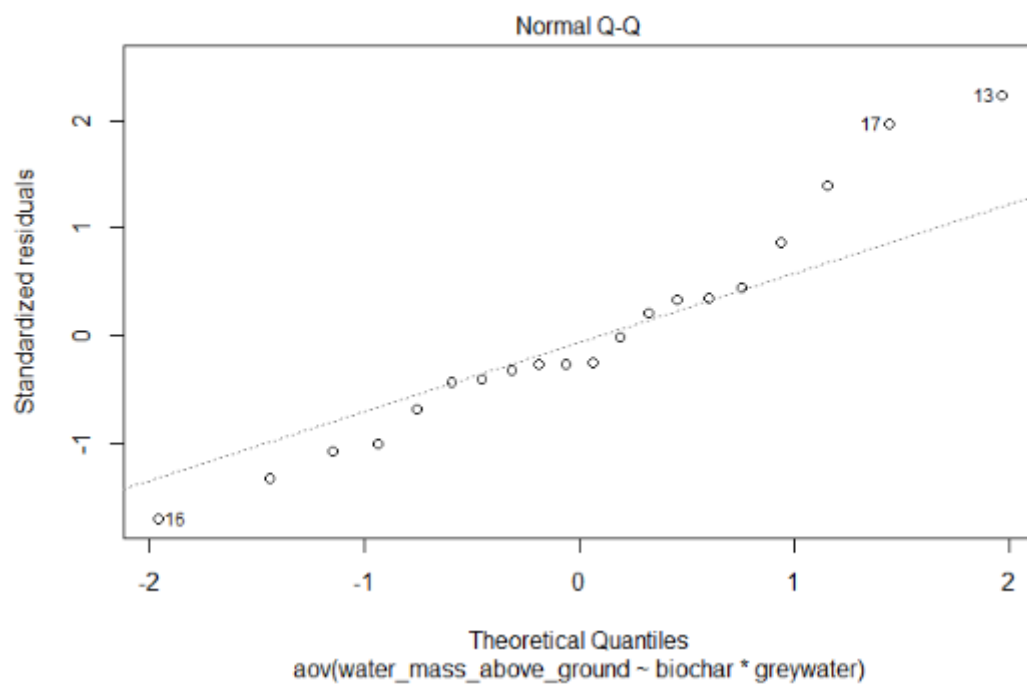
2-way ANOVA, for water mass below ground for *G. Macrorrhizum* (appendix 19)

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
biochar	1	0.38	0.380	0.022	0.885
greywater	1	6.94	6.944	0.395	0.539
biochar:greywater	1	18.24	18.240	1.037	0.325
Residuals	15	263.93	17.596		

Dry biomass:

A. maritima: above ground 2-way ANOVA result (appendix 20)

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
biochar	1	11.93	11.932	1.493	0.2420
greywater	1	21.49	21.495	2.689	0.1233
biochar:greywater	1	31.55	31.554	3.947	0.0669 .
Residuals	14	111.91	7.993		

Below ground (appendix 21)

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
biochar	1	48.5	48.49	0.926	0.351
greywater	1	0.2	0.15	0.003	0.958
Residuals	15	785.6	52.37		

G. Macrorrhizum dry mass, above ground 2 way - ANOVA result (appendix 22)

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
biochar	1	21.34	21.342	3.082	0.0983 .
greywater	1	0.43	0.426	0.062	0.8072
biochar:greywater	1	11.86	11.858	1.712	0.2091
Residuals	16	110.79	6.924		

Below ground (appendix 23)

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
biochar	1	30.40	30.402	1.770	0.202
greywater	1	0.66	0.656	0.038	0.848
biochar:greywater	1	23.02	23.019	1.340	0.264
Residuals	16	274.87	17.179		

All code and collected data can be found at:

https://github.com/mr2214/bacerlor_thesis.git