

Appendix – Martin Roe Bachelors thesis

Physical properties of biochar (appendix 1):

vlastnost, veličina	jednotka	vzorek	EBC standard		ÚKZÚZ	ČSN 46 5735 Průmyslové komposty
			základní	prémium	Pomocná půdní	
frakce > 5 mm	%	13,9	-	-	-	-
frakce 2 – 5 mm	%	26,3	-	-	-	-
frakce 0,5 – 2 mm	%	30,2	-	-	-	-
frakce < 0,5 mm	%	29,6	-	-	-	-
sypaná hmotnost	g·dm ⁻³	163	deklarace		-	-
zdánlivá hustota, ρ_{H_0}	g·cm ⁻³	0,346	-	-	-	-
skeletální hustota, ρ_{H_0}	g·cm ⁻³	1,95	-	-	-	-
porozita, ϵ	-	0,823	-	-	-	-
specifický povrch, S_{RET}	m ² /g	564	deklarace, nejlépe > 150		-	-
specifický povrch mesopórů, S_{meso}	m ² /g	258	-	-	-	-
specifický celkový objem pórů, V_{tot}	mm ³ _{tu} /g	443	-	-	-	-
specifický objem mikropórů, V_{micro}	mm ³ _{tu} /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 _v ^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	ČSN 46 5735
			základní	prémium	Pomocná půdní látka	Průmyslové komposty
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				
acenaftthen	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)perylene	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 ·4H ₂ O	0.945	4	283.5	1200	1L (Macro A)
KNO ₃	0.607	6	182.1	1800	
NH ₄ H ₂ PO ₄	0.115	1	34.5	300	1L (Macro B)
MgSO ₄ ·7H ₂ O	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 ₃ BO ₃	2.86	46.2	2860	46.2	1L
MnCl ₂ ·4H ₂ O	1.81	9.1	1810	9.1	
ZnSO ₄ ·7H ₂ O	0.22	0.8	220	0.8	
CuSO ₄ ·5H ₂ O	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

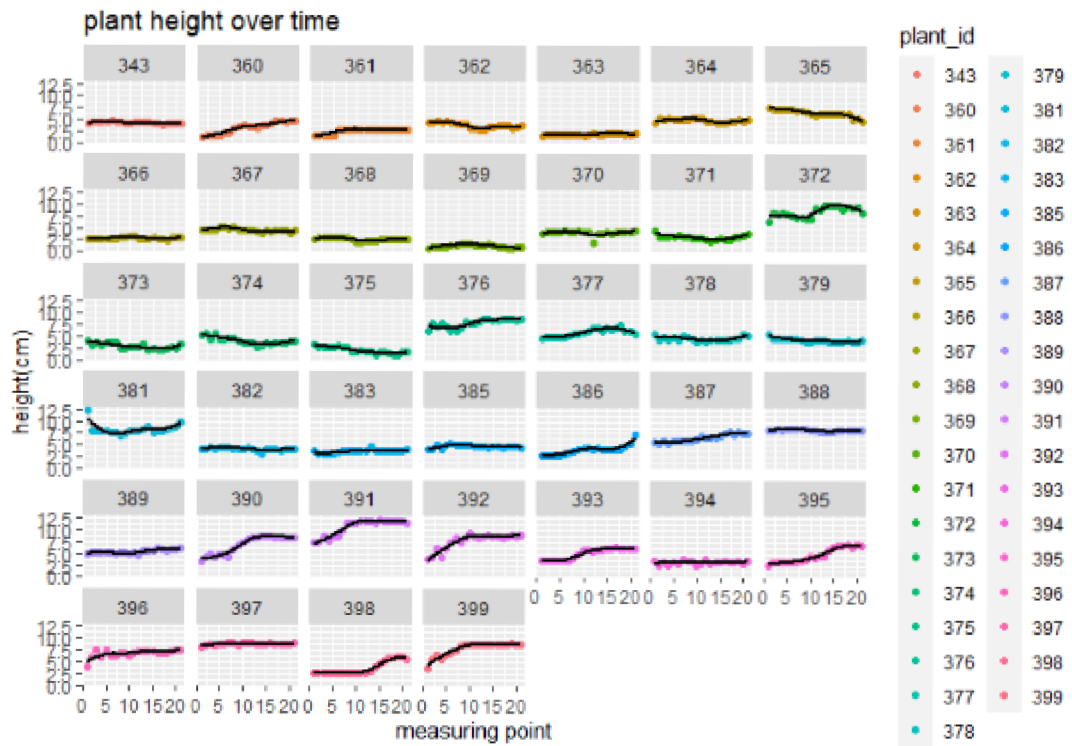
4. (NH₄)₆Mo₇O₂₄·4H₂O

složení	Konečná koncentrace roztoku		Koncentrace zásobního roztoku		Celkové množství zásobního roztoku
	mg/L	µM	mg/L	mM	
(NH ₄) ₆ Mo ₇ O ₂₄ ·4H ₂ O	0.18	1.0 µM for Mo	180	1.0	1L
		50nM	9	50 µM	1L

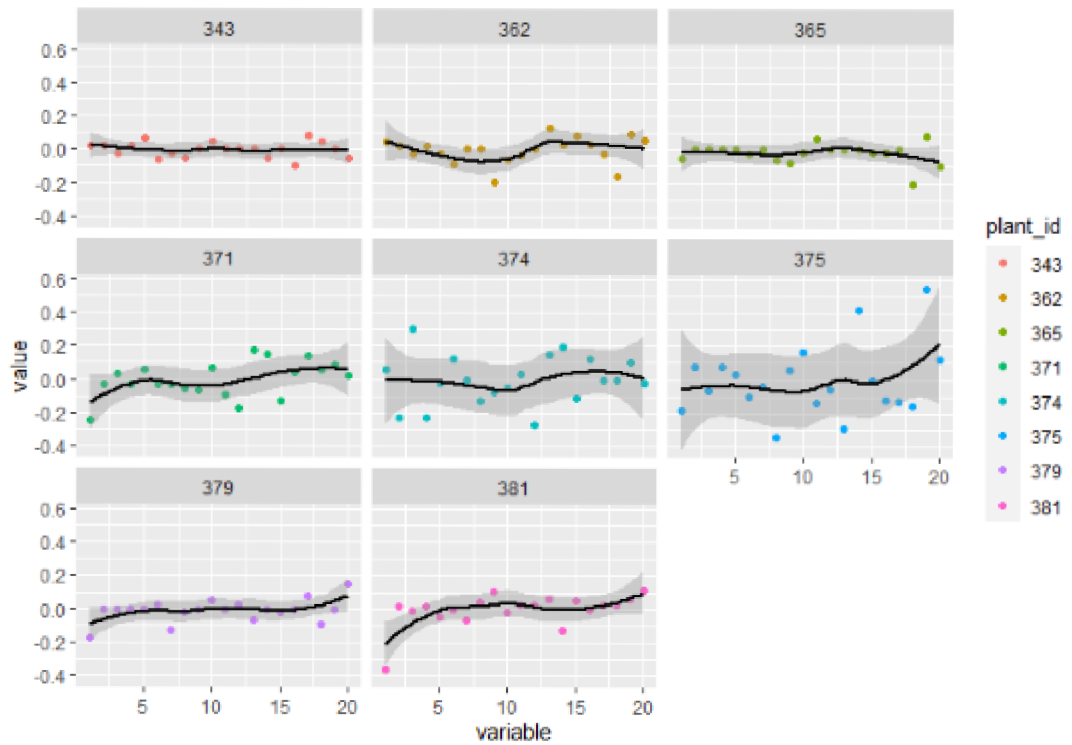
The individual components were weighed on a laboratory balance and dissolved using distilled water. The calculated amount was then measured from the stock solutions to the total required fertilizer amount of 40 L (8 weeks supply) according to the prescribed formulas for the macro-elements.

Results:

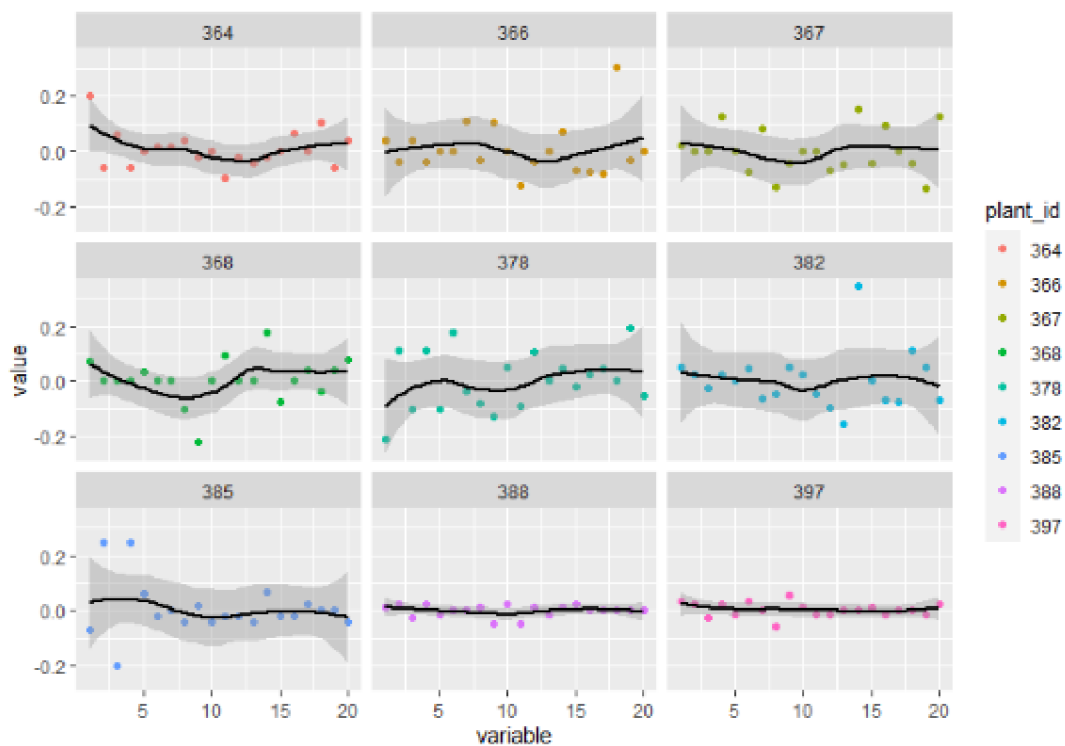
Plant height over time (appendix 4):



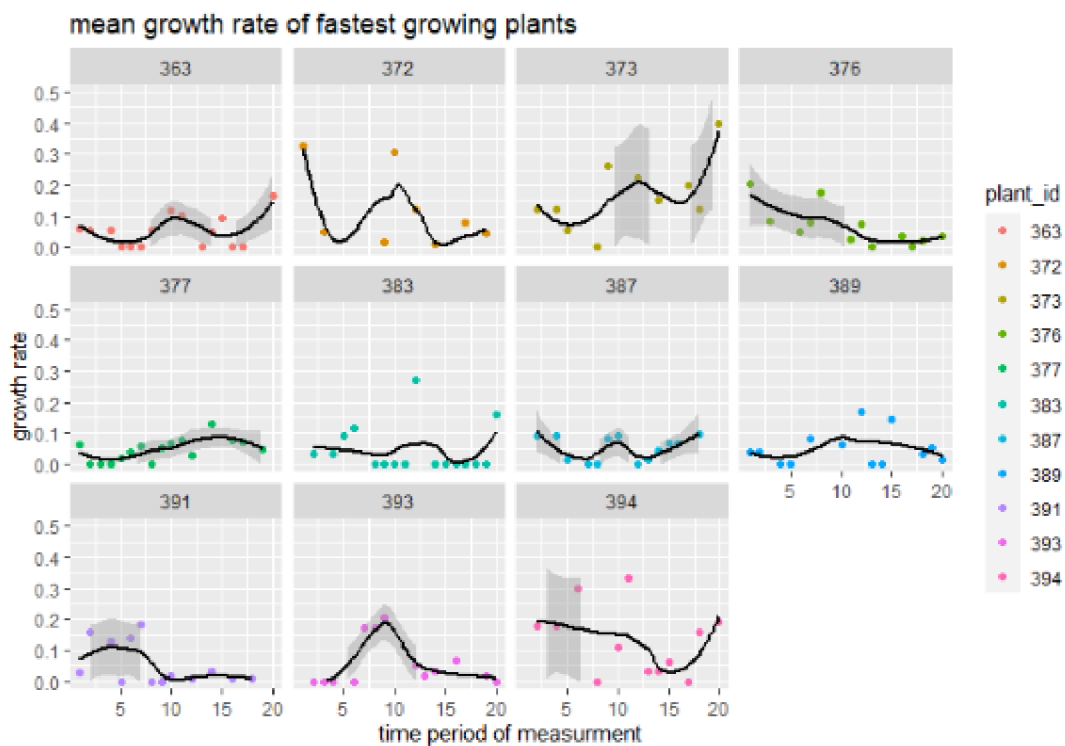
Plants with negative growth rate (appendix 5):



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. byzantina
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

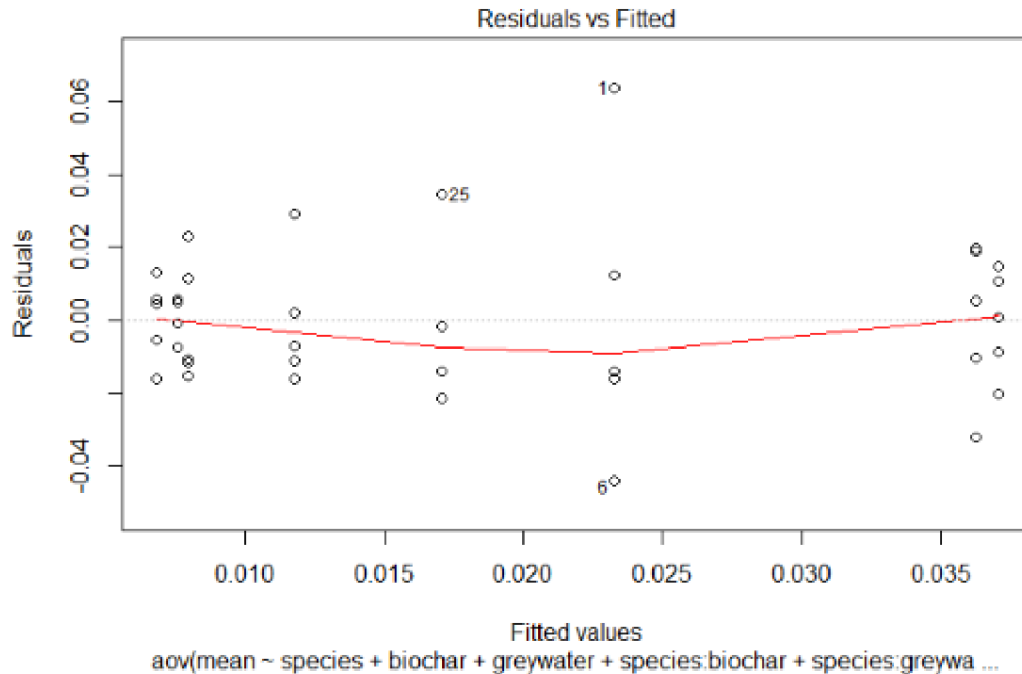
34	394	0.02	0.33	-0.27	0.17	0.02	10.23	0.02	0.05	-0.06	0.60	A.maritima
35	395	0.05	0.21	-0.09	0.09	0.05	1.81	0.09	0.23	-0.56	0.30	A.maritima
36	396	0.04	0.50	-0.19	0.15	0.01	3.54	0.55	0.08	-0.22	0.69	A.maritima
37	397	0.00	0.06	-0.06	0.02	0.00	5.70	0.53	0.07	-0.08	0.11	A.maritima
38	398	0.04	0.26	-0.13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

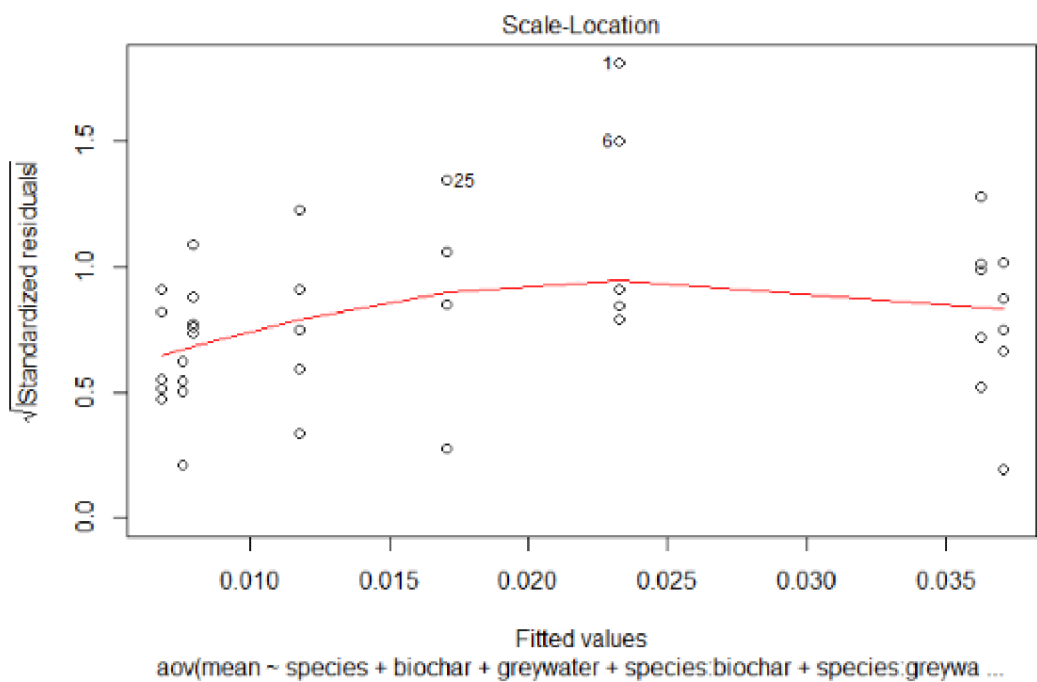
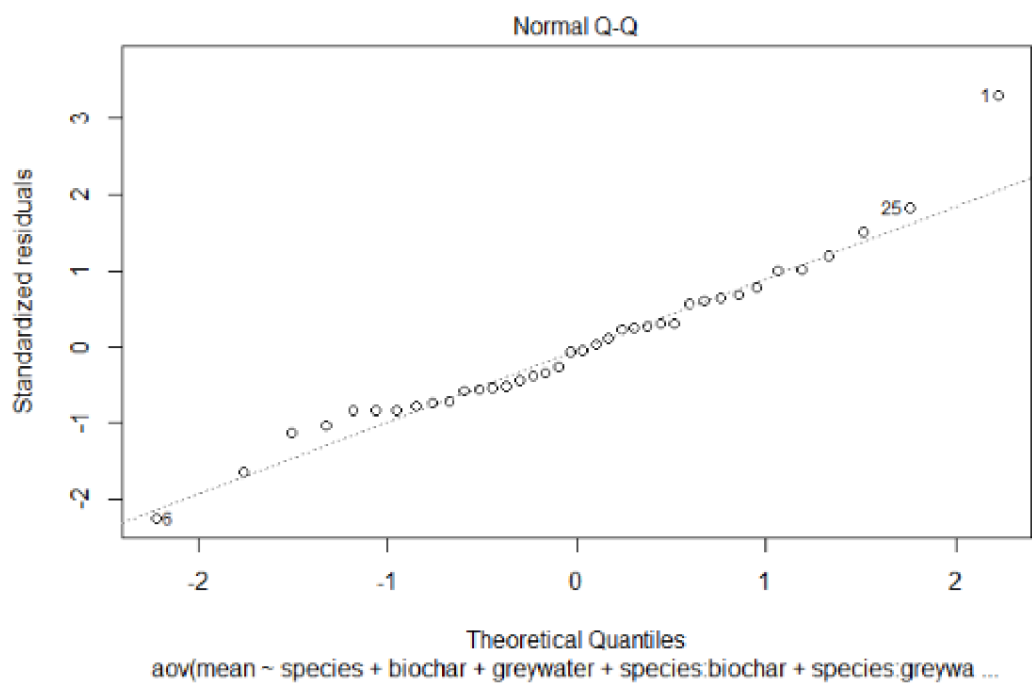
3-way ANOVA table – updated since Biochar: Greywater: species was not a significant effect (appendix 9)

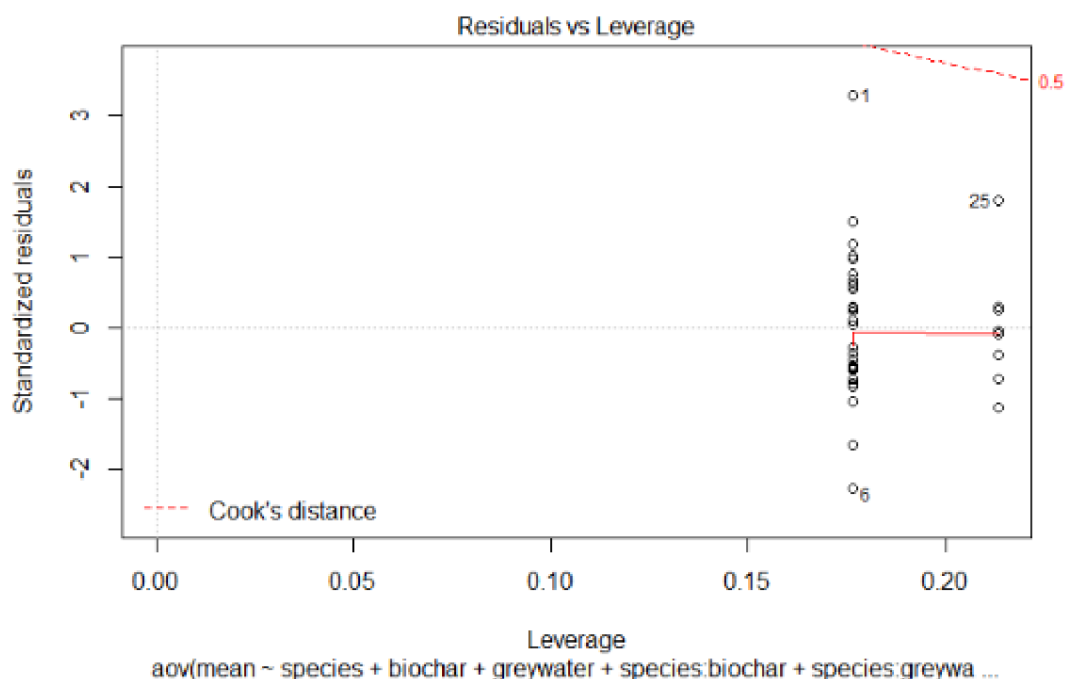
```

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

```







Poisson general linear model for number of leaves in *G. macrorrhizum* (appendix 10)

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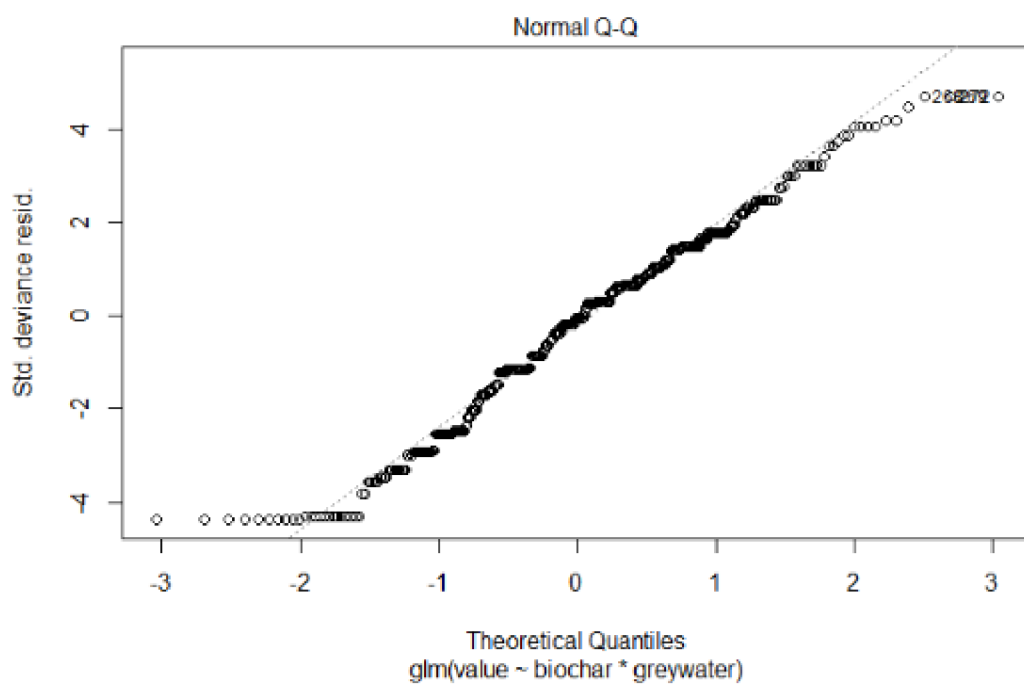
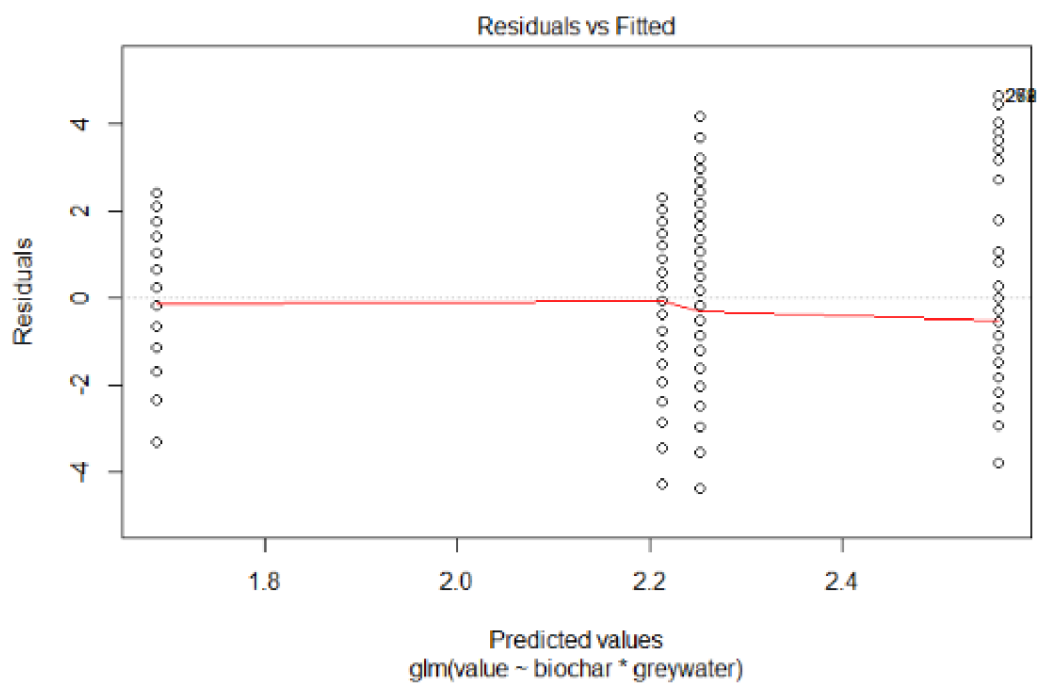
Coefficients:
              Estimate Std. Error z value Pr(>|z|)
(Intercept)    2.21297    0.03227   68.566 <2e-16 ***
biochar         0.03782    0.04522    0.836  0.403
greywatery     -0.52481    0.05294   -9.914 <2e-16 ***
biochar:greywatery 0.83457    0.06739   12.385 <2e-16 ***
---
Signif. codes: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

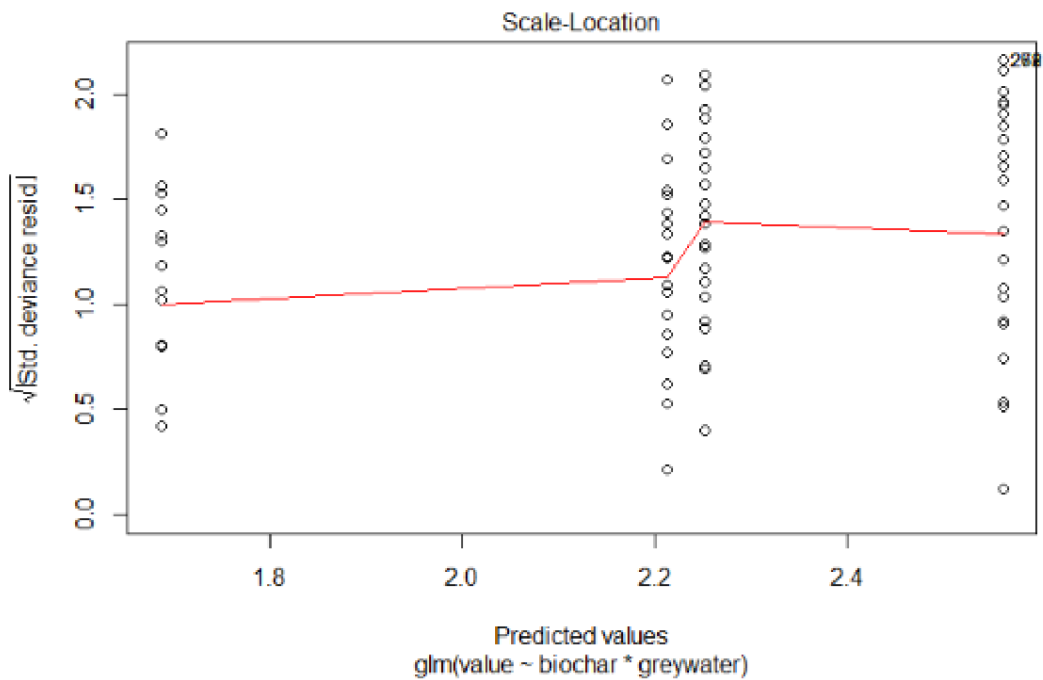
(Dispersion parameter for poisson family taken to be 1)

    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

```





Poisson general linear model for number of flowers in *A. maritima* (appendix 11)

```

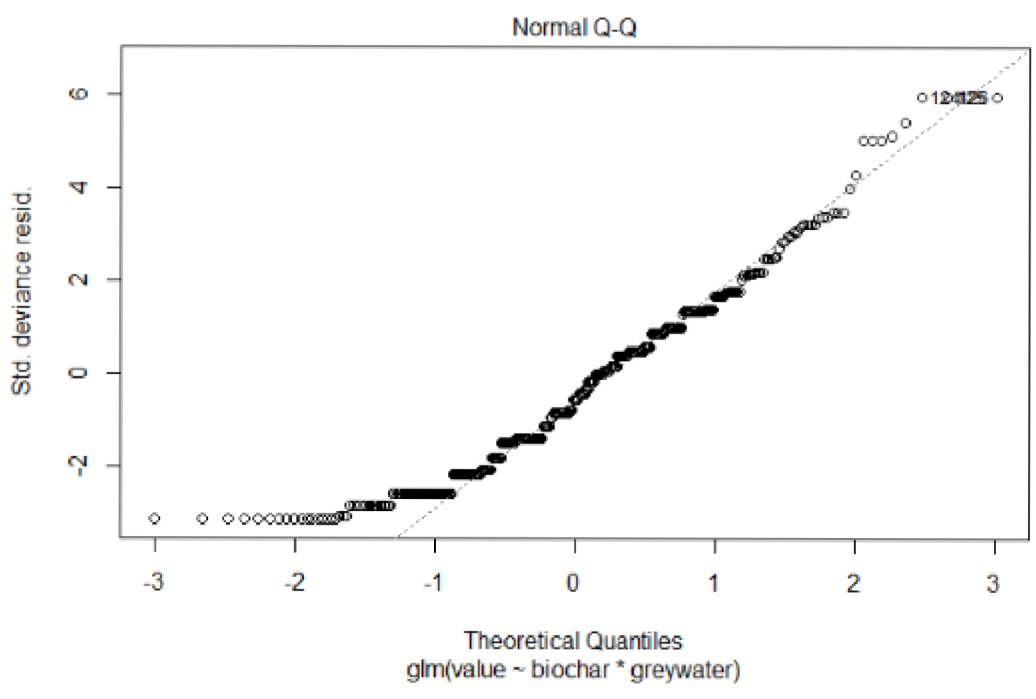
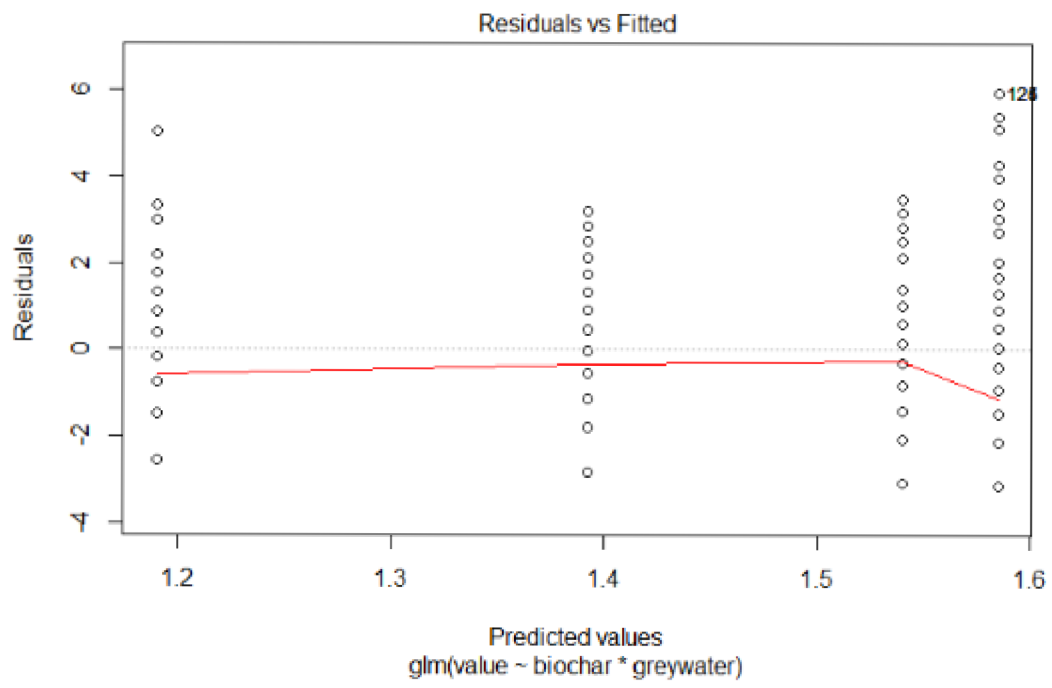
Coefficients:
              Estimate Std. Error z value Pr(>|z|)
(Intercept)    1.58534    0.04938  32.102 < 2e-16 ***
biochar        -0.04490    0.06693  -0.671  0.50236
greywatery     -0.19311    0.07347  -2.629  0.00858 **
biochar:greywatery -0.15775    0.10167  -1.552  0.12076
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

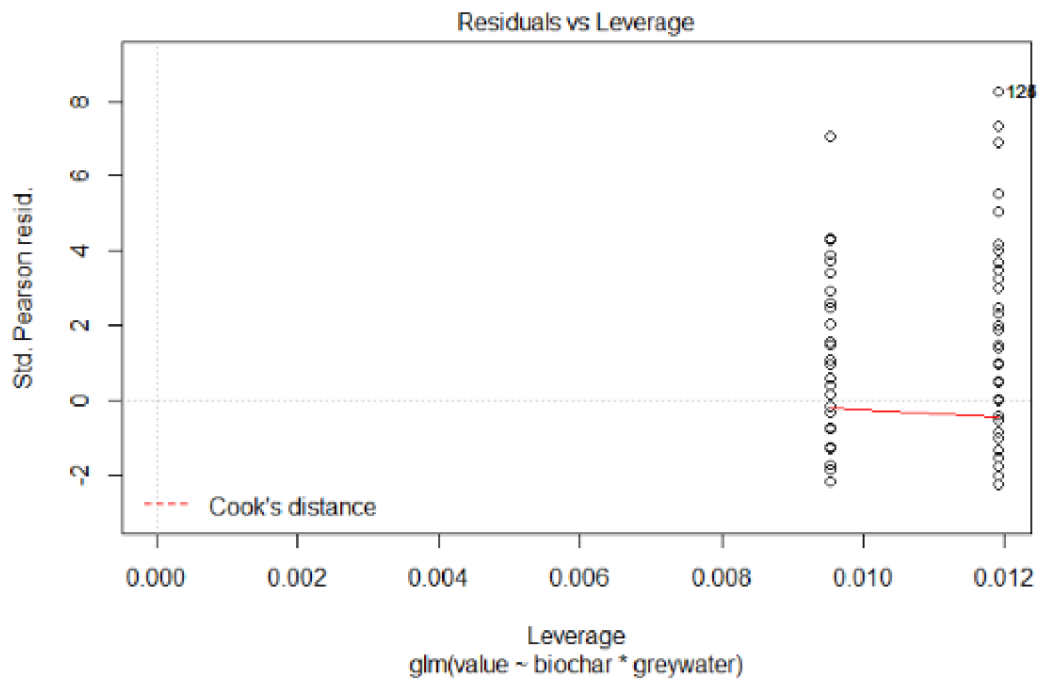
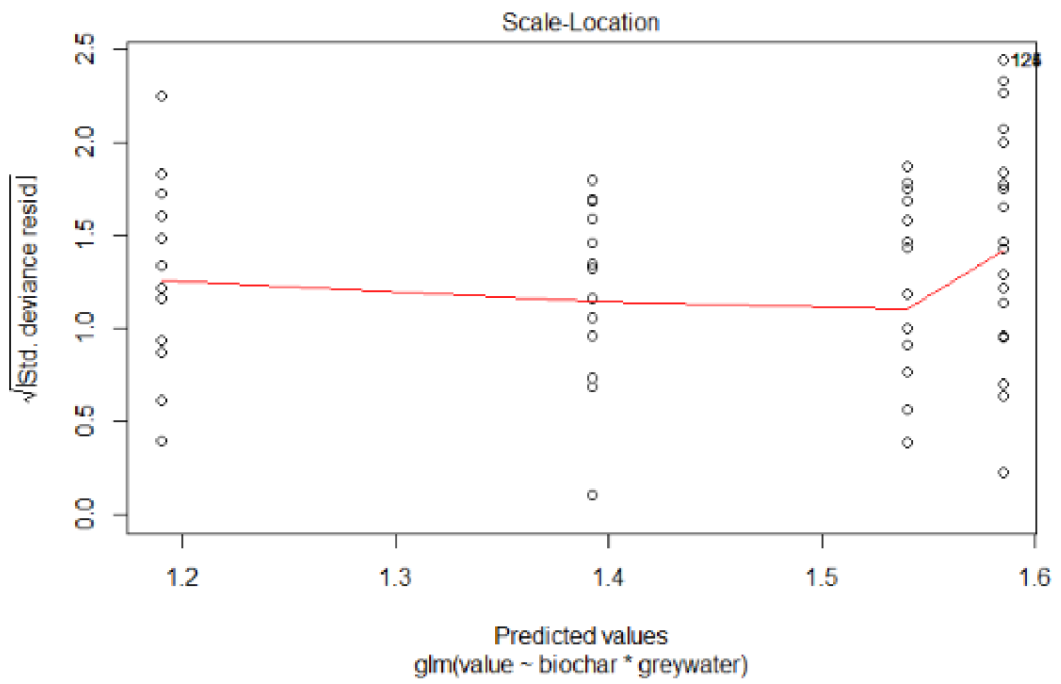
(Dispersion parameter for poisson family taken to be 1)

    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

```





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
    
```

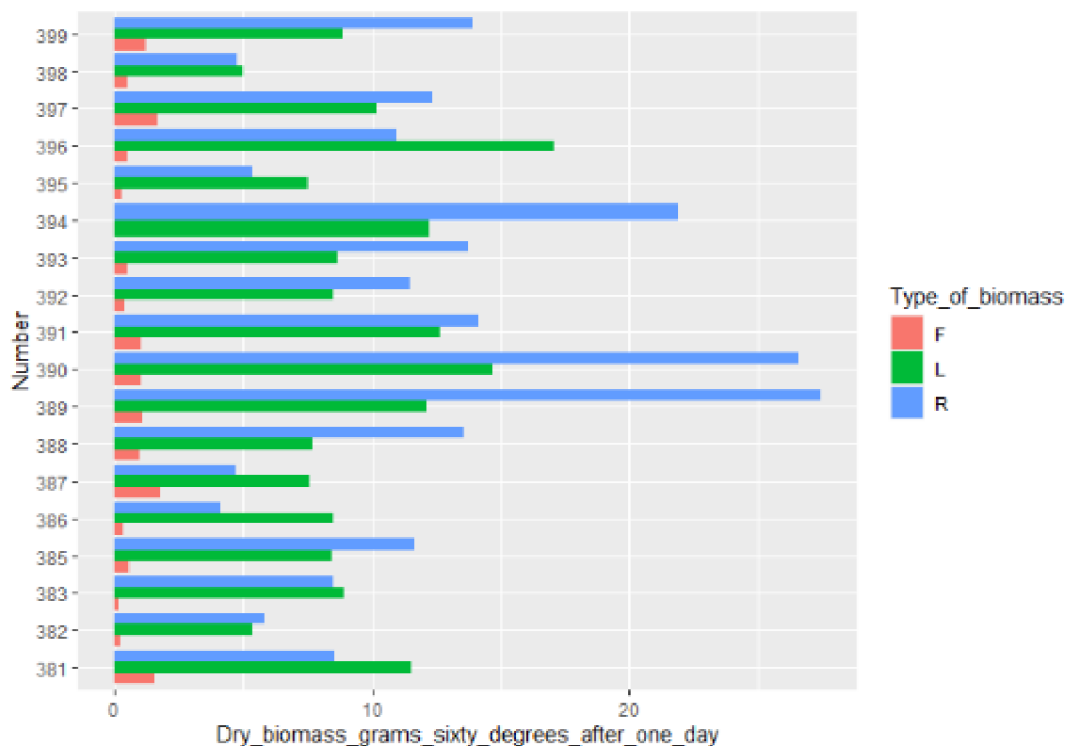
Correlation analysis between number of leaves and weight of dry biomass in *A. maritima* (appendix 13)

```

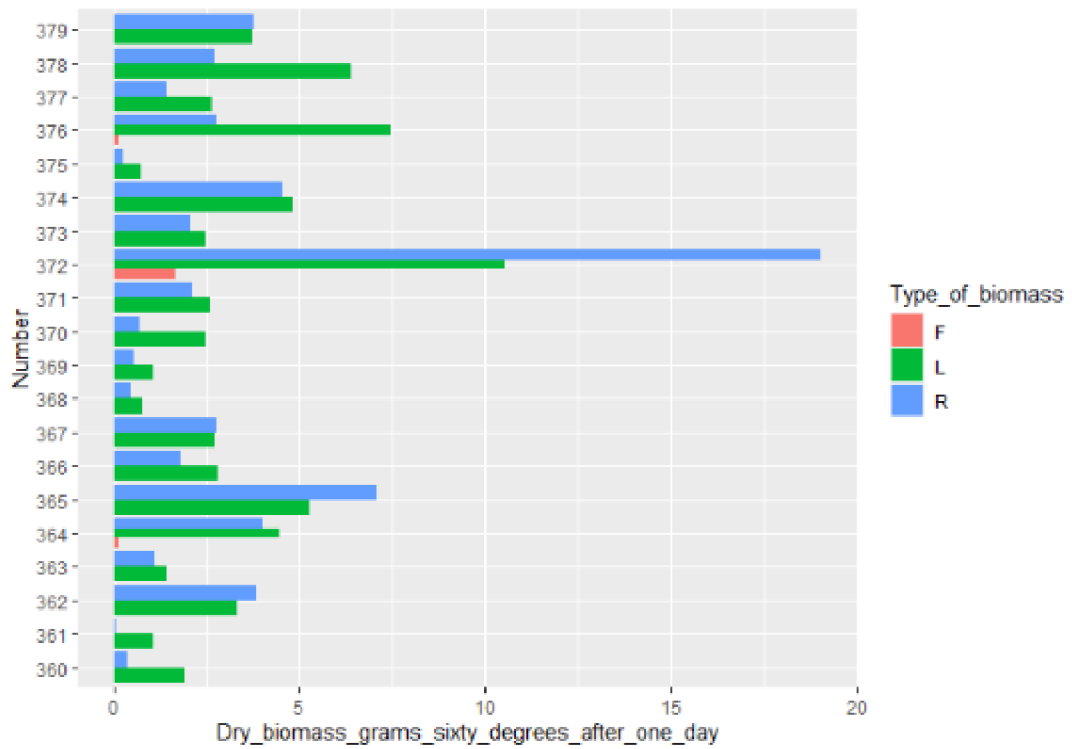
Spearman's rank correlation rho

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)



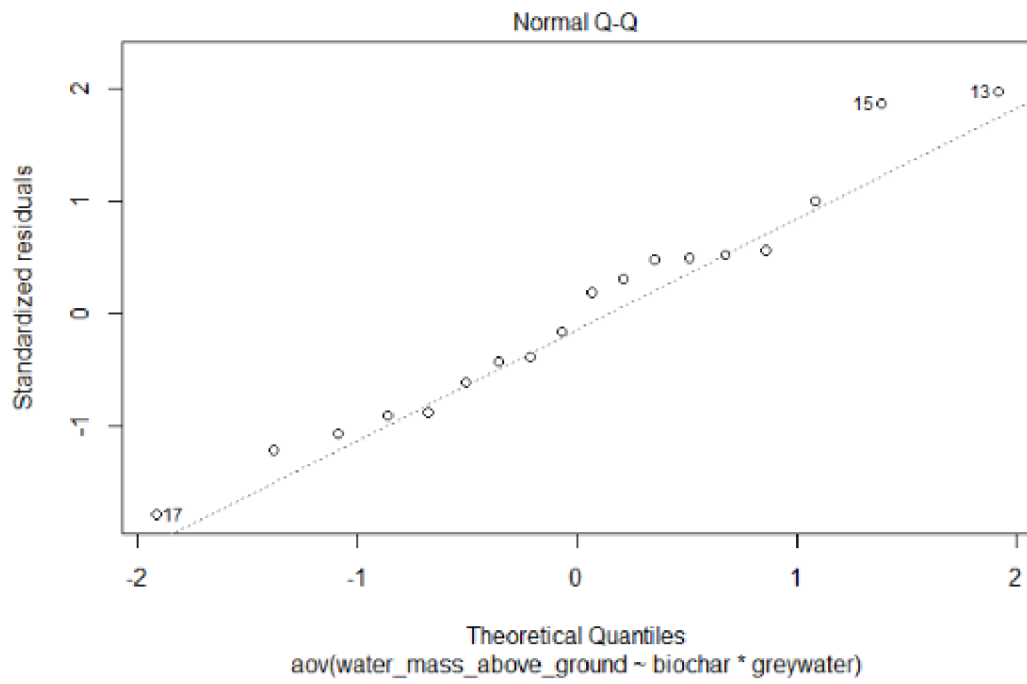
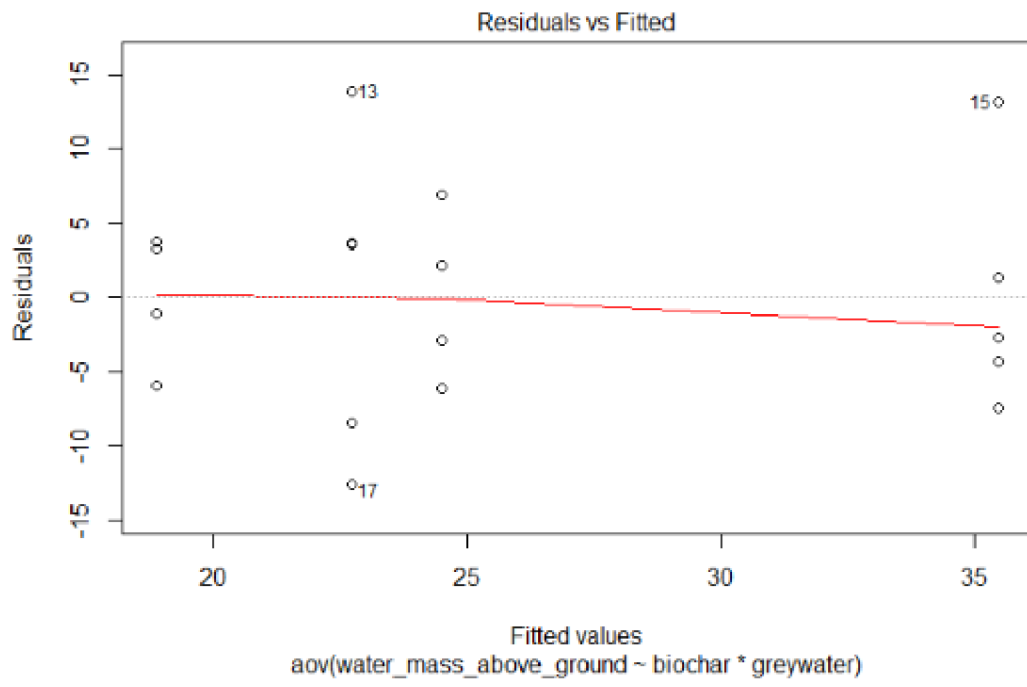
Type and weight of biomass in *G. Macrorrhizum* (appendix 15)

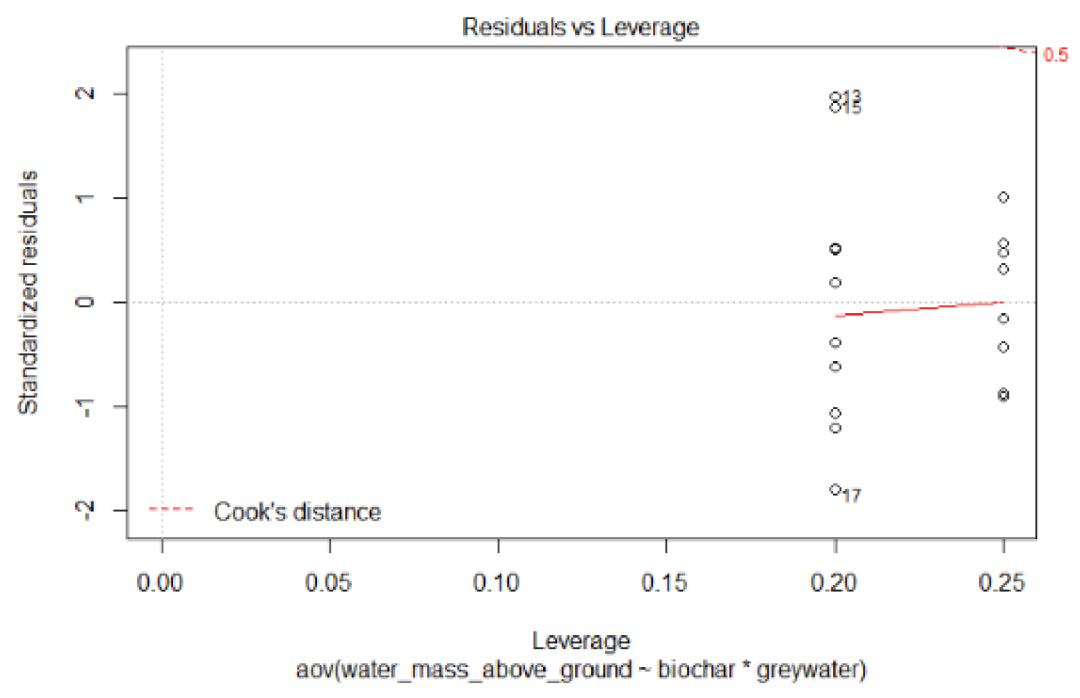
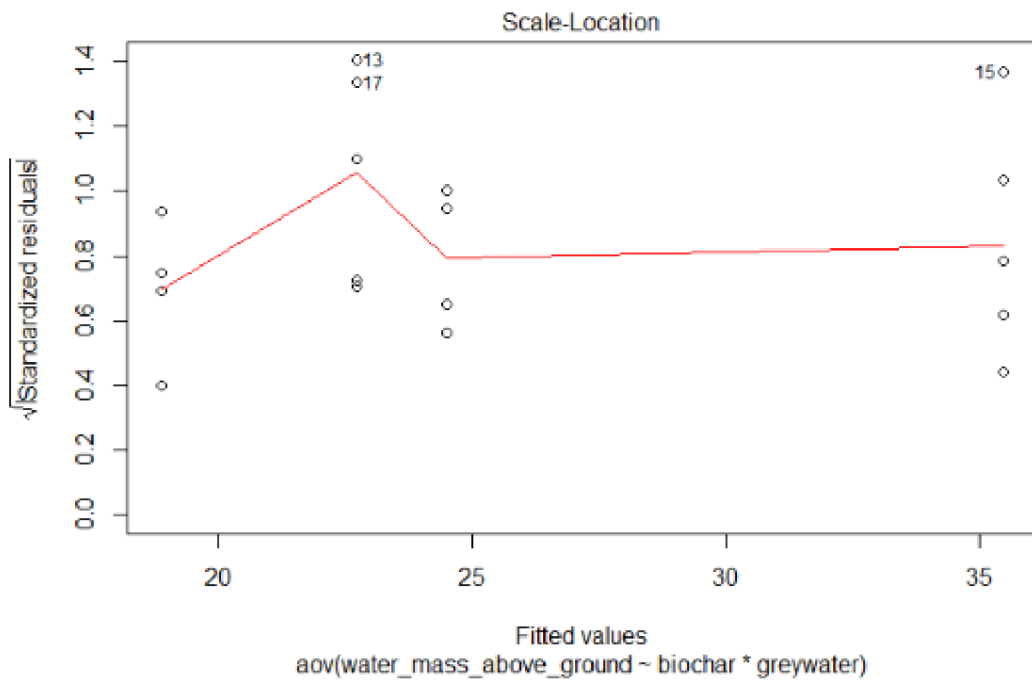


2-way ANOVA, for water mass above ground for *A. maritima* (appendix 16)

	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





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

```

> summary(Anova)

```

	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)

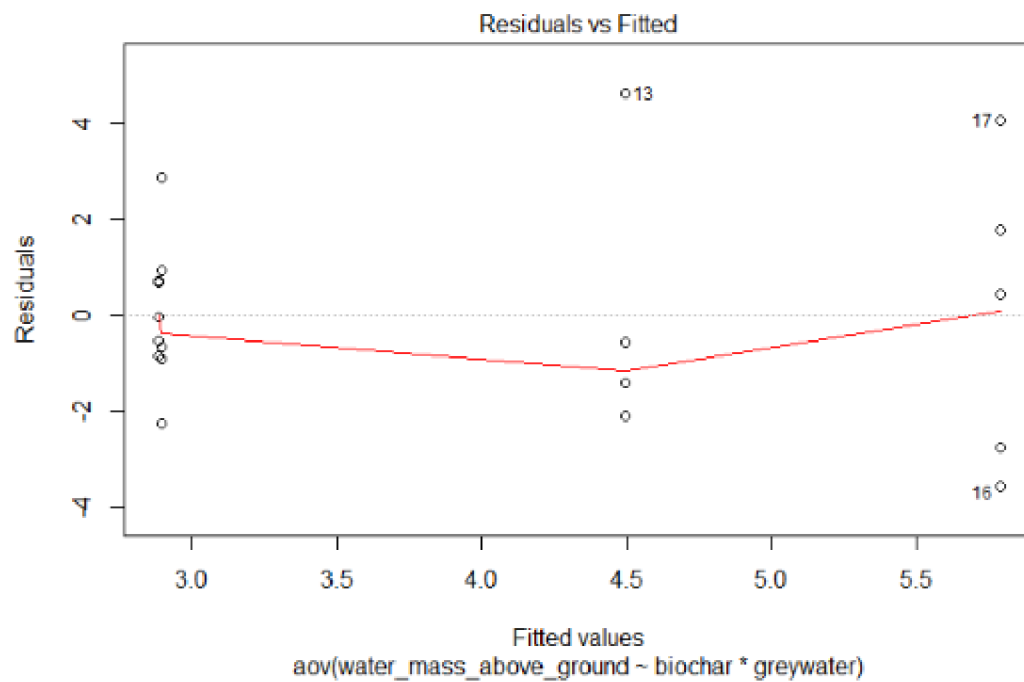
```

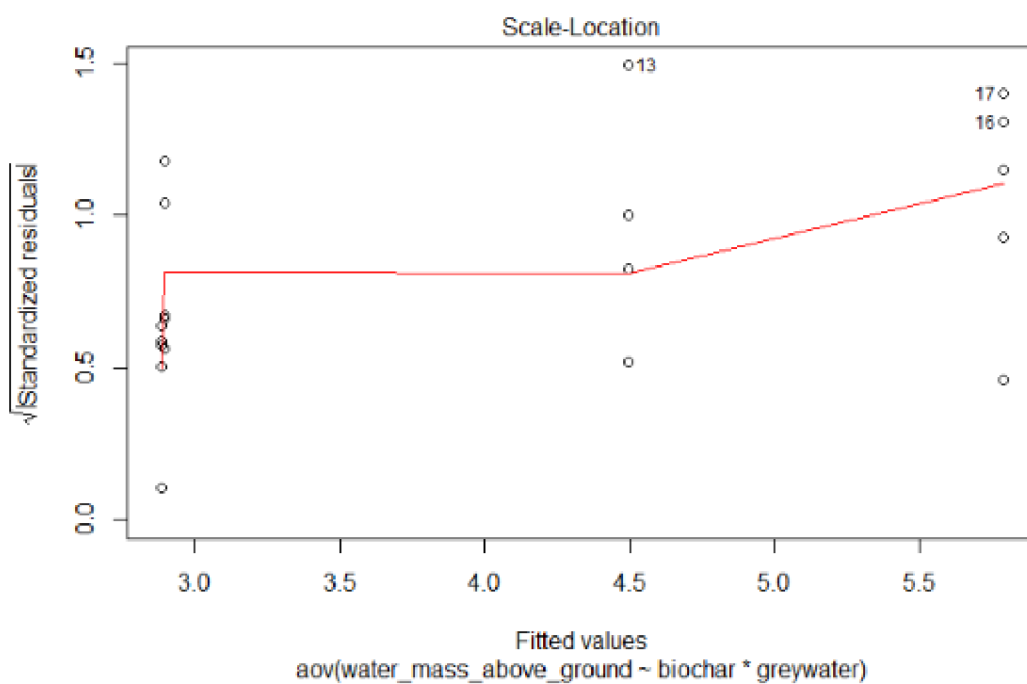
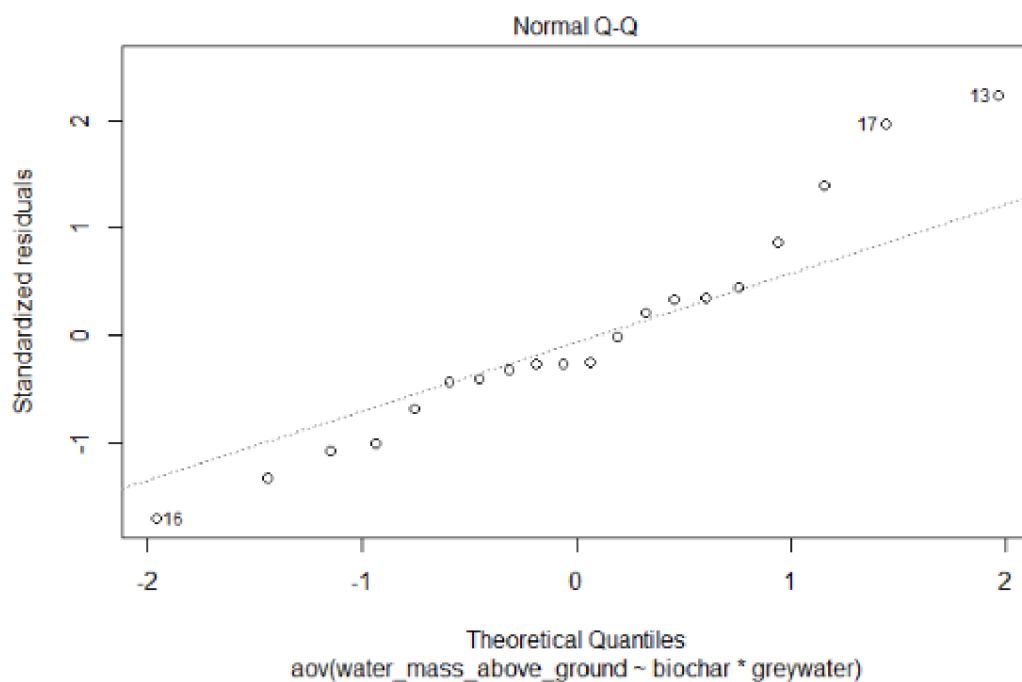
> summary(Anova)

```

	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





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