



Supplement of

Effects of basalt and biochar addition on base cations and trace metals in plants and soil in an urban field trial

Arthur Vienne et al.

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S1. Timeline

Table S1: Overview of the timeline of Belfast experiments.

	Date	Clover plots	Mustard plots
Summer (S1)	16-19 May 2023	Establish clover plots and seeding	
	16-19 May 2023	Clover soil sampling for testing in Antwerp (1)	
	monday 13 november 2023	6-month clover biomass sample	
Winter (W1)	monday 20 november 2023		Establish mustard plots and seeding
	tuesday 7 mei 2024	12-month clover biomass sample	6-month mustard biomass sample
Winter (W2)	tuesday 12 november 2024	Clover soil sampling for testing in Antwerp (2)	12-month mustard biomass sample

S2. (Heavy) metals in plants and soil fractions

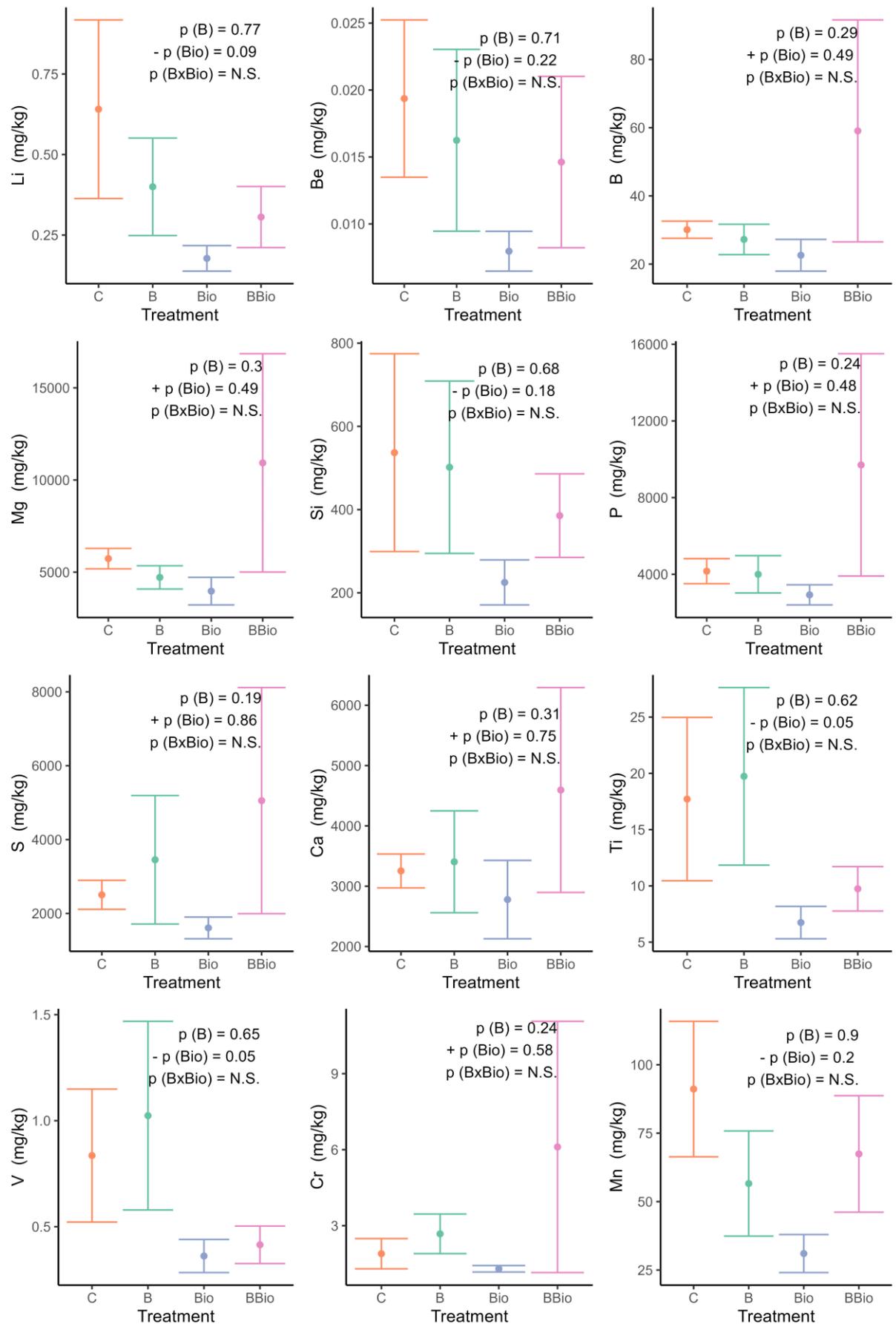


Fig. S1: Trace elements in clover plants. Significance of basal p(B), biochar p(Bio) and interaction p(BxBio) are indicated on the figures. Dots and error bars represent averages and standard errors.

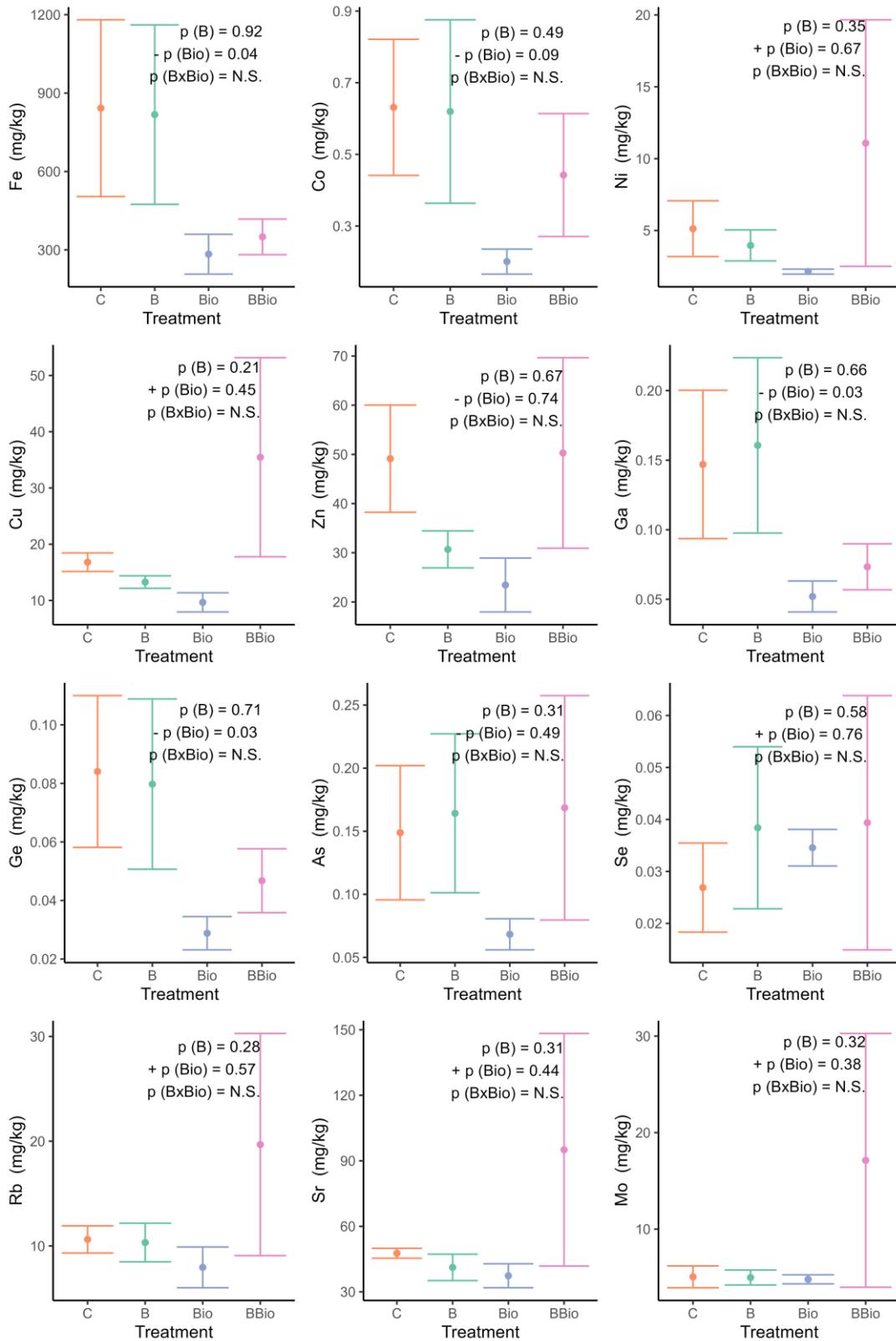


Fig. S2: Trace elements in clover plants. Significance of basal p(B), biochar p(Bio) and interaction p(BxBio) are indicated on the figures. Dots and error bars represent averages and standard errors.

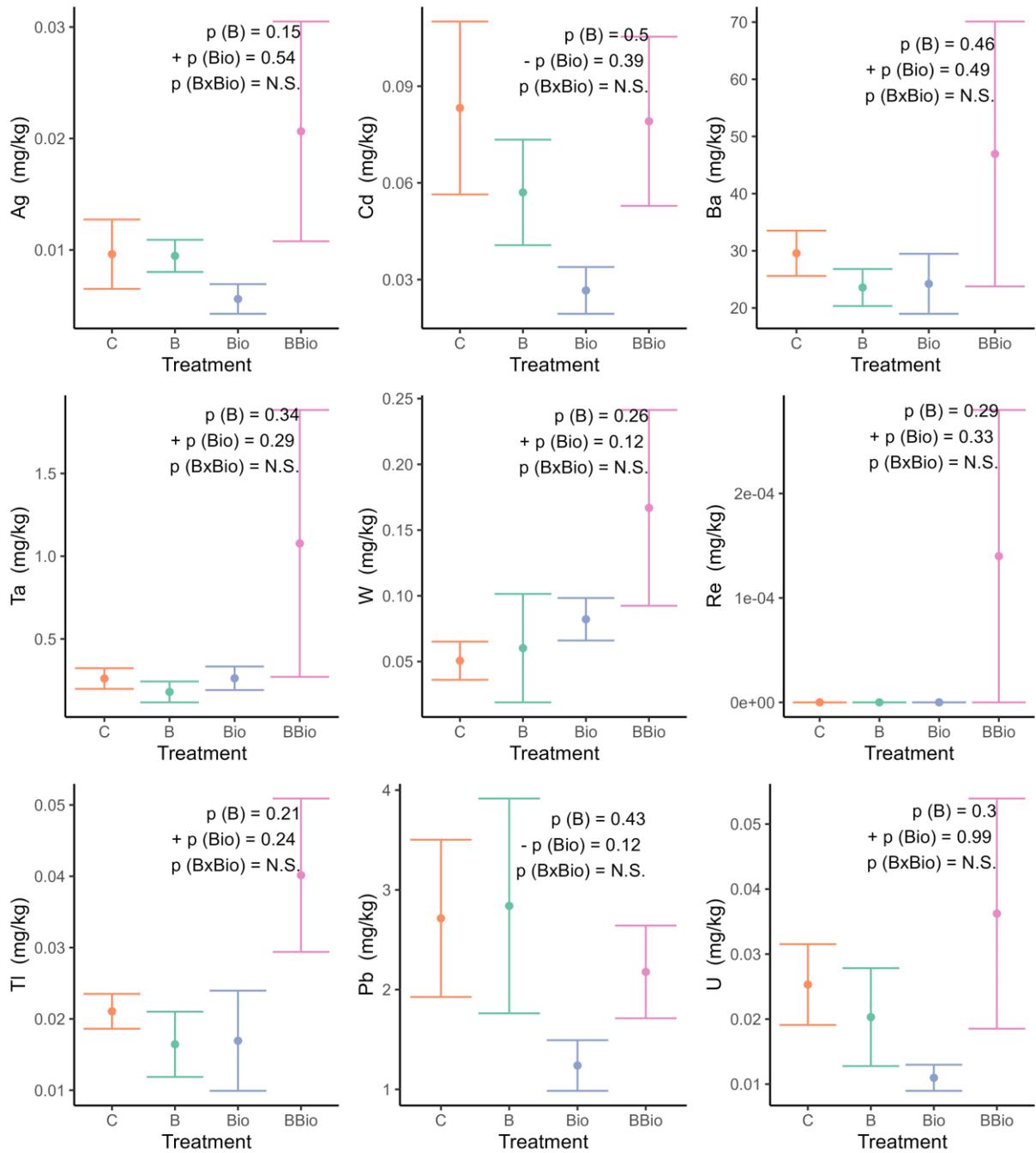


Fig. S3: Trace elements in clover plants. Significance of basal p(B), biochar p(Bio) and interaction p(BxBio) are indicated on the figures. Dots and error bars represent averages and standard errors.

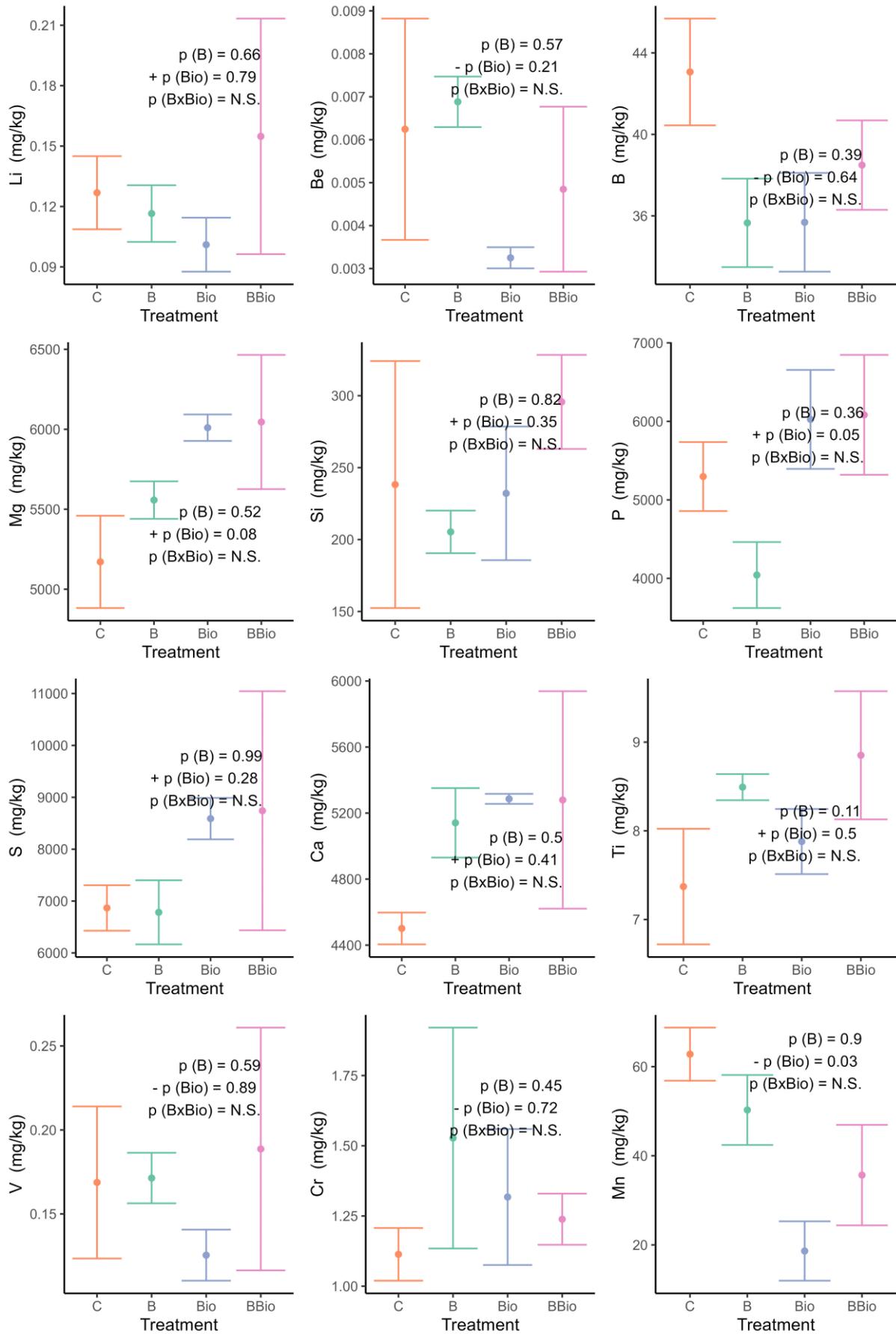


Fig. S4 : Trace elements in mustard plants. Significance of basalt p(B), biochar p(Bio) and interaction p(BxBio) are indicated on the figures. Dots and error bars represent averages and standard errors.

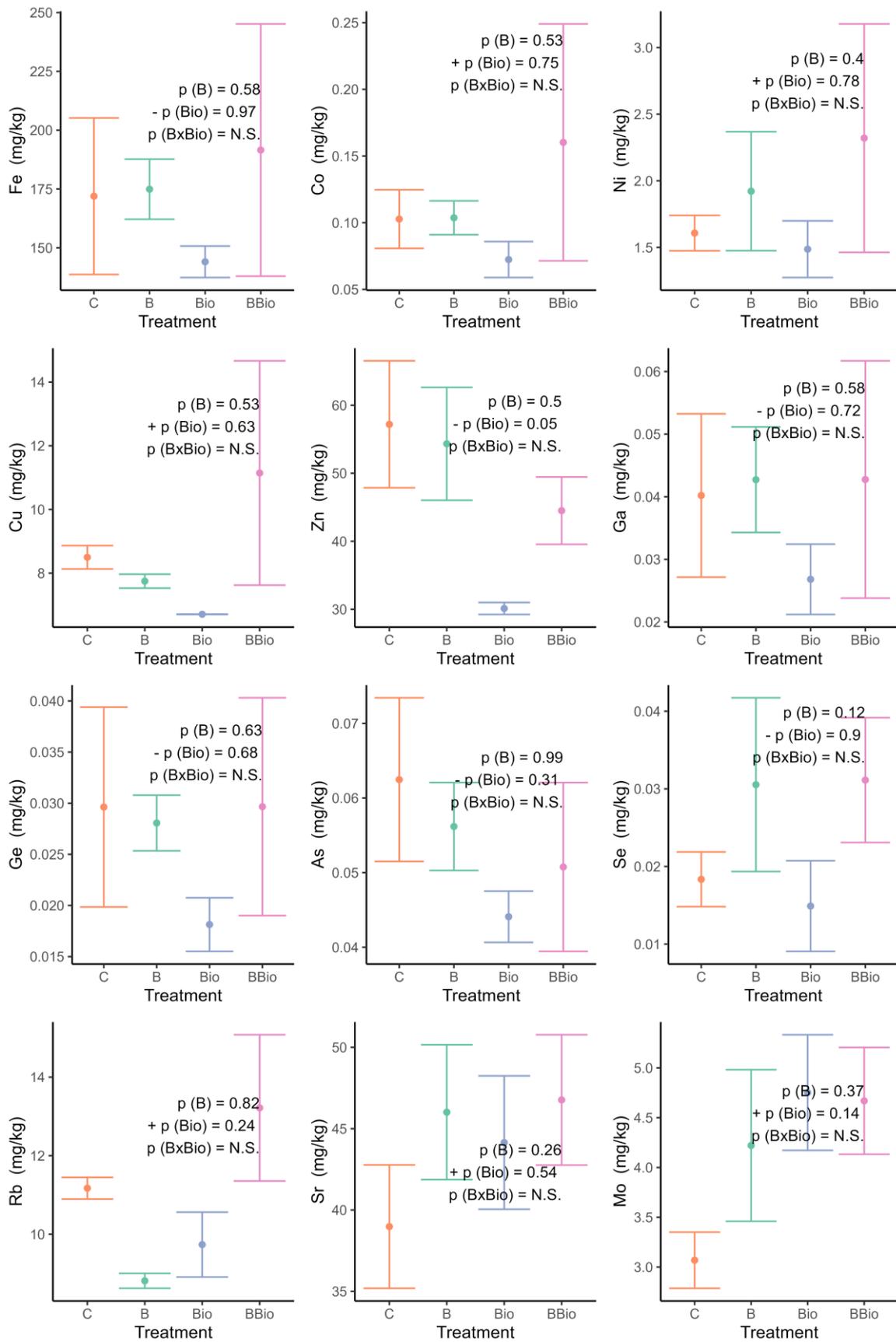


Fig. S5: Trace elements in mustard plants. Significance of basalt p(B), biochar p(Bio) and interaction p(BxBio) are indicated on the figures. Dots and error bars represent averages and standard errors.

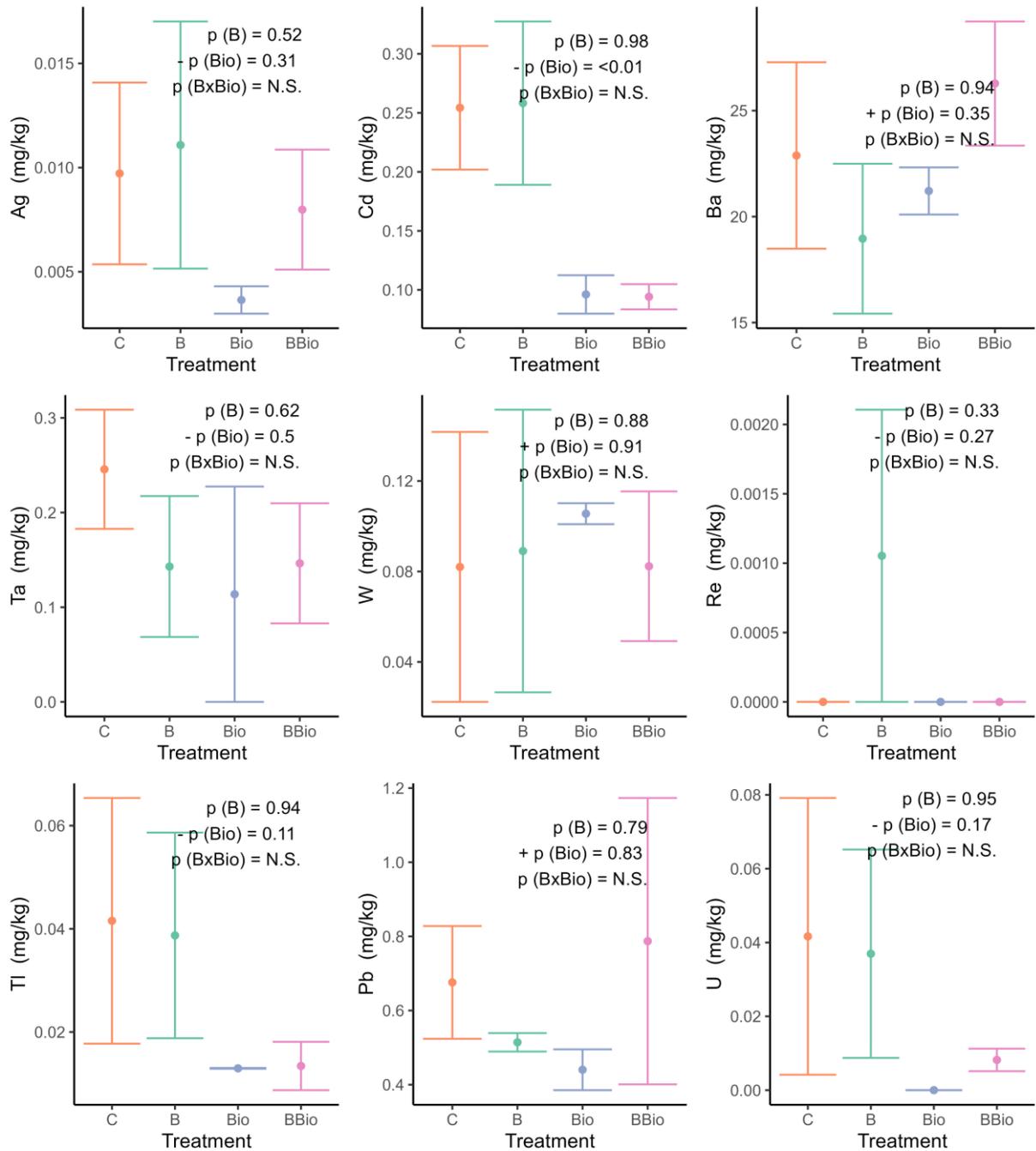


Fig. S6: Trace elements in mustard plants. Results of the statistical analysis are shown on the figures as p-values for basalt (p(B)), biochar (p(Bio)), and their interaction (p(BxBio)) effects. Dots and error bars represent averages and standard errors.

In soils, we find that biochar amendment significantly decreased exchangeable Ni, while basalt significantly increased heavy metals (Ni and Cr) in the reducible soil fraction (which typically has low plant availability) (Table S2). Also reducible soil Cu tended to be higher after basalt amendment.

Table S2: Outcome of linear model analyses for biochar, basalt and interaction effects (if any) as logical factors for elements in soil fractions (1 = exchangeable, 2 = carbonate, 3 = reducible and 4 = oxidizable). Significant effects are shown in bold. Samples were taken 550 days after amendment in clover planted plots. Carbonate elements were below detection limit and therefore are excluded from this table.

element	fraction	variables	Effect size	pvalues
Ni	1	intercept	2.20e-01	
Ni	1	Basalt (0/1)	-1.07e-02	0.80

element	fraction	variables	Effect size	pvalues
Ni	1	Biochar (0/1)	-8.97e-02	0.04
Ni	1	Basalt x Biochar (0/1)	NA	N.S.
Pb	1	intercept	6.24e-01	
Pb	1	Basalt (0/1)	-7.14e-02	0.70
Pb	1	Biochar (0/1)	-2.04e-01	0.27
Pb	1	Basalt x Biochar (0/1)	NA	N.S.
Cr	1	intercept	-1.12e-02	
Cr	1	Basalt (0/1)	2.24e-02	0.36
Cr	1	Biochar (0/1)	1.86e-02	0.45
Cr	1	Basalt x Biochar (0/1)	NA	N.S.
Zn	1	intercept	9.81e-01	
Zn	1	Basalt (0/1)	-1.01e-02	0.97
Zn	1	Biochar (0/1)	-1.43e-01	0.57
Zn	1	Basalt x Biochar (0/1)	NA	N.S.
Cu	1	intercept	4.23e-01	
Cu	1	Basalt (0/1)	7.30e-02	0.29
Cu	1	Biochar (0/1)	2.85e-02	0.67
Cu	1	Basalt x Biochar (0/1)	NA	N.S.
Ni	3	intercept	5.53e+00	
Ni	3	Basalt (0/1)	3.44e+00	0.04
Ni	3	Biochar (0/1)	-6.19e-01	0.69
Ni	3	Basalt x Biochar (0/1)	NA	N.S.
Pb	3	intercept	2.04e+01	
Pb	3	Basalt (0/1)	4.21e+00	0.40
Pb	3	Biochar (0/1)	-2.32e+00	0.64
Pb	3	Basalt x Biochar (0/1)	NA	N.S.
Cr	3	intercept	1.89e+00	
Cr	3	Basalt (0/1)	8.49e-01	<0.01
Cr	3	Biochar (0/1)	-2.28e-01	0.39
Cr	3	Basalt x Biochar (0/1)	NA	N.S.
Zn	3	intercept	1.87e+01	
Zn	3	Basalt (0/1)	4.31e+00	0.17
Zn	3	Biochar (0/1)	3.21e+00	0.30
Zn	3	Basalt x Biochar (0/1)	NA	N.S.
Cu	3	intercept	2.89e+00	
Cu	3	Basalt (0/1)	1.92e+00	0.08
Cu	3	Biochar (0/1)	-1.10e+00	0.29
Cu	3	Basalt x Biochar (0/1)	NA	N.S.
Ni	4	intercept	3.54e+00	
Ni	4	Basalt (0/1)	6.43e-01	0.05
Ni	4	Biochar (0/1)	-7.95e-02	0.79
Ni	4	Basalt x Biochar (0/1)	NA	N.S.

element	fraction	variables	Effect size	pvalues
Pb	4	intercept	3.37e+00	
Pb	4	Basalt (0/1)	2.33e-01	0.77
Pb	4	Biochar (0/1)	-3.76e-01	0.64
Pb	4	Basalt x Biochar (0/1)	NA	N.S.
Cr	4	intercept	4.58e+00	
Cr	4	Basalt (0/1)	-2.19e-01	0.62
Cr	4	Biochar (0/1)	-1.39e-01	0.75
Cr	4	Basalt x Biochar (0/1)	NA	N.S.
Zn	4	intercept	5.50e+00	
Zn	4	Basalt (0/1)	-1.11e-01	0.89
Zn	4	Biochar (0/1)	-1.19e-01	0.88
Zn	4	Basalt x Biochar (0/1)	NA	N.S.
Cu	4	intercept	6.95e+00	
Cu	4	Basalt (0/1)	1.56e+00	0.31
Cu	4	Biochar (0/1)	1.30e+00	0.40
Cu	4	Basalt x Biochar (0/1)	NA	N.S.

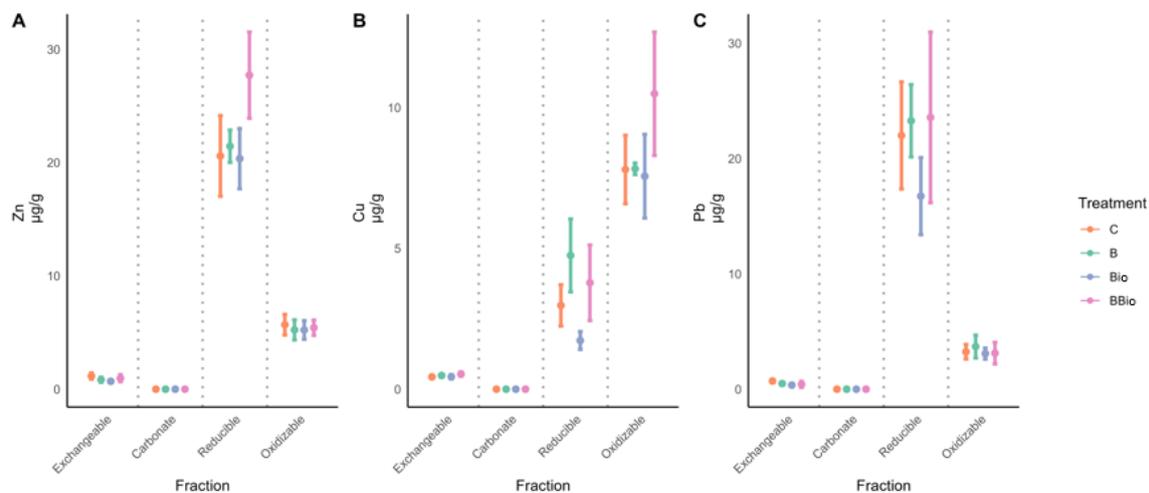


Fig. S7: Difference in Zn and Cu concentrations relative to the control soils for the 4 different considered soil fractions. These soil elements were extracted after initial soil sampling in clover planted plots. Carbonate fraction Zn, Cu and Pb were below the detection limit. A vertical dotted line is plotted in between different soil fractions. Significant positive and negative effects are indicated with a + and – respectively.

For other soil metals, we did a second measurement 1 year after amendment (**Table 3**). Biochar increased exchangeable bases (Na, K and Mg) and also increased Ca, K and Na in the carbonate soil fraction (while decreasing Fe- and Al carbonates). Basalt also increased metals in the reducible pool here, namely Fe (**Figure 5**), Mg, K and Si, which suggest that amorphous clay (precursors) have been generated, that may have become unextractable at the last sampling. Oxidizable Al, Fe decreased for basalt, while basalt increased Mg and Na in this fraction.

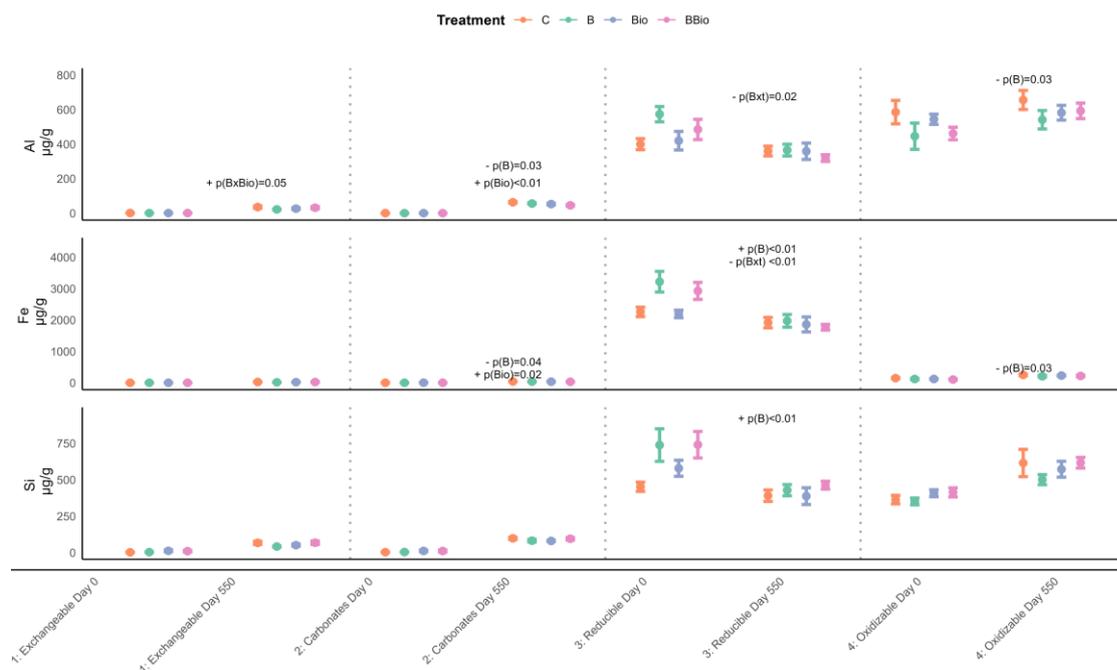


Fig. S8: Delta in elements relative to control soils of Al, Fe and Si for the 4 different considered soil fractions. These soil elements were extracted after initial soil sampling and after 550 days in clover planted plots. A vertical dotted line is plotted in between different soil fractions. Significant positive and negative effects are indicated with a + and – respectively.

Table S3: Outcome of repeated measure linear model analyses for biochar, basalt and interaction effects (if any) as logical factors for elements in soil fractions (1 = exchangeable, 2= carbonate, 3= reducible and 4 = oxidizable). Significant effects are shown in bold. Samples were taken directly after amendment and 550 days later in clover planted plots.

element	fraction	variables	Effect size	P values
Al	1	intercept	4.24e+00	
Al	1	Time (day)	5.35e-02	<0.01
Al	1	Basalt (0/1)	-5.42e+00	0.37
Al	1	Biochar (0/1)	-5.30e+00	0.95
Al	1	Basalt : Biochar (0/1)	9.84e+00	0.049
Al	1	time : Basalt	-6.62e-03	0.47
Al	1	time : Biochar	1.35e-03	0.88
Ca	1	intercept	1.20e+03	
Ca	1	Time (day)	-5.80e-01	<0.01
Ca	1	Basalt (0/1)	1.44e+02	0.046
Ca	1	Biochar (0/1)	7.08e+01	0.33
Ca	1	Basalt : Biochar (0/1)	NA	N.S.
Ca	1	time : Basalt	NA	N.S.
Ca	1	time : Biochar	NA	N.S.
Fe	1	intercept	1.78e+00	
Fe	1	Time (day)	3.72e-02	<0.01
Fe	1	Basalt (0/1)	-1.69e+00	0.36
Fe	1	Biochar (0/1)	7.09e-01	0.7
Fe	1	Basalt : Biochar (0/1)	NA	N.S.

element	fraction	variables	Effect size	P values
Fe	1	time : Basalt	NA	N.S.
Fe	1	time : Biochar	NA	N.S.
K	1	intercept	1.87e+02	
K	1	Time (day)	7.17e-02	0.03
K	1	Basalt (0/1)	-7.33e+01	0.5
K	1	Biochar (0/1)	5.99e+02	<0.01
K	1	Basalt : Biochar (0/1)	NA	N.S.
K	1	time : Basalt	NA	N.S.
K	1	time : Biochar	-9.69e-01	0.013
Mg	1	intercept	2.14e+02	
Mg	1	Time (day)	-8.98e-02	0.037
Mg	1	Basalt (0/1)	2.54e+01	0.35
Mg	1	Biochar (0/1)	6.59e+01	0.015
Mg	1	Basalt : Biochar (0/1)	NA	N.S.
Mg	1	time : Basalt	NA	N.S.
Mg	1	time : Biochar	NA	N.S.
Na	1	intercept	3.19e+01	
Na	1	Time (day)	1.50e-03	0.017
Na	1	Basalt (0/1)	-2.38e+01	0.6
Na	1	Biochar (0/1)	2.15e+02	0.017
Na	1	Basalt : Biochar (0/1)	NA	N.S.
Na	1	time : Basalt	NA	N.S.
Na	1	time : Biochar	-3.79e-01	0.02
Si	1	intercept	5.72e+00	
Si	1	Time (day)	9.07e-02	<0.01
Si	1	Basalt (0/1)	-2.56e+00	0.63
Si	1	Biochar (0/1)	6.69e+00	0.21
Si	1	Basalt : Biochar (0/1)	NA	N.S.
Si	1	time : Basalt	NA	N.S.
Si	1	time : Biochar	NA	N.S.
Al	2	intercept	7.80e-01	
Al	2	Time (day)	1.14e-01	<0.01
Al	2	Basalt (0/1)	-1.69e-01	0.03
Al	2	Biochar (0/1)	2.25e-03	<0.01
Al	2	Basalt : Biochar (0/1)	NA	N.S.
Al	2	time : Basalt	-1.27e-02	0.04
Al	2	time : Biochar	-1.90e-02	<0.01
Ca	2	intercept	6.02e+01	
Ca	2	Time (day)	1.84e-01	<0.01
Ca	2	Basalt (0/1)	3.39e+01	0.25
Ca	2	Biochar (0/1)	6.23e+01	0.036
Ca	2	Basalt : Biochar (0/1)	NA	N.S.

element	fraction	variables	Effect size	P values
Ca	2	time : Basalt	NA	N.S.
Ca	2	time : Biochar	NA	N.S.
Fe	2	intercept	2.60e+00	
Fe	2	Time (day)	7.20e-02	<0.01
Fe	2	Basalt (0/1)	-2.39e+00	0.039
Fe	2	Biochar (0/1)	1.60e+00	0.023
Fe	2	Basalt : Biochar (0/1)	NA	N.S.
Fe	2	time : Basalt	NA	N.S.
Fe	2	time : Biochar	-1.50e-02	<0.01
K	2	intercept	1.40e+01	
K	2	Time (day)	1.25e-02	0.15
K	2	Basalt (0/1)	-5.87e-01	0.96
K	2	Biochar (0/1)	4.80e+01	0.027
K	2	Basalt : Biochar (0/1)	NA	N.S.
K	2	time : Basalt	NA	N.S.
K	2	time : Biochar	-8.02e-02	0.048
Mg	2	intercept	1.20e+01	
Mg	2	Time (day)	2.07e-02	0.034
Mg	2	Basalt (0/1)	4.69e+00	0.38
Mg	2	Biochar (0/1)	1.32e+01	0.014
Mg	2	Basalt : Biochar (0/1)	NA	N.S.
Mg	2	time : Basalt	NA	N.S.
Mg	2	time : Biochar	NA	N.S.
Na	2	intercept	7.18e+00	
Na	2	Time (day)	-8.53e-03	<0.01
Na	2	Basalt (0/1)	5.36e-01	0.86
Na	2	Biochar (0/1)	1.32e+01	0.025
Na	2	Basalt : Biochar (0/1)	NA	N.S.
Na	2	time : Basalt	NA	N.S.
Na	2	time : Biochar	-2.23e-02	0.046
Si	2	intercept	7.16e+00	
Si	2	Time (day)	1.47e-01	<0.01
Si	2	Basalt (0/1)	-3.92e-01	0.93
Si	2	Biochar (0/1)	2.54e+00	0.57
Si	2	Basalt : Biochar (0/1)	NA	N.S.
Si	2	time : Basalt	NA	N.S.
Si	2	time : Biochar	NA	N.S.
Al	3	intercept	4.28e+02	
Al	3	Time (day)	-9.67e-02	<0.01
Al	3	Basalt (0/1)	1.17e+02	0.1
Al	3	Biochar (0/1)	-3.04e+01	0.3
Al	3	Basalt : Biochar (0/1)	NA	N.S.

element	fraction	variables	Effect size	P values
Al	3	time : Basalt	-2.43e-01	0.023
Al	3	time : Biochar	NA	N.S.
Ca	3	intercept	4.55e+02	
Ca	3	Time (day)	-7.42e-01	<0.01
Ca	3	Basalt (0/1)	2.35e+02	0.12
Ca	3	Biochar (0/1)	1.31e+02	0.39
Ca	3	Basalt : Biochar (0/1)	NA	N.S.
Ca	3	time : Basalt	NA	N.S.
Ca	3	time : Biochar	NA	N.S.
Fe	3	intercept	2.31e+03	
Fe	3	Time (day)	-6.28e-01	<0.01
Fe	3	Basalt (0/1)	8.40e+02	<0.01
Fe	3	Biochar (0/1)	-1.59e+02	0.29
Fe	3	Basalt : Biochar (0/1)	NA	N.S.
Fe	3	time : Basalt	-1.56e+00	<0.01
Fe	3	time : Biochar	NA	N.S.
K	3	intercept	4.85e+01	
K	3	Time (day)	-1.11e-01	0.053
K	3	Basalt (0/1)	1.76e+01	0.58
K	3	Biochar (0/1)	5.92e+01	0.06
K	3	Basalt : Biochar (0/1)	NA	N.S.
K	3	time : Basalt	NA	N.S.
K	3	time : Biochar	NA	N.S.
Mg	3	intercept	3.57e+02	
Mg	3	Time (day)	-5.09e-01	0.044
Mg	3	Basalt (0/1)	3.26e+02	0.019
Mg	3	Biochar (0/1)	5.03e+01	0.72
Mg	3	Basalt : Biochar (0/1)	NA	N.S.
Mg	3	time : Basalt	NA	N.S.
Mg	3	time : Biochar	NA	N.S.
Na	3	intercept	2.78e+01	
Na	3	Time (day)	-4.62e-02	0.022
Na	3	Basalt (0/1)	1.15e+01	0.3
Na	3	Biochar (0/1)	1.94e+01	0.081
Na	3	Basalt : Biochar (0/1)	NA	N.S.
Na	3	time : Basalt	NA	N.S.
Na	3	time : Biochar	NA	N.S.
Si	3	intercept	5.47e+02	
Si	3	Time (day)	-3.90e-01	<0.01
Si	3	Basalt (0/1)	1.35e+02	<0.01
Si	3	Biochar (0/1)	3.54e+01	0.44
Si	3	Basalt : Biochar (0/1)	NA	N.S.

element	fraction	variables	Effect size	P values
Si	3	time : Basalt	NA	N.S.
Si	3	time : Biochar	NA	N.S.
Al	4	intercept	5.53e+02	
Al	4	Time (day)	1.55e-01	0.018
Al	4	Basalt (0/1)	-7.98e+01	0.027
Al	4	Biochar (0/1)	-1.04e+01	0.77
Al	4	Basalt : Biochar (0/1)	NA	N.S.
Al	4	time : Basalt	NA	N.S.
Al	4	time : Biochar	NA	N.S.
Ca	4	intercept	1.38e+02	
Ca	4	Time (day)	-6.78e-02	0.28
Ca	4	Basalt (0/1)	3.43e+01	0.42
Ca	4	Biochar (0/1)	7.38e+01	0.083
Ca	4	Basalt : Biochar (0/1)	NA	N.S.
Ca	4	time : Basalt	NA	N.S.
Ca	4	time : Biochar	NA	N.S.
Fe	4	intercept	1.43e+02	
Fe	4	Time (day)	1.89e-01	<0.01
Fe	4	Basalt (0/1)	-2.51e+01	0.028
Fe	4	Biochar (0/1)	-1.34e+01	0.24
Fe	4	Basalt : Biochar (0/1)	NA	N.S.
Fe	4	time : Basalt	NA	N.S.
Fe	4	time : Biochar	NA	N.S.
K	4	intercept	3.25e+00	
K	4	Time (day)	4.42e-02	<0.01
K	4	Basalt (0/1)	1.23e+00	0.87
K	4	Biochar (0/1)	1.17e+01	0.11
K	4	Basalt : Biochar (0/1)	NA	N.S.
K	4	time : Basalt	NA	N.S.
K	4	time : Biochar	NA	N.S.
Mg	4	intercept	2.46e+02	
Mg	4	Time (day)	-9.35e-02	0.081
Mg	4	Basalt (0/1)	6.09e+01	0.042
Mg	4	Biochar (0/1)	4.41e+01	0.14
Mg	4	Basalt : Biochar (0/1)	NA	N.S.
Mg	4	time : Basalt	NA	N.S.
Mg	4	time : Biochar	NA	N.S.
Na	4	intercept	-5.11e-01	
Na	4	Time (day)	4.88e-02	<0.01
Na	4	Basalt (0/1)	6.94e+00	0.048
Na	4	Biochar (0/1)	6.40e+00	0.068
Na	4	Basalt : Biochar (0/1)	NA	N.S.

element	fraction	variables	Effect size	P values
Na	4	time : Basalt	NA	N.S.
Na	4	time : Biochar	NA	N.S.
Si	4	intercept	3.93e+02	
Si	4	Time (day)	3.30e-01	<0.01
Si	4	Basalt (0/1)	-2.99e+01	0.49
Si	4	Biochar (0/1)	3.40e+01	0.43
Si	4	Basalt : Biochar (0/1)	NA	N.S.
Si	4	time : Basalt	NA	N.S.
Si	4	time : Biochar	NA	N.S.

S3.Temperature and soil moisture

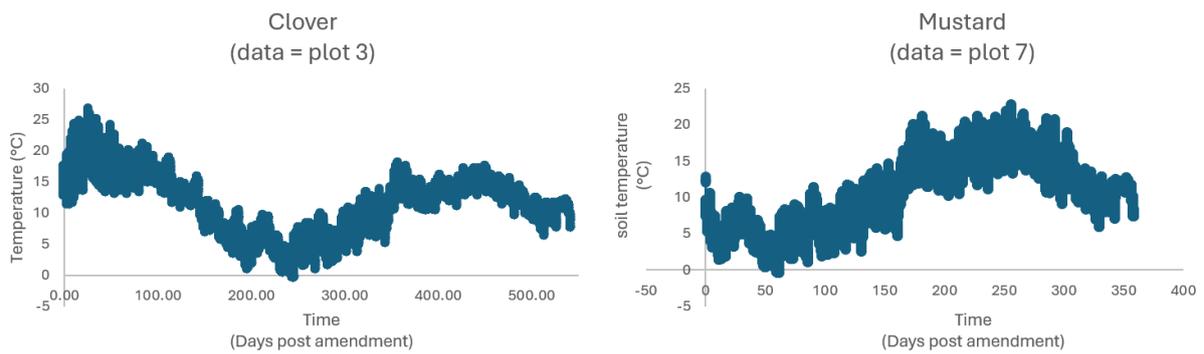


Fig. S9: Continuous temperature profile of the clover (left) and mustard (right) plots. Daily fluctuations are shown as vertical dotted ranges.

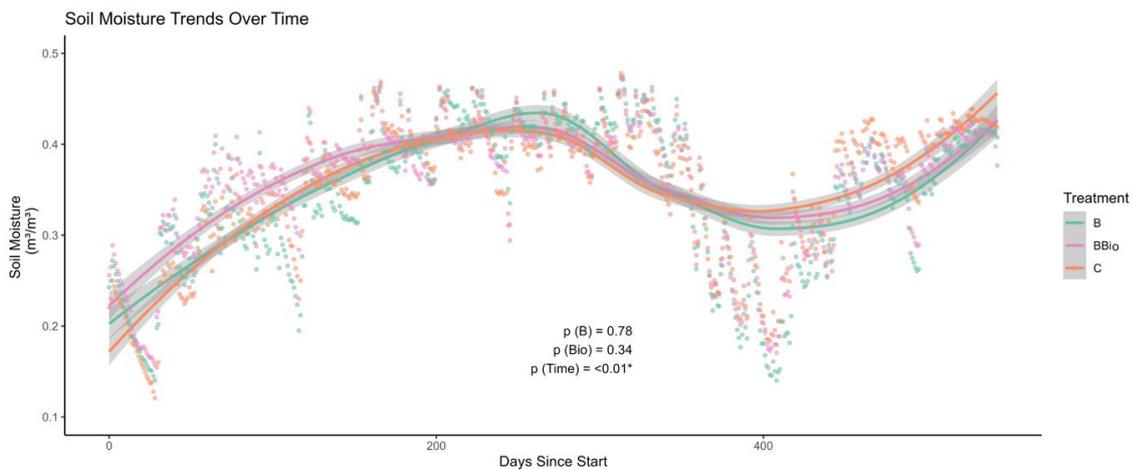


Fig. S10: Soil moisture profile in time for clover planted plots: datapoints with a loess smoother and statistical result of multiple linear repeated measures modelling.

S4. Loss on ignition

From **Figure 11** can be derived that the SOC change in time (red and blue slope) was similar for control and basalt soil. Significant different slopes in SOC changes among treatments could thus not be identified from LOI (N= 20 at each date) in this relatively short-term experiment.

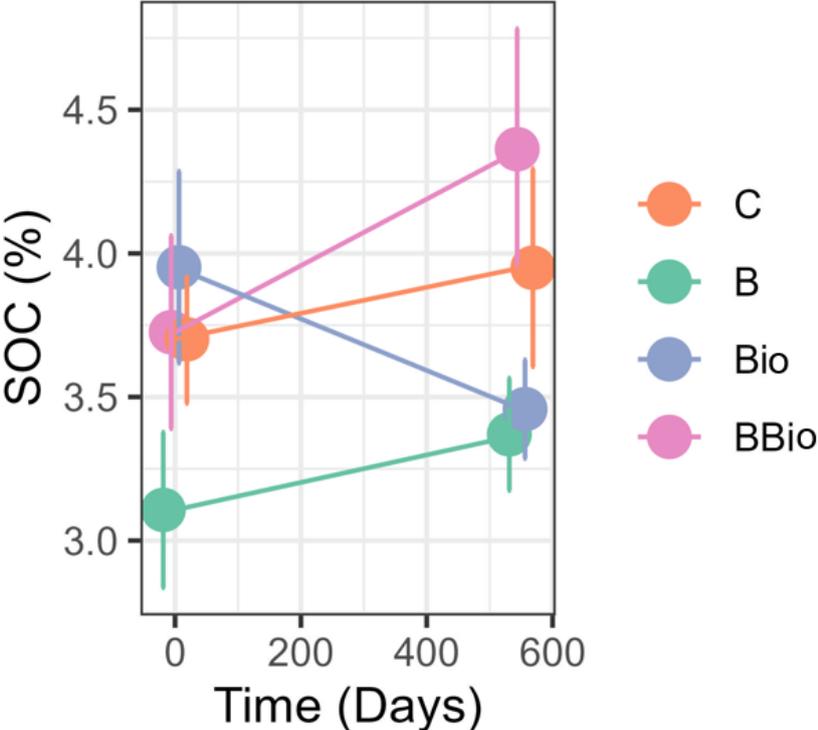


Fig. S11: SOC in clover plots for basalt (blue) and control (red), measured at two sampling times and derived from LOI assuming 58% C in soil organic matter. SOC measurements of Biochar treatments are expected to be heavily influenced by the amount of biochar in the sample.

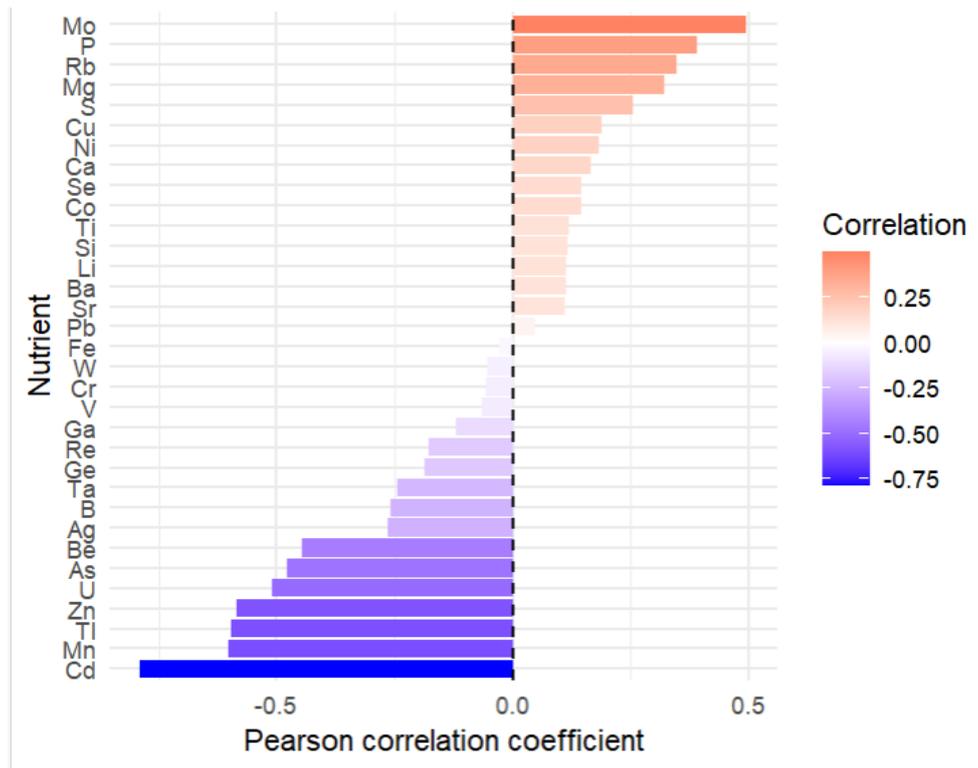


Fig. S12: Correlations for mustard aboveground biomass and aboveground biomass elemental composition.

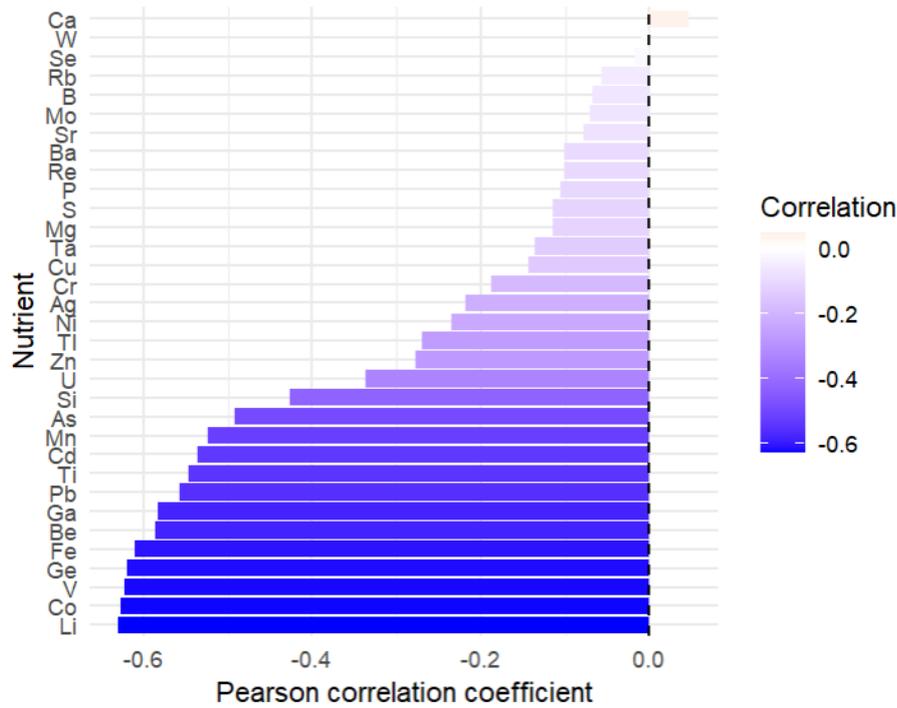


Fig. S13: Correlations for clover aboveground biomass and aboveground biomass elemental composition.

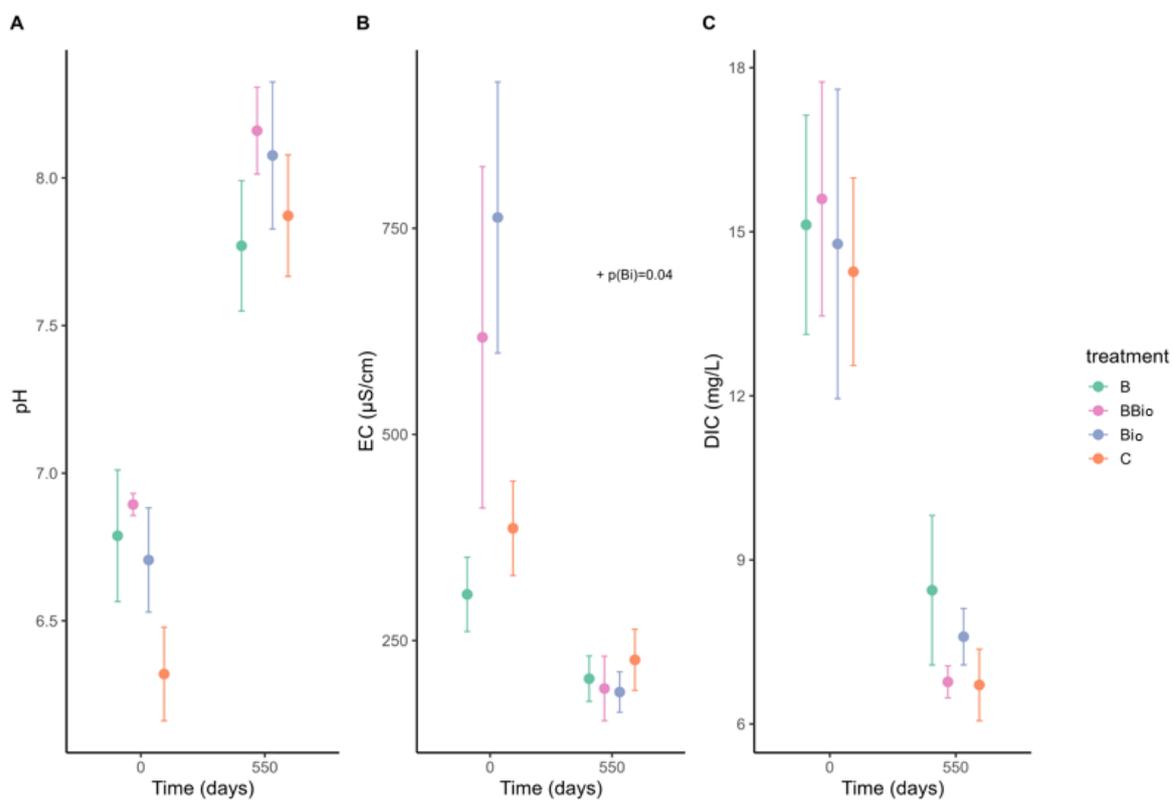


Fig. S14: (A) pH (B) Electrical conductivity (C) DIC in function of time among different treatments. Dots and error bars represent mean values \pm the standard error of the mean.

Table S4: Elemental composition of input water used for the soil leaching test.

Element	Concentration (mg/L)
Al	0.005
Ca	7.419
Cr	<0,002
Cu	0.018
Fe	0.084
K	3.342
Mg	0.283
Na	1.207
Ni	0.024
Si	0.699
Zn	0.278
NH ₄ ⁺ -N	0.267
NO ₃ ⁻ -N	0.222
Phosphate-P	0.061