Biochar amendments in vineyard soils increase nitrate without enhancing nitrous oxide efflux when fertilized with leguminous cover crops or compost.

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Introduction

Biochar is a very stable, pyrolized biomass that can be added to soil with the intention of climate change mitigation through net C sequestration and reduction of N_2O and CH_4 GHGs. Both C sequestering potential and N cycling effects due to biochar amendments have not been extensively studied applied to perennial agro-ecosystems.

Varied N-cycling responses to biochar have devalued its' viability as a widespread amendment to cropped systems.

- Increased soil aeration after biochar addition can reduce denitrification potential and thus N_2O-N efflux.
- Microbe available N can be decreased through the adsorption of NH_4-N to negatively charged biochar surface.
- Small labile C quantities from biochar could increase single season labile C:N ratios, leading to microbial immobilization of mineral N.

Furthermore, N cycling effects of biochar applied in concert with leguminous cover crops and composts is unknown and could prevent such immobilization by providing a source of microbe available N.

Objective

In this study, we sought to obtain metrics for N_2O and CO_2 efflux as indicators of soil N loss and microbial activity. We also acquired regular measurements of NO_3 and NH_4 "mineral N" to estimate biologically available N. These parameters would be compared among no-N input "conventional", cover crop, or compost fertilizations "organic" with or without biochar amendments.

Results

Nitrous Oxide: Only two the two specified rain events evolved any appreciable N_2O-N (Figure 3). Conventionally managed soils with biochar produced more N_2O-N (79.52 ± 28.12 μg/m²/hr) on average than cover crop (11.29 ± 3.99 μg/m²/hr) and compost (30.95 ± 10.94 μg/m²/hr) fertilizations with biochar.

Carbon Dioxide (not shown): CO_2 -C efflux was insignificantly different between treatments at all points measured.

Ammonium: Conventional (21.69 ± 5.46 μg/g soil) and cover crop (18.44 ± 3.93 μg/g soil) treatments without biochar had significantly higher [NH_4-N] than corresponding fertilizations with biochar: 14.08 ± 1.97 μg/g soil and 12.24 ± 0.51 μg/g soil. (Figure 4A)

Nitrate: Compost (peaking at 12.95 ± 3.24 μg NO_3-N g^{-1} soil) and cover cropped (peaking at 9.36 ± 2.19 μg NO_3-N g^{-1} soil) soils had significantly more [NO_3-N] than organic controls when amended with biochar after each precipitation event (Figure 4B, Table 2). There was no difference in [NO_3-N] among biochar and no-biochar plots under conventional fertilization.

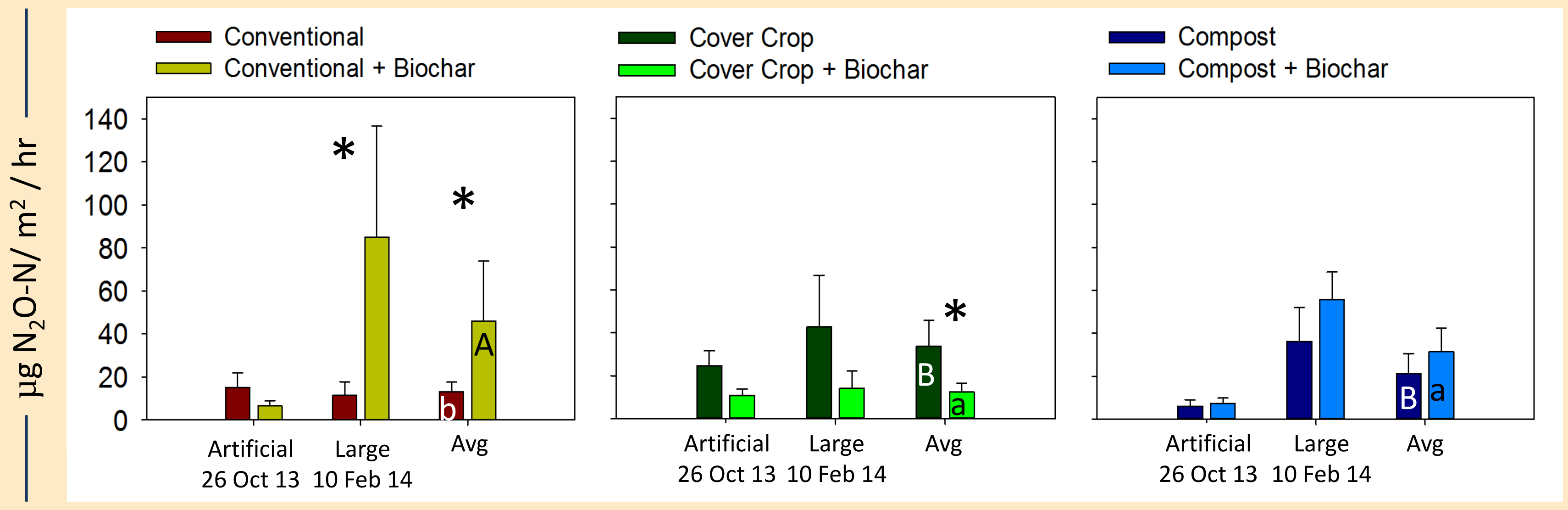


Figure 3: N_2O flux by rain event."" Indicates significant difference ($p<0.05$) between biochar and no-biochar plots within fertilizations. Between fertilizations, corresponding upper case and lower case letters represent larger and smaller means.*

Discussion

There is possible sorption of NH_4-N to biochar in conventional and cover crop treatments, evidenced by lower overall [NO_3-N] compared to compost – biochar. Enhanced nitrification is apparent in both in organic - biochar plots than those without biochar demonstrated by higher [NO_3-N]. Moreover, greater NH_4- N sorption to biochar in cover cropped plots did not negatively impact NO_3-N availability.

Plummeting [NO_3-N] among all treatments after the large rain event suggests that denitrification was a source of N_2O emissions. Notable lower N_2O-N efflux in cover cropped and composted systems with biochar compared to conventional controls leads us to conclude that enhanced [NO_3-N] observed in organic-biochar treatments did not influence GHG production.

With little OM inputs, N was likely immobilized in conventional plots. Nitrogen fixation by legume nodules and possible increased soil organic matter by residue and compost decomposition could be supplying [NO3-N], preventing immobilization. Residues and compost could also be providing some measure of labile C, which in adequate supply with N, could discourage facultative operations as denitrification. It is true that all treatments had similar initial C:N, but it is unclear what portion of the C was labile (Table 1).

Conclusions

- Biochar adsorbed a small amount of NH_4-N when used with conventional and cover crop fertilizations.
- Enhanced [NO_3-N] observed in organic-biochar plots did not contribute to increased N_2O emissions.
- Reduced N_2O efflux from organic-biochar treatments could be explained by high N and C availability, discouraging denitrification which is a facultative process.
- Future investigations in microbial C and N usage are needed to verify these conclusions.

Experimental Design and Methods

Figure 1: Biochar spreading at UC Oakville Station

Site 1 acre block Cabernet Sauvignon (*Vitis vinifera* cv.) at the UC Oakville Station.

Soil Gravelly loam. fine-loamy, mixed, superactive, thermic Cumulic Ultic Haploxeroll.

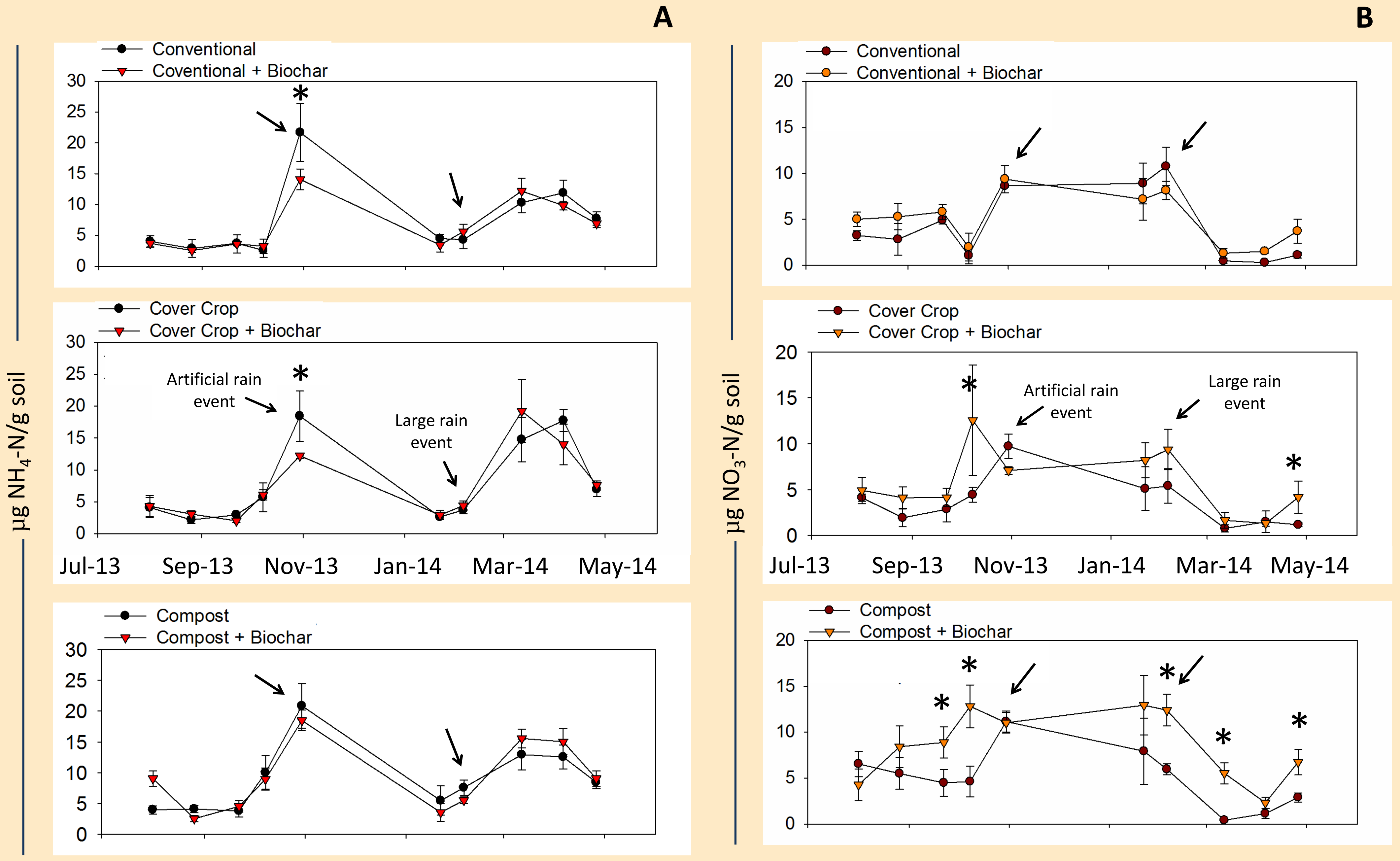
Design Split Plot RCB (4 replications/treatment)
Main Plots: Conventional, compost, or cover crop fertilization.
Sub Plots: Biochar or no-biochar amendments.

Treatments
Biochar: hardwood from a Sonoma Biochar Initiative donation.
Cover crops: Mix of cayuse oats, magnus peas, bell bean and common vetch.
Compost: Grape pomace composted with horse manure.

Figure 2: Artificial rain event

Methods All measurements were taken immediately after and in between precipitation events.
GHG Flux: Samples were taken from vineyard alleys using the static chamber method and measured using a Shimadzu GC-2014 gas chromatographer. Flux values were calculated from the derivative of t = O from quadratic regression.
Mineral N: Soil samples were augured from 0-15cm. After sieving to 2mm, soils were extracted with 2M KCl then coulometrically assayed for NH_4-N and NO_3-N.
C:N: was calculated from evolved N_2 and CO_2 due to soil combustion at 1000°C.
All means separations were carried out using orthogonal contrasts with [block*main plot] as an error term.

Rain Events
Artificaial rain event: vineyard plots were wetted with an irrigation apparatus for two hours on 25 Oct 13. GHG flux and mineral N were measured at regular intervals for 24 hours afterward.
Large rain event: Oakville experienced the largest continual rainfall (~2cm) of the year from 2 Feb 14 - 9 Feb 14.



Figures 4A and 4B: [NH_4-N] and [NO_3-N] with time."" indicates significant difference ($p<0.05$) within fertilizations. Significant differences between fertilizations of [NO_3-N] displayed in Table 2.*

Treatment	C:N (g/g)		
Conventional	10.4	±	0.14
Conv+Biochar	12.8	±	0.70
Cover crop	10.8	±	0.56
CC+Biochar	12.7	±	0.89
Compost	11.7	±	0.25
Compost+Biochar	12.2	±	0.37

Table 1: C:N ratios of each treatment immediately after establishment.

Lower Mean		Higher Mean	Dates Significant
Conventional	vs	**Conventional + Biochar**	NS
Cover Crop	vs	**Cover Crop + Biochar**	8 Oct, 26 Apr
Compost	vs	**Compost + Biochar**	22 Sep, 8 Oct, 5 Feb, 12 Mar, 26 Apr
Conventional	vs	**Cover Crop**	NS
Conventional	vs	**Compost**	8 Oct, 12 Mar, 26 Apr
Conventional + Biochar	vs	**Cover Crop + Biochar**	8 Oct
Conventional + Biochar	vs	**Compost + Biochar**	26 Apr

Table 2: Orthogonal contrasts of [NO_3-N]. $p<0.05$.

	Effect On:			
Treatment	**N_2O-N**	**CO_2-C**	**NH_4-N**	**NO_3-N**
Biochar + Conventional	↑ -	↔ +	↑ -	↓ -
Biochar + Cover Crop	↓ +	↔ +	↑ -	↑ +
Biochar + Compost	↔	↔ +	↔	↑ +

↑	Increases specified metric	+	Positive response
↓	Decreases specified metric	-	Negative response
↔	Neither increases nor decreases		

Table 3: Summary of biochar and fertilization effects.

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