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Effect of biochar on the greenhouse gas emissions from farmland and its physicochemical properties

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Abstract. To investigate the effects of biochar on greenhouse gas (GHGs) emissions by static chamber-gas chromatograph method, a field experiment with three treatments was conducted: soil without fertilizer (CK), soil with conventional fertilizer (N) and soil with chemical fertilizer after biochar application (NB). The results showed that biochar reduced the N_2O emission significantly and increased the absorption of CH_4 to soil. Compared to N, the N_2O emission from NB decreased by 21.76%, and increased CH_4 absorption by 55.31%, but no significant difference of CO_2 emission was showed between NB and N. Meanwhile biochar increased soil pH, total nitrogen content and organic carbon content, and also decreased soil NH_4^+ -N content and bulk density. Biochar provided a new way to reduce GHGs from farmland and force air pollution of China's agriculture.

1 Introduction

Recently， The global warming has caused much attention around the world，and Promoting low carbon development mode has become consensus in the world[1]. Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are the main greenhouse gases (GHGs) forcing global warming in atmospheric[2]. Farmland is a main source of GHGs emission[3], and reducing GHGs from farmland and increasing carbon sequestration to terrestrial ecosystem play an important role in dealing with climate changes at present.

Biochar is pyrolysized from biomass under hypoxic conditions[4, 5]. Biochar could increase the storage of soil stability carbon[6] while decreasing GHGs emission[7] and improving crop productivity[8] when it applied to farmland soil. So it gradually becomes a kind of new way to increase carbon storage and reduce GHGs emissionsm [9]. It showed that after adding biochar to the soil of grassland and soybean field at rates of 20 $t \cdot hm^{-2}$ reduced the N_2O emission of soil by 80% and 50% respectively, the emission of CH_4 was completely restrain[10]. Zhang et al.[11] reported when applyed biochar at rate of 40 $t \cdot hm^{-2}$ into soil, CH_4 emission from paddy land increased by 34% and 41% respectively under the condition of applying and not applying nitrogenous fertilizer, and reduced N_2O emission by 40%-51% and 21%-28% respectively.

Yuan et al.[12] indicated that if weight ratio of biochar and soil was up to 20% or the more, CO_2 emissions of the soil could be reduced. Other researches showed that biochar application could led to an increase of CO_2 emission from SOC-rich soil[13]. When applied pasture waste biochar(10 $t \cdot hm^{-2}$) into soil, it showed increased CO_2 and N_2O emission than CK whereas net absorption of CH_4[14]. The researches on the effect of biochar on farmland GHGs emissions have not reached a consensus right now, and also the mechanism is not well understood. studies of that on maize field is even less, so this study is aimed to investigate the effect of biochar made from maize straw applied into soil on GHGs emissions from farmland and soil physical chemical properties. The objectives of this study were to provide theoretical basis for slowing the global climate change by promoting and application of biochar in agricultural.

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2 Methods

2.1 Experiment site

The experiment was carried out at Shenyang agricultural university testing site in Shenyang, Liaoning province in 2013. The soil type is brown earth. The physicochemical properties of the soil were showed as Table 1.

Table 1. Basic physicochemical properties of soil and boichar

Physicochemical properties	Soil	Biochar
pH	7.9	9.2
Bulk density（$g \cdot cm^{-3}$）	1.31	—

Available N（mg·kg^{-1}）	84.5	—
Available P（mg·kg^{-1}）	15.9	—
Available K（mg·kg^{-1}）	158.7	—
Total N（g·kg^{-1}）	1.1	10.7
Total P（g·kg^{-1}）	0.39	7.8
Total K（g·kg^{-1}）	22.0	16.8
Organic C（g·kg^{-1}）	11.3	679.0

2.2 Experiment material

He biochar used for test is produced by maize straw. Basic properties of biochar are shown in Tab.1 Maize (ZD 958) was selected as experimental material which was sowed on May 17 and gained on September 29 with density 3970 plants·hm^{-2} and conventional management during the crop growth.

2.3 Experiment design

Three experimental treatments marked as CK, N and NB. CK: soil without fertilizer, N: soil with conventional fertilizer, NB: soil with chemical fertilizer after biochar application. The biochar was applied at rates of 20 t·hm^{-2}. Fertilizer and biochar was applied before sowing. N, P and K Fertilizer were urea (46% content of N), potassium chloride (50% content of K_2O) and monocalcium phosphate (12% content of P_2O_5) respectively. Urea was applied at 160 kg N·hm^{-2} which was mixed with soil before dusting within the plot evenly. Also as basal fertilizers, monocalcium phosphate and potassium chloride were applied at 70 kg P_2O_5·hm^{-2} and 150 kg K_2O·hm^{-2} respectively to all plots. There were 15 experimental plots which was 60 m^2 consisted of 10 rows of maize, each 6 m in length with 60 cm between rows.

N_2O, CH_4 and CO_2 emission was monitored with a closed chamber method produced by transparent plexiglass which is 40 cm×40 cm×40 cm cube. There was a sunction hole on the top and a small fan and a thermometer. The closed chamber was pressed into the soil and covered with soil around to isolate inside of charmber from the outside air. The gas smple taking process was strictly controlled during 9 am-11 am. The sample were collected after 0 min, 15min, 30min and 45 min of monitor process respectively. Gas sample was simultaneously analyzed with a gas chromatograph (Agilent 7890A).

2.4 Measurement content and methods

N_2O emission was calculated by the method of [15] as following formula:

$$F=60\times[273/(273+T)]\times(P/P0)\times\rho\times V/A\times(dc/dt)\times 28/40$$

F: N_2O-N emission flux(μgN·m^{-2}·h^{-1}) P: the normal atmospheric pressure (mm Hg), P0: atmospheric pressure as a standard atmospheric pressure; Rho to 0 ℃ and the standard air pressure under the condition of CO_2, CH_4 and N_2O density (1.977 g·L^{-1}, 0.717 g·L^{-1}, 1.970 g·L^{-1}); V : sampling box volume (m^3); A : sampling box area over the soil(m^2); Dc/dt : the rate of the changes of gas concentration in the sampling box, T: the temperature of the interior of the sampling box (℃). The rate of gas concentration changed is calculated obtained by the three regressions.

Cumulative amounts of the gas emission is calculated as following formula:

$$M=\Sigma(F_{i+1}+F_i)/2\times(t_{i-1}-t_i)\times 24$$

M: cumulative amounts of gas (N_2O, CH_4 or CO_2), F: gas emission flux, i: number of times for sampling, t: the date for sampling (days after seeding)

The concentration of soil organic C, soil available nitrogen, soil available P and soil available K were measured in accordance with the method of Lu[16]. The soil total nitrogen and carbon content was measured by elemental analyzer (produced by Foss company, German). Statistical Analyses All data collected from this experiment were determined by means of one-way analysis of variance (ANOVA) (SPSS 20.0). In addition, the cartography tool is Microsoft Excel 2010.

3 Results and discussion

3.1 The influence of biochar on N_2O emission

As shown in the Figure 1, the N_2O emission of CK was stable and kept at a lower level during the whole growing season, which lay between 4.36-9.26 ug·m^{-2}·h^{-1}. During the first 10 days after nitrogen fertilization, the N_2O emission flux of N and NB increased rapidly and arrived a peak value by the 10th day, which were 65.54 ug·m^{-2}·h^{-1} and 52.01 ug·m^{-2}·h^{-1} respectively. After 10 days, the N_2O emission flux of N and NB dropped sharply so far as jointing stage(about 35 days after seeding), and then kept at a stable and low level. During the whole growing season, the means of emission flux of CK, N and NB were 5.98 ug·m^{-2}·h^{-1}, 16.97 ug·m^{-2}·h^{-1} and 13.06 ug·m^{-2}·h^{-1} respectively, and all the differences were significant. It showed that nitrogen fertilizer played a important role in N_2O emission, and biochar application could restrained the emission of N_2O efficiently. Cavigelli[17] showed that biochar improved aeration with decreased bulk density which depressed the denitrification in soil and decreased the N_2O emission. The another mechanism of leading to reduction in N_2O emissions in field was that biochar could potentially favor the activity of N_2O reductase from denitrifying microorganisms as soil pH was increased while enhancing the conversion of N_2O to N_2[18,19].

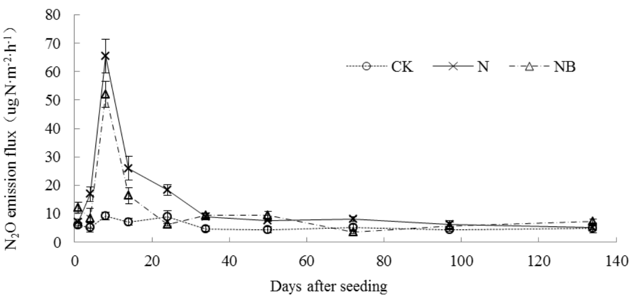

Figure 1. Emission flux of N_2O emission in soil

3.2 The influence of biochar on CH_4 emission

As shown in the Figure 2, soil CH_4 emission fluxes of three treatments all presented fluctuation which was sharp at beginning and then became mild, it was reflected the absorption and emission of CH_4 from soil. The changing trends of N and NB were basically the same during the 75 days after seeding, while CK was opposite. The variations of three treatments were consistent after 75th day. During the whole growing season, the average CH_4 emission flux of CK, N and NB were -0.0059 $mg·m^{-2}·h^{-1}$, -0.014 $mg·m^{-2}·h^{-1}$ and -0.019 $mg·m^{-2}·h^{-1}$ respectively, so CH_4 was absorbed by soil in three treatments, and the average value in NB was the highest.

It was reported that the mechanism of reducing CH4 emissions from the soil by way of biochar application might be due to the increasing soil permeability, which inhibited the activity of methanogenic bacteria or enhanced the activity of methane-oxidizing bacteria[11]. In this experiment, biochar decreased soil bulk density (Table.2) and increased soil porosity which might lead to the variations of methanogenic bacteria activity.

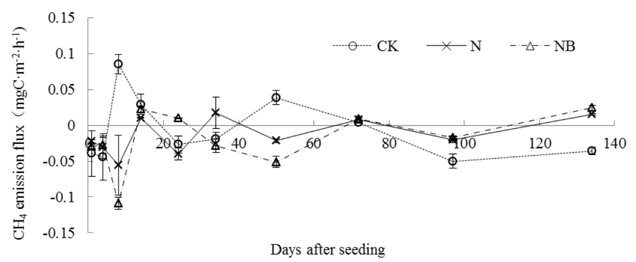

Figure 2. Emission flux of CH_4 emission in soil

3.3 The Influence of Biochar on CO_2 Emission

The CO_2 emissions of the three treatments during the whole growing season were shown in the Figure 3, and the CO_2 emission presented a distinct seasonal variation, which is increased firstly and then decreased. Two obvious peaks of CO_2 emission were found, one was after seeding and fertilizer application, the other one was in the grouting period, when where were abundant rainfall, the high temperature and sufficient soil moisture content, so the vigorous metabolism of root system promoted CO_2 emissions as a result. Nitrogen fertilizer application could promote the soil CO_2 emissions obviously, because the addition of nitrogen source contributed to the activities of soil respiration consequently. During the whole growing season, the average CO_2 emissions flux of CK, N and NB were 19.21 $mg·m^{-2}·h^{-1}$, 21.52 $mg·m^{-2}·h^{-1}$ and 24.29 $mg·m^{-2}·h^{-1}$ respectively.

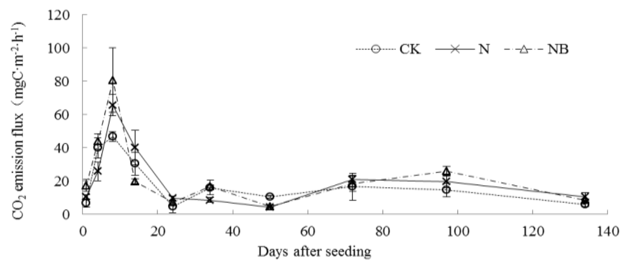

Figure 3. Emission flux of CO_2 emission in soil

3.4 The influence of biochar on physicochemical properties of soil

Incorporation of biochar into soil may provide benefits for the physical, chemical and biological properties of the soil and sustainable agriculture[20]. It was found that biochar had a great influence on soil physiochemical properties. Biochar application increased pH, contents of total N and total C in soil significantly, but reduced soil bulk density. The results showed that normal fertilization could increase the contents of total N, NH_4^+-N and NO_3^--N in soil significantly. Compared with N, NB significantly increased pH, content of total N and organic C of soil by 2.68%, 7.89% and 19.64%, respectively, while NB significantly decreased bulk density and NH_4^+-N content of soil by 9.80% and 26.17%.

Table 2. Effects of biochar on physical and chemical properties of soil

	CK	N	NB
pH	8.03±0.11b	8.18±0.07b	8.40±0.12a
Bulk density ($g.cm^{-3}$)	1.21±0.03a	1.21±0.02a	1.10±0.04b
Total N（$g.kg^{-1}$）	1.22±0.08c	1.52 ±0.01b	1.64±0.02a
Organic C（$g.kg^{-1}$）	18.74±0.87a	15.22±0.01b	18.85±0.54a
NH_4^+-N（$mg.kg^{-1}$）	1.68±0.30c	5.31±0.71a	3.92±0.39b
NO_3^--N（$mg.kg^{-1}$）	15.18±0.84b	21.69±3.66a	25.95±4.42a

None：Different small letter means signification at 0.05 level.

4 Conclusion

Biochar can improved the physicochemical properties of field soil and relieved the GHGs emission in a certain extent. In this study, total nitrogen, organic carbon contents and pH in the soil were increased by 7.89%, 19.64% and 2.68%, as well as, the bulk density was decreased by 9.8% under biochar application at 20 t·hm^{-2} compared to no biochar and N fertilization treatments. Therefore, biochar application into soil could improve microenvironment, porosity and fertilizer of the farmland soil whose physicochemical properties were modified. Meanwhile, the total N_2O emission was decreased by 21.76%, but the total CO_2 emission was unchanged with biochar application at 20 t·hm^{-2} compared to conventional fertilization treatment. The total CH_4 emission of all treatments are negative that showed the three treatments all had net absorption and the biochar application treatment had a maximum, more than 55.31% compared with conventional fertilization treatment.

Currently, To pursue high yield of crops, N_2O emission from farmland because of nitrogen fertilizer application made a great contribution to GHGs[3,21]. This study suggested N_2O emission from the farmland soil was decreased and the CH_4 uptake by farmland increased during the whole maize growing season, which achieve simultaneously high grain yield and low global warming potential intensity during maize production, and reaching a balance between the land-use and environmental pollution. It provided a new way to reduce greenhouse gas emissions from farmland and force air pollution of China's agriculture.

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