CO_2 Emission from Acidified Black Soils Amended with Alkaline Ameliorants of Lime and Plant Ash

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Abstract: Incubation experiments were conducted to investigate the CO_2 emission from acidic pH 5.34 arable black soils as affected by different alkaline ameliorants lime (CaO) and plant ash, and nitrogen fertilization. The experimental treatments consisted of CK, CaO and plant ash fertilized with none nitrogen, NH_4^+-N or NO_3^--N as nitrogen resource. The results showed that nitrogen fertilization and ash promoted dramatically CO_2 emissions, while CaO had a negative effect on CO_2 fluxes. Compared to NO_3^--N fertilizer, NH_4^+-N fertilizer had a much higher CO_2 fluxes. For ammonium fertilization, there was insignificant difference in CO_2 emissions among different amendment soil (P>0.05), although the highest cumulative CO_2 emissions appeared in ash amendment soil (197 mg CO_2-C kg^{-1}). For nitrate fertilization, the highest cumulative CO_2 emissions also appeared in ash amendment soil (186 mg CO_2-C kg^{-1}), and there was significant difference in CO_2 emissions between ash amendment and other two soils ($P<0.05$). Dissolved organic carbon (DOC) dramatically decreased with N-fertilization at all tested soil. However, NO_3^--N fertilization resulted in the largest negative increment of DOC in contradiction to the lower CO_2 emissions. The findings suggested that N-fertilization significantly enhanced CO_2 emissions, and the application of CaO induced lower CO_2 emissions was to a large extent attributed to the chemical reaction of CaO with CO_2 to $CaCO_3$.

Key words: Soil respiration; Alkaline ameliorant; Carbon dioxide; Greenhouse gas; Black soils

1. Introduction

CO_2 is a potent greenhouse gas contributing to global radioactive forcing and contributed to global warming [1]. Soil pH is the primary control of soil microbial activity and regulates organic matter decomposition, which is the most important agriculture sources of CO_2 [2]. The so-called new type of black soil degradation in northeast of China was frequently related to 'long-term N fertilization' resulting in accelerated soil acidification and induced nutritional disturbances [3]. Many studies have demonstrated that soil pH and substrate availability are important factors in determining soil microbial activities.

Under conventional farming practices, lime and plant ash are usually applied on the soil surface and then incorporated into the soil to ameliorate soil acidity [4]. Most studies on the effects of soil pH on microbial processes have focused on forest soil; less work has been done on arable, grassland and other soil [5, 6]. However, the investigation to the black soil acidity was much less. It has been recognized that the chemical liberation of CO_2 from lime can contribute significantly to the CO_2 emissions from agriculture soils [7]. Lime is considered as improve soil condition and thus to increase microbial respiration and loss of soil organic carbon (SOC) as CO_2 [8]. The objective of this research was to investigate the CO_2 emissions influenced by different soil alkaline ameliorants.

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2. Materials and Methods

2.1 Soil descriptions

The tested soil (pH 5.33) was sampled from the Key Observation Station of the Harbin Black Soil Ecology Harbin city, Heilongjiang province, China (126°35′E, 45°40′ N). The soils were taken from the 0-20cm horizon and sieved (2mm) to remove stones and coarse roots prior to incubation. The soil texture is the loess clay.

2.2 Experimental treatments

There are 9 treatments, *i.e.* 3 ameliorants (CK, Lime and Plant ash) multiplying 3 nitrogen resources (None Nitrogen addition, Ammonium and Nitrate). CaO and soybean ash were applied at the rate of 0.4% and 0.2% for lime and plant ash treatments, and increased the original soil pH from 5.33 to 7.20 and 6.10, respectively. $(NH_4)_2SO_4$ and KNO_3 solutions were added at the rate of 100 mg N kg^{-1} soils as ammonium and nitrate resources. Each treatment has three replicates.

2.3 Incubation procedures

25.000g soil samples were weighed into 36 flasks. Nitrogen resource was added as N solution. Soil samples were incubated at soil moisture of 60% water holding capacity and at 25℃ for 144 hours. After flushing the flasks with ambient air for 15s, then were sealed with rubber stopper in order to evacuate them, then added enough pure air. Gas samples were taken after 12h, 24h, 48h, 72h, 96h, 120h, and 144h. Prior to each sampling, the air in the bottles was mixed by flushing a 60-ml syringe three times and then 60-ml gas sample injecting into sealed gas bags for analysis.

2.4 Analysis methods

CO_2 was analyzed by Agilent 4890D GC equipped with flame ionization detector (FID). The detector, column and injector temperature is 330℃, 55℃ and 375℃, respectively. The dissolved organic carbon (DOC) was extracted with 2M KCl and determined by Micro C/N analyzer (Jena, Germany).

3. Results and Discussion

3.1 CO_2 flux

The CO_2 emissions from soil ameliorated by CaO did not have the potential to respond positively to addition of nitrogen (Figure 1), because the carbonate looping processes are based on the capture of carbon dioxide via the $Ca(OH)_2$ to $CaCO_3$ [9]. The application of ash exhibited the maximum CO_2 emissions in all tested soil. The soil ameliorated by CaO emitted the lowest CO_2. It is impossible to reliably quantify Cao-capatured CO_2 and lime-derived CO_2 through this experiment. For none N fertilization, the CO_2 fluxes were largely limited by soil acidity and C, N resource. The application had only a relatively small increasing effect on CO_2 flux. For ammonium fertilization, the greatest CO_2 flux appeared at 0-24h except for the soil ameliorated by CaO (0-48h), and then sharply decreased after 48h, with a nearly similar but small flux in the later incubation time. For nitrate fertilization, the CO_2 flux was only stimulated by ash ameliorant. These findings revealed that the CO_2 flux from the soil ameliorated by ash had the potential to respond positively to nitrogen addition, however, there were no significant changes to the CO_2 flux fertilized by ammonium or nitrate resource.

3.2 Cumulative CO_2 emission

N-fertilization significantly increased cumulative CO_2 emissions from all tested soils (Table 1). For none N-fertilization, there was significant difference in cumulative CO_2 emissions from soils (P<0.05), which were in the order lime < CK < Ash. Although the ammonium fertilizer drastically stimulated cumulative CO_2 emission and the highest emission appeared in soil ameliorated by ash (197 CO_2-C kg^{-1}), there was insignificant difference in cumulative CO_2 emissions from soils with ammonium resource (P>0.05). For nitrate fertilization, cumulative CO_2 emission from soil ameliorated by ash was as 2.15 times as that of soil ameliorated by lime. These results implied that application of CaO was effective for mitigating the CO_2 emission. In addition, the findings suggested that different soil respiration occurring in the tested soil under different fertilizer: ammonium fertilizer had a greater influence on soil respiration. However, some studies proved that the effects of N fertilization on soil respiration mainly depended on the concentration of easily decomposed organic carbon in soil and N fertilization possibly reduced soil respiration in the planted soils [10].

3.3 DOC increment

DOC increment which were calculated by subtracting initial DOC concentration from DOC concentration after 144-hour incubation were used to evaluate the change of carbon substrate that can indicates soil CO_2 respiration. Compared to none N-fertilization, the nitrogen addition

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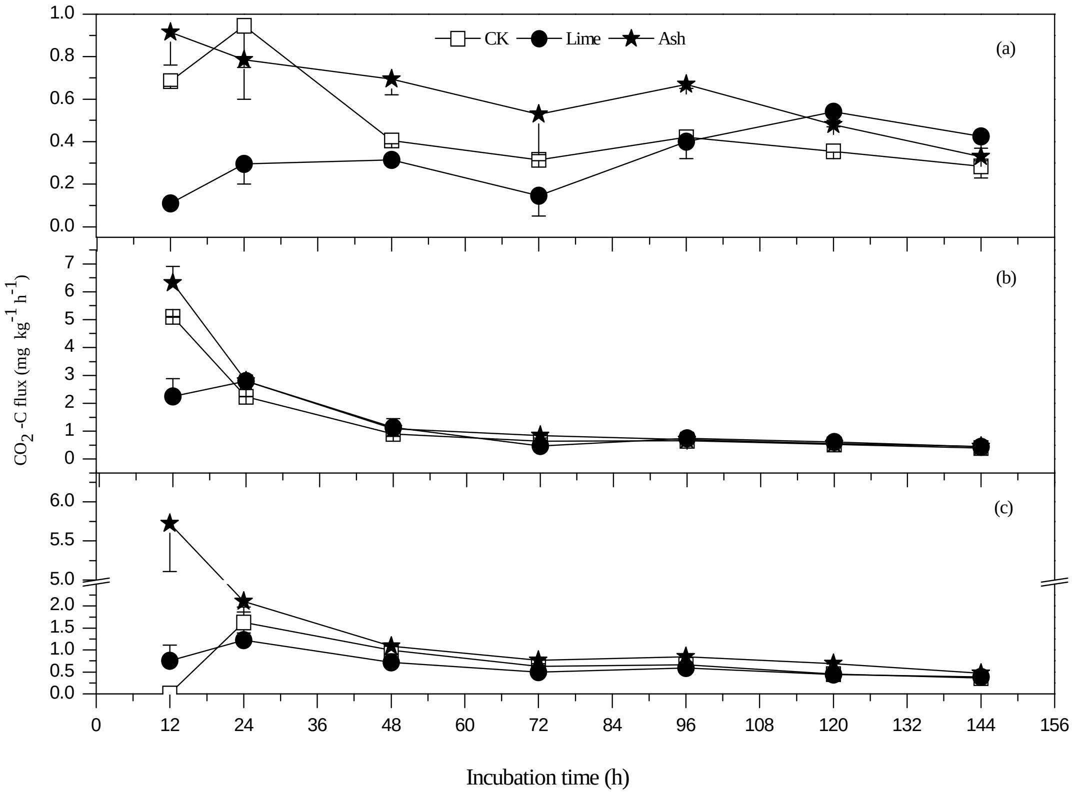

Figure 1. Effects of ameliorants on CO_2 flux from soils fertilized without nitrogen addition (a), with ammonium (b) and nitrate (c).

Table 1. 144-h cumulative CO_2-C emission (Mean ± SD, mg CO_2-C kg^{-1})

Fertilization	CK	Lime	Ash
CK	62.4 ± 0.846 BC b	48.7 ± 0.482 B b	85.3 ± 3.14 A b
NH_4^+-N	163 ± 0.877 A a	143 ± 17.1 A a	197± 15.7 A a
NO_3^--N	93.6 ± 0.094 B bc	86.7 ± 3.88 B b	186 ± 5.11 A a

Different small and capital letters in the same column and row indicates significant difference at $p<0.05$, respectively.

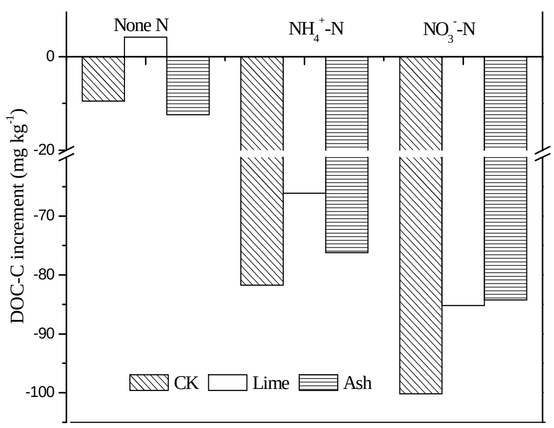

Figure 2. DOC increment in different treatments after 144-h incubation.

decreased markedly the concentration of DOC. To a large extent, this was attributed the consumption of DOC. Many investigations had proved that lime distinctly increased CO_2 emission and loss of DOC [4, 11]. However, the disappearance of DOC was insignificantly correlated with the CO_2 emission. The largest decrement of DOC appeared in CK soil with nitrate resource, while cumulative CO_2 emission in this treatment was only 60% of ammonium treatment. These results suggested that the changes of DOC concentration were much influenced by the characteristics of ameliorants and original soil than that of by soil pH.

4. Conclusion

Nitrogen fertilization increases soil CO_2 emission, practically the ammonium fertilizer. The application of CaO decreases the CO_2 emission, while ash application improves soil microbial activity leading to more CO_2 emission. The increment of CO_2 emission is largely dependent on the characteristic of ameliorants. N-fertilization increases the DOC consumption. Further.

Experiment should be conducted to investigate whether the refinement of the CO_2 emissions as a consequence of liming in different soil conditions.

References

[1] IPCC, 1996, Intergovernmental Panel on Climate Change, Technologies, Policies and Measures for mitigating climate change [M]. Watson RT, Zinyowera MC, Moss RH (eds). Cambridge University Press, Cambridge, UK. P3-7.

[2] Yao HY, Bowman D, Rufty T, Shi W, Interactions between N fertilization, grass clipping addition and pH in turf ecosystems: Implication for soil enzyme activities and organic matter decomposition [J]. Soil Biology and Biochemistry, 2009, 41, P1425-1432.

[3] WANG Jingkuan, LI Shuangyi, ZHANG Xudong，WEI Dan，CHI Fengqin, Spatial and temporal variability of soil quality in typical black soil area in Northeast China in 20 years [J], Chinese Journal of Eco-Agriculture, 2007, 15(1), P19-24 (Ch).
汪景宽，李双异，张旭东，魏丹，迟凤琴. 20 年来东北典型黑土地区土壤肥力质量变化. 中国生态农业学报，2007, 15(1), P19-24.

[4] Fuentes JP, Bezdicek DF, Flury M, Albrecht S, Smith JL, Microbial activity affected by lime in a long-term no-till soil. Soil and Tillage Research [J], 2006, 88(1-2), P123-131.

[5] Bååth E, Anderson TH, Comparison of soil fungal/bacterial ratios in a pH gradient using physiological and PLFA-based techniques [J], Soil Biology and Biochemistry, 2003, 35(7), P955-963.

[6] Bardgett RD, Jones AC, Jones DL, Kemmitt SJ, Cook R, Hobbs P, Soil microbial community patterns related to the history and intensity of grazing in sub-montane ecosystems [J], Soil Biology and Biochemistry, 2001, 33(12-13), P1653-1664.

[7] Robertson GP, Paul EA, Harwood RR, Greenhouse gases in intensive agriculture: contributions of individual gases to the radioactive forcing of atmosphere [J], Science, 289(5486), P1922-1925.

[8] Biasi C, Lind SE, PekkarinenNM, Huttunen JT, Shurpali NJ, Hyvönen NP, Repo ME, Martikainen PJ, Direct experimental evidence for the contribution of lime to CO_2 release from managed peat soil [J], Soil Biology and Biochemistry, 2008, 40(10), P2660-2669.

[9] Nikulshina V, Hirsch D, Mazzotti M, Steinfeld A, CO_2 capture from air and co-production of H_2 via the $Ca(OH)_2$–$CaCO_3$ cycle using concentrated solar power–Thermodynamic analysis [J], Energy, 2006, 31(12), P1715-1725.

[10] Ding WX, Yu HY, Cai ZC, Han FX, Xu ZH. Responses of soil respiration to N fertilization in a loamy soil under maize cultivation [J], Geoderma, 2010, 155(3-4), P381-389.

[11] Kreutzer K, Effects of forest liming on soil process [J], Plant and Soil, 1995, 168-169(1): P447-470.