

Effects of Soil pH on CO₂ Emission from Long-Term Fertilized Black Soils in Northeastern China

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Abstract: Soil pH in a large extent alters the rates of microbial carbon turnover, and thus can regulate CO₂ emissions. Laboratory incubation experiments were conducted to investigate the effects of different soil pH on the CO₂ flux from acidified black soils. The experiment was designed as a full factorial with 3 N-fertilization (None, Ammonium and Nitrate) and 4 pH values (3.65, 5.00, 6.90 and 8.55). The results showed that CO₂ emission increased significantly due to N fertilizer addition. CO₂ emission increased positively with soil pH ($R^2=0.98$, $P<0.01$). The lowest CO₂ emission (30.2 mg CO₂-C kg⁻¹) was presented in pH3.65 soils without N-fertilization. For ammonium fertilization, the highest cumulative N₂O emissions appeared in the pH8.55 soils was 199 mg CO₂-C kg⁻¹. For nitrate fertilization, the highest cumulative N₂O emissions appeared in pH6.90 soils was 184 mg CO₂-C kg⁻¹. However, there was insignificant difference in CO₂ emissions between ammonium and nitrate fertilization at soil pH values from acidic to alkaline ($P>0.05$). Dissolved organic carbon (DOC) dramatically decreased with N-fertilization at all soil tested pH values. The findings suggested that pH-increasing and N-fertilization significantly enhanced CO₂ emissions and heterotrophic microbial respiration played a dominant role in CO₂ emissions in the tested soil.

Key words: Acidification; Carbon dioxide; Greenhouse gas; Black soil

1. Introduction

Carbon dioxide, the primary greenhouse gas, is long-lived in the atmosphere and is the major contributors to positive increases in radiation ^[1]. The biogenic sources of CO₂ efflux from soils can be grouped in root respiration, rhizosphere microbial respiration, decomposition of plant residues, the priming effect induced by root exudation or by addition of plant residues, and basal respiration by microbial decomposition of soil organic matter ^[2, 3]. Soil pH affects all chemical, physical and biological soil properties and inevitably disturbs the C flux ^[4]. The alkaline soils had significantly higher CO₂-to-soil organic C (SOC) ratios, and consequently SOC in the alkaline soils did not seem more chemically stable against mineralization ^[5]. Soil respiration decreased markedly in samples from acidified soil plots ^[6]. Impacts of anthropogenic activity on increased CO₂

emission have been investigated for many years. However, there was little reports about the acidification affected the CO₂ emission from black arable soil.

It is well known that carbon storage capacity of soil will change in response to management practices such as fertilization and nature characteristic of soil. Black soil is the representative soil with high organic carbon content. The intensity of soil respiration closely related to the decomposition of soil organic carbon, even the small changes of organic matter content and soil pH will dramatically affect the dynamic of carbon ^[7]. Regretfully, in recent years, soil acidification is the main form of black soil degradation ^[8]. Black soils degradation poses a great challenge to agricultural sustainability and exerts important influences on the edaphic conditions and the environment in our country. In this paper, we investigated the CO₂ variation with different nutrient in different soil pH values. This will provide theoretical support for soil fertilization and environment-friendly sustainable agriculture.

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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 (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.

2.2 Experimental treatments

There are 12 treatments, *i.e.* 4 soil values (3.65, 5.00, 6.90 and 8.55) multiplying 3 nitrogen resources (None Nitrogen addition, Ammonium and Nitrate). The pH of soil slurry was adjusted by adding either 0.1M NaOH or 0.1M HCl^[9]. Then, the slurry was evaporated to formal ratio (1:2.5) at 25°C. Re-adjust the slurry pH and repeat the above experiment until the slurry pH values remained stable. (NH₄)₂SO₄ and KNO₃ solutions were added at the rate of 100 mg N kg⁻¹ soils as ammonia and nitrate resources. Each treatment was triplicate.

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°C 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

CO₂ was analyzed by Agilent 4890D GC equipped with flame ionization detector (FID). The detector, column and injector temperature is 330°C, 55°C and 375°C, 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 CO₂ flux

CO₂ fluxes were dramatically increased with N addi-

tion. The results were consistent with the conclusion that the microbial activity was stimulated by the addition of inorganic N fertilizer^[10]. The greatest CO₂ flux appeared at 0-24h except for the lowest acidic soil (0-48h), and then sharply decreased after 48h, with a steady but small flux in the later incubation time (Figure 1). It may be attributed to the microbial activity need time to adapt to lowest soil pH 3.65. Although the neutral and alkaline soil stimulated the carbon dioxide fluxes, the increments were limited by N source without N-fertilization (Figure 1a). For nitrogen resources, CO₂ fluxes from soils shared the similar tendency with ammonium and nitrate in different soil. The largest fluctuation of CO₂ flux appeared at slighter acidic soil (pH 5.00) with N addition, and the CO₂ flux fertilized with nitrate was higher than that of ammonium. These findings revealed that different soil pH could vary greatly in the CO₂ flux and different N-fertilizer inputs clearly appeared to increase the respiration.

3.2 Cumulative CO₂ emission

N-fertilization significantly increased cumulative CO₂ emissions from acidic soil to alkaline soil (Table 1). For none N-fertilization, cumulative CO₂ emission increased positively with soil pH ($R^2=0.98$, $P<0.01$), cumulative CO₂ emission from pH8.55 soil was as 3.07 times as that of pH3.65. For ammonium fertilization, the lowest accumulative CO₂ emission (132 mg CO₂-C kg⁻¹) was presented in the soil with pH5.00, which was very near to soil background pH5.33. This indicated that traditional cultivation with soil background pH and urea fertilization had the lowest CO₂ emission, and alkaline soil increased CO₂ emission. Cumulative CO₂ emission from pH3.65 soils was significantly lower than that of other three pH soils with nitrate fertilization. There were insignificant difference in cumulative CO₂ emission among pH5.00, 6.90 and 8.55. Increasing pH with nitrate fertilization enhanced CO₂ emission. The microorganism seemed to be more adapted to high pH than the microorganism community in the low pH^[11].

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

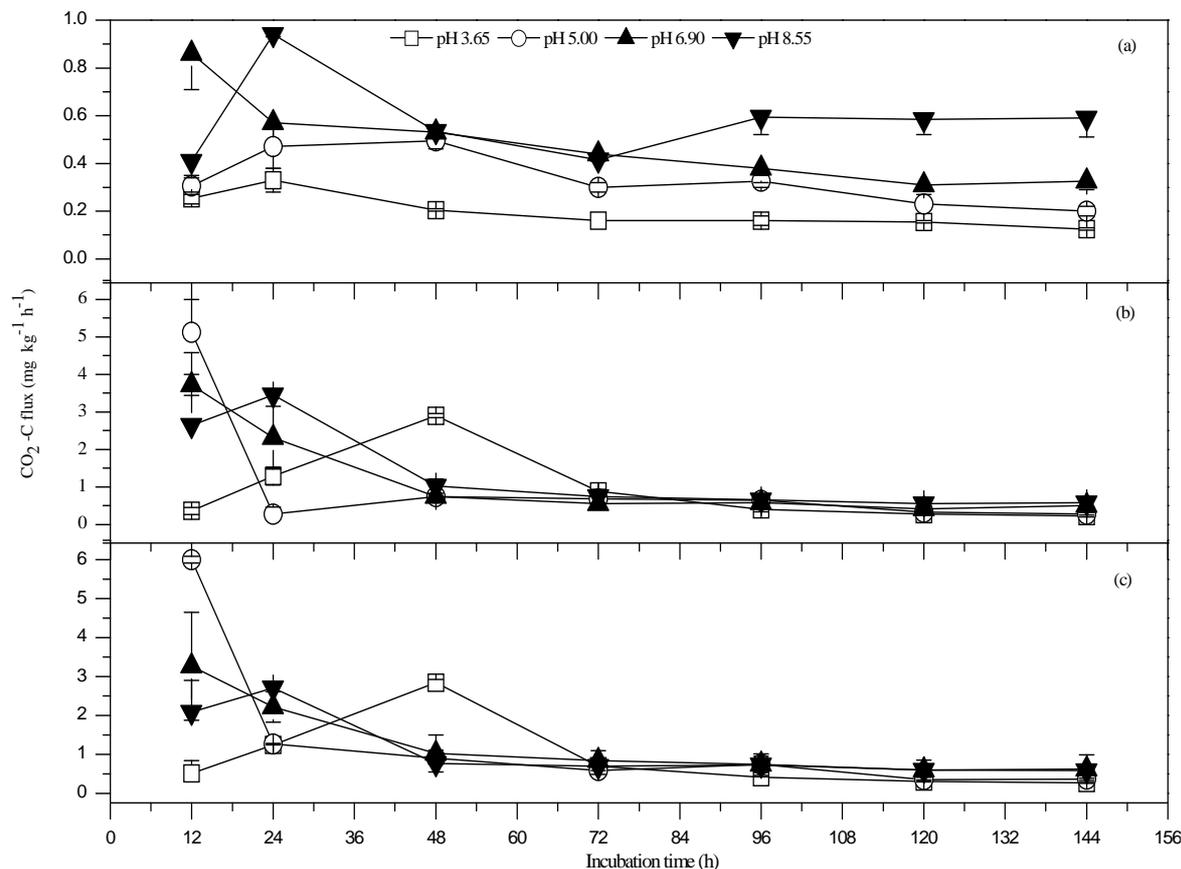


Figure 1. Effects of soil pH on CO₂ flux from soils fertilized without nitrogen addition (a), with ammonium (b) and nitrate (c).

Table 1. 144-h cumulative CO₂-C emission (Mean ± SD, mg CO₂-C kg⁻¹)

Fertilization	pH 3.65	pH 5.00	pH 6.90	pH 8.55
None	30.2 ± 0.71 D b	52.2 ± 8.73 C c	71.6 ± 2.40 B b	92.6 ± 5.11 A b
NH ₄ ⁺ -N	147 ± 2.00 BC a	132 ± 16.0 C b	167 ± 23.1 B a	199 ± 16.0 A a
NO ₃ ⁻ -N	144 ± 3.15 B a	173 ± 11.5 AB a	184 ± 32.0 A a	170 ± 19.0 AB a

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

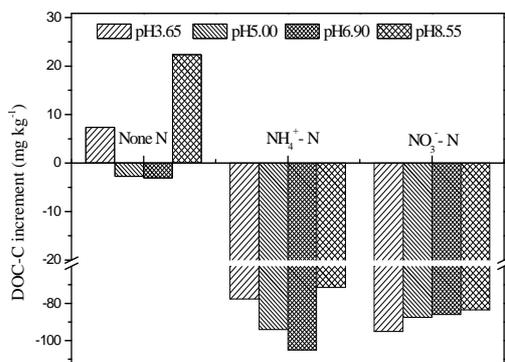


Figure 2. DOC increment in different treatments after 144-h incubation

carbon substrate that can indicate soil CO₂ respiration. The concentrations of DOC were dramatically decreased with N-fertilization at all soil pH values (Figure 2), suggesting that conditions were favorable for microbial growth, which consumed a large amount of DOC. Soil respiration was positively correlated with DOC [12]. There was a positive increment in alkaline pH8.55 soil for none N-fertilization. It suggested that the positive increment to a large extent was due to a stimulation of microbial organic matter mineralization. Consumption of DOC was dependent on soil pH and N-fertilization species. But

there wasn't a good correlation DOC increment to CO₂ emission.

4. Conclusion

Soil acidification decreases the CO₂ emission. CO₂ emission is lower in high soil pH. Soil acidification inhibits the soil microbial respiration. Nitrogen fertilization increases soil CO₂ emission. Nitrogen fertilizer application improves soil microbial activity leading to more CO₂ emission. The increment of CO₂ emission is dependent on the soil acidity and fertilizer species. N-fertilization increases the DOC consumption.

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