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Effects of elevated CO_2 and O_3 and N fertilization on amount of soil microbial biomass carbon in spring wheat growing season

Rui Fang [1, 2], Yi Shi [1*], Caiyan Lu [1], Xin Chen [1]
[1] Key Laboratory of Terrestrial Ecological Process, Institute of Applied Ecology, Chinese Academy of Sciences
[2] Graduate School of the Chinese Academy of Sciences
Shenyang, China ; Beijing, P R China
fangrui2630@163.com，shiyi@iae.ac.cn, microyan76@126.com, chenxin@iae.ac.cn

***Abstract*—Experimental platform of Open-top chambers (OTC) was established in 2006 over a spring wheat system, it located at the National Field Observation and Research Station of Shenyang Agro-ecosystems, a member of Chinese Ecosystem Research Network (CERN) established in 1987. We compared the dynamics of soil microbial biomass C with high (225.0 kg N hm^{-2}) and low (150.0 kg N hm^{-2}) application rate of chemical fertilizer N exposed to the elevated CO_2, O_3, CO_2 plus O_3 and CK after the spring wheat growing season in 2010. The results showed that under elevated CO_2 concentration at the jointing stage, high application rate of chemical fertilizer N significantly declined the amount of soil microbial biomass C by 64.97%, compared with the low N application rate of chemical fertilizer N ($p<0.01$). In treatment with low application rate of chemical fertilizer N, elevated O_3 concentration significantly declined the amount of soil microbial biomass C by 52.49% ($p<0.05$), compared with CK. In treatment with high application rate of chemical fertilizer N, the interaction of CO_2 and O_3 increased significantly the amount of soil microbial biomass C by 50.03% ($p<0.05$), compared with CK. At the ripening stage, under elevated CO_2 concentration and interaction of CO_2 and O_3, high application rate of chemical fertilizer N significantly decreased the amount of soil microbial biomass C by 32.92% and 41.45%, compared with low N application rate of chemical fertilizer N, respectively ($p<0.05$). In treatment with low application rate of chemical fertilizer N, elevated CO_2 and interaction of CO_2 and O_3 significantly increased the amount of soil microbial biomass C by 25.32% and 38.59% ($p<0.05$), compared with CK, respectively.**

Keywords - Elevated CO_2, O_3, CO_2 plus O_3; N fertilization; soil microbial biomass C

I. INTRODUCTION

In the present, people are concerned about the global changes by the greenhouse effect increasingly which influences many fields such as agriculture, climate, environment, and so on. Since the industrial revolution, the concentration of tropospheric carbon dioxide (CO_2) and ozone (O_3) have been rising due to human activity. Currently, the concentration of global CO_2 have increased up to today's 370 ppm, and are predicted to increase to 700 ppm by the end of the 21st century [1, 2], while increase of O_3 is expected to continue at the level of 1-2% per year, which may results in triplication of O_3 concentration within the next 30-40 years [3, 4].

The effect of elevated CO_2 are mainly considered beneficial for plants, and it will increase the photosynthesis, growth, and resource allocation of plant system since rising CO_2 [5, 6]. Thus, elevated CO_2 may increase the production of organic compounds in above-below ground of plant system, and then will affect the activity of soil microbes [7]. Vegetation assimilates increasing amounts of C as atmospheric CO_2 concentration [8], which may result in a flux of labile C to soils. Some experiments of CO_2 enrichment have shown an increase in soil organic C [9], and more report on an increase in soil C inputs [10, 11].

Unlike CO_2, O_3 is highly phytotoxic. O_3 has a potential harm on the crop yield and the above-ground growth of soybean, cotton (*Gossypium hirsutun* L.), wheat (*Triticum aestivum*), and other crops due to inhibits the photosynthesis and other physiological processes [12, 13]. Even more significantly, the harmful effects of elevated O_3 may be extended to reductions in below-ground processes, such as carbon allocation and root growth [14, 15]. And these will influence the active organic carbon pool in the soils.

It has been reported that elevated CO_2 could ameliorate the negative effects of O_3 in above-ground processes [16]. In soybean, elevated CO_2 increased nonstructural carbohydrate levels while O_3 suppressed their accumulation [17, 18]. Factors such as elevated atmospheric CO_2 and O_3 may affect the global C cycle, because the changes rates of organic C turnover by affecting the plant productivity and chemistry [19, 20].

To understand how soil organic matter affects soil quality and ecosystem functioning, we would gain through knowledge of its dynamics [21]. As a portion of the active carbon, the soil microbial biomass C (MBC) responds more rapidly than soil organic matter as a whole to changes in management practices, and MBC is a source and sink of biologically mediated nutrients, and is responsible for transforming organic matter and nutrients within soil. Elevated CO_2 and O_3 will affect the microbial communities that can cause alterations in the whole soil ecosystem.

In this paper, an enrichment experiment with open-top chamber was conducted to examine the effects of elevated CO_2, O_3, their combination, and different application rate of chemical fertilizer N on the contents of MBC in the soil of spring wheat growing season.

II. MATERIALS AND METHODS

A. Study Site

The enrichment experiment with open-top chamber was conducted at the National Field Observation and Research Station of Shenyang Agro-ecosystems, a member of Chinese Ecosystem Research Network (CERN) established in 1987 (41°31′N, 123°24′E) in the Shenyang suburb of Northeast China. This Station locates on the Lower Liao River Plain, with a humid and semi-humid continental monsoon climate of warm-temperate zone. The mean annual temperature is 7-8°C, with the minimum and maximum mean monthly temperature in January (-13°C) and July (24°C), respectively. The mean active accumulated temperature (≥10°C) is 3300-3400°C, total solar radiation is 5410-5600 kJ cm^{-2}, duration of frost-free season is 147-168 d, and mean annual precipitation is about 700 mm. The soil with 10.78 g C kg^{-1}, 1.23 g N kg^{-1} is meadow burozem, and pH was 6.99.

The open-top chamber was 3 m in diameter and 2.8 m in height. CO_2 and O_3 were provided 24 h a day and 7 h at daytime (8:00-12:00 am, 14:00-17:00 pm), respectively. The CO_2 and O_3 concentrations in open-top chamber were respectively inspected by ES-D (SenseAir, Sweden) infrared CO_2 sensor and S-900 O_3 analyzer (S-900 Aeroqual, New Zealand), with a variance ±5.4%for CO_2 and ±12.5% for O_3.

Four treatments were examined, i.e., control (ambient air with 342 μmol mol^{-1} CO_2 and 40 nmol mol^{-1} O_3, CK), elevated CO_2 (550 μmol CO_2 mol^{-1}), elevated O_3 (60 nmol O_3 mol^{-1}), and elevated CO_2 plus O_3 (550 μmol CO_2 mol^{-1} plus 60 nmol O_3 mol^{-1}), which were arranged in a randomized complete block design with three replicates. Spring wheat (*Triticum aestivum* L.) cultivar Liaochun 17 was sown on 2 April 2010 and harvested on 14 July 2010. Urea as basal fertilizer were applied with high (225 kg N hm^{-2}) and low application rate (150 kg N hm^{-2}) of chemical fertilizer N. Diammonium phosphate and potassium chloride were applied as basal fertilizer, with the application rate of 40 kg P hm^{-2} and 60 kg K hm^{-2}, respectively.

B. Sampling and Analysis

Soil samples were collected at jointing (22 June) and ripening stages (14 July). Soil microbial mass C was determined by the fumigation-extraction method and by Multi N/C 3100 analyzer [22].

Effects of N fertilization, elevated CO_2 and O_3, and the combination of CO_2 and O_3 on accumulation of soil microbial mass C were statistically analyzed by One-Way ANOVA using SPSS 13.0 software. Differences were considered significant only when $p < 0.05$.

III. RESULTS AND DISCUSSION

A. The amount of MBC in the jointing stage

There were significant differences in the amount of soil microbial biomass C (MBC) between the treatments with low and high N application rate of chemical fertilizer N exposed to elevated CO_2 concentration ($p < 0.01$, Fig. 1). The amount of MBC was significantly lower at high application rate chemical fertilizer N than low application rate chemical fertilizer N by 64.97% at the jointing stage. The amount of MBC was lower by 53.59%, 3.99% and 3.58% at high application rate chemical fertilizer N than low application rate chemical fertilizer N under CK, elevated O_3, O_3 plus CO_2 conditions at the jointing stage, respectively. This may be that high application rate chemical fertilizer N cause a reduction of the biomass activity, and reduce the soil microbial biomass, and the result was consistent with that of Liang [23].

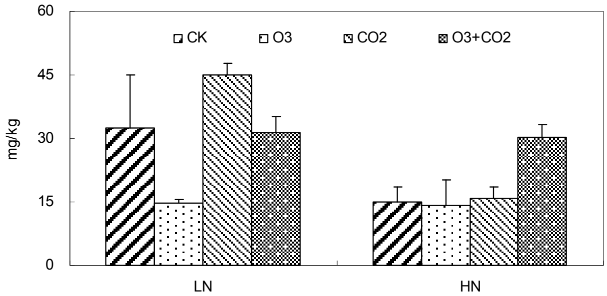

Figure1. The amount of soil microbial biomass C under different treatments at the jointing stage

In treatment with low application rate of chemical fertilizer N, elevated O_3 concentration significantly declined the amount of soil microbial biomass C by 52.49% ($p<0.05$, Fig. 1), compared with CK. Elevated CO_2 concentration increased the amount of soil microbial biomass C by 27.59%, while the interaction of CO_2 and O_3 decreased the amount of soil microbial biomass C by 3.66% compared with CK, but the differences were not significant. It indicated that elevated O_3 had harmful effects on the below-ground process, which was consistent with Anderson [14].

In treatment with high application rate of chemical fertilizer N, the interaction of CO_2 and O_3 increased significantly the amount of soil microbial biomass C by 50.03% ($p<0.05$, Fig. 1), compared with CK. Elevated O_3 decreased the amount of soil microbial biomass C by 6.21%, while elevated CO_2 increased the amount of soil microbial biomass C by 6.63% compared with CK, but the differences were not significant ($p>0.05$, Fig. 1).

B. The amount of MBC in the ripening stage

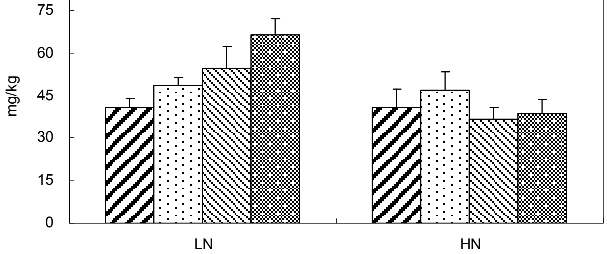

Figure2.The amount of soil microbial biomass C under different treatments at the ripening stage

In the treatments elevated CO_2 concentration and interaction of CO_2 and O_3, high application rate of chemical fertilizer N significantly decreased the amount of soil microbial biomass C by 32.92% and 41.45%, compared with low N application rate of chemical fertilizer N, respectively ($p<0.05$, Fig. 2). The amount of soil microbial biomass C was lower by 0.25% and 3.86% at high application rate chemical fertilizer N than low application rate chemical fertilizer N in the treatments with CK and elevated O_3 concentration at the ripening stage, respectively, but the differences were not significant ($p>0.05$, Fig. 2).

In treatment with low application rate of chemical fertilizer N, elevated CO_2 concentration and interaction of CO_2 and O_3 significantly increased the amount of soil microbial biomass C by 25.32% and 38.59% ($p<0.05$, Fig. 2), compared with CK, respectively.

In treatment with high application rate of chemical fertilizer N, elevated CO_2 concentration and the interaction of CO_2 and O_3 declined the amount of soil microbial biomass C by 10.42% and 4.88%, compared with CK, while elevated O_3 concentration increased the amount of soil microbial biomass C by 12.57%, compared with CK, but the differences were not significant ($p>0.05$, Fig. 2).

IV. CONCLUSION

At jointing and ripening stages, the amount of soil microbial biomass C in the high application rate of chemical fertilizer N were lower than low application rate of chemical fertilizer N over all treatments.

At the ripening stage, elevated O_3 concentration increased the amount of soil microbial biomass C compared with CK.

In low application rate of chemical fertilizer N treatments, elevated CO_2 concentration increased the amount of soil microbial biomass C compared with CK.

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