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Elevated ozone effects on soil nitrogen cycling differ among wheat cultivars

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ABSTRACT

Elevated O_3 (eO_3) has strong effects on natural and managed ecosystems, including decreased plant growth, plant tissue quality, species richness, plant litter inputs, decomposition, and root turnover. However, the effects of eO_3 on soil nitrogen (N) cycling are poorly understood. Here, a free -air O_3 enrichment experiment was conducted from 2007 to 2012, in which two O_3-tolerant wheat cultivars and two O_3-sensitive cultivars were grown under ambient O_3 (aO_3, 40 ppb) and eO_3 (60 ppb). We used a ^{15}N pool dilution technique to investigate N transformation rates and N availability in the soils in 2012. Both gross and net N transformation rates were significantly decreased ($P < 0.05$) by eO_3 in soils growing sensitive wheat cultivars, but were unchanged in soils growing tolerant cultivars. Compared with aO_3, NH_4^+ and NO_3^- concentrations were significantly increased ($P < 0.05$) by eO_3 in soils growing sensitive cultivars but not in soils growing tolerant cultivars. Ammonia monooxygenase activity was significantly increased by eO_3 while nitrate reductase activity was significantly decreased. Additionally, redundancy analysis (RDA) suggested that microbial community structure was largely shaped by soil and plant characteristics such as DOC, root C/N ratio, MBC/MBN, shoot/root ratio, root N, soil N and pH. In conclusion, wheat cultivars play an important role in determining the effects of elevated O_3 on N transformations. This study provides new insights into our understanding of how changes in microbial diversity and metabolism as mediated by plants will alter N cycling and ecosystem N availability in response to eO_3 and suggests that these effects will differ among different plants.

1. Introduction

The concentrations of ozone (O_3) in the troposphere have been rising from about 10 ppb during pre-industrial times to 25–40 ppb today, due to rapid industrial development and anthropogenic activities, and are predicted to increase by 40–70% by the year 2100 (Dentener et al., 2006). Ozone is an extremely phytotoxic pollutant that could decrease plant growth, yield, quality and cause loss of some species (Ainsworth, 2008; Feng et al., 2008) by suppressing photosynthesis, inducing foliar damage and accelerating leaf senescence (Dermody et al., 2006). Elevated O_3 may significantly change plant litter inputs, decomposition, root turnover and carbon exudation and alter belowground microbial ecological processes, leading to altered ecosystem C and N cycling rates (Wittig et al., 2009; Betzelberger et al., 2010; Simpson et al., 2014). However, little is known about the effects of elevated O_3 on soil N dynamics, and most previous studies have focused on forest species (Holmes et al., 2003, 2006).

Global economic losses induced by elevated O_3 on four major crops (wheat, soybean, rice and maize) were estimated to range from 14 to 26 billion US dollars on the basis of world market prices for the year 2000, and about 40% of this damage occurred in China and India (Van Dingenen et al., 2009). By 2030, total global agricultural losses (soybean, maize, and wheat) are estimated to reach 17–35 billion US dollars (Avnery et al., 2011). Wheat is one of the staple food crops in the world supporting nearly two-thirds of the world population, with an annual production of more than 650 million metric tons and a harvested area of over 200 million

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