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Short communication

Effects of increasing precipitation on soil microbial community composition and soil respiration in a temperate desert, Northwestern China

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ABSTRACT

Soil microbial communities play a critical role in soil carbon cycling and influence soil carbon–climate feedbacks. However, little information exists regarding the response of soil microbial communities in temperate desert ecosystems to projected increases in precipitation and the resulting effects on soil carbon emissions. A three-year precipitation addition experiment was conducted to explore the responses of soil respiration (R_s), microbial respiration (R_m) and microbial community composition to low (extra 15%) and medium (extra 30%) precipitation increases in a temperate desert ecosystem. R_s, R_m, microbial biomass carbon (MBC) and nitrogen (MBN), and microbial PLFAs consistently increased with increasing precipitation. R_s and R_m were positively correlated with MBC and microbial PLFAs. However, precipitation addition had no impacts on microbial community composition and fungal to bacterial PLFAs ratio. These results suggest that projected precipitation increase may synergistically increase bacterial and fungal abundance, and stimulation of microbial biomass can increase soil carbon release in desert ecosystems.

Global climate models predict the precipitation pattern will change in future, especially, with an increasing precipitation in mid-latitude regions (IPCC, 2007). Changes in the precipitation pattern are expected to impact ecosystem structure and function, especially in arid and semiarid ecosystems where water availability is the major limiting factor for both plants and soil organisms. However, only a few studies have concentrated on the impacts of increased precipitation on soil microbial organisms which are responsible for the major carbon release in sparse vegetation regions (Lal, 2004). The mosaic pattern of vegetation distribution is accompanied with the resource heterogeneity in arid and semiarid regions. “Shrub islands” effects have been found to exert the variations of water availability and vegetation growth between beneath shrubs and interplant soil (Jackson and Caldwell, 1993; Aguiar and Sala, 1999). To determine the effects of increasing precipitation on microbial activity and community structure, and the consequences on soil carbon cycling, a manipulative field experiment with 15% and 30% increase in precipitation was conducted from 2011 to 2013 in a temperate desert (the Gurbantunggut Desert). We hypothesized that 1) increased precipitation would alleviate the water-limitation of soil microbes and consequently increase heterotrophic respiration and soil carbon release; 2) soil microbial biomass, activity and carbon release would be significantly higher beneath shrubs than interplant soil because of the ‘fertile islands’ effects; 3) increasing precipitation may differentially impact activity patterns of microbial communities and exert indirect effects on soil carbon release.

The experiments were conducted in the vicinity of the southeastern Gurbantunggut Desert (44°17′N, 87°56′E, and 475 m a.s.l.). *Haloxylon ammodendron* is the dominant shrub. Soil organic carbon, total nitrogen and total phosphorus at 0–5 cm soil layer are significantly higher beneath *H. ammodendron* than those in interplant. The total precipitation in the site was 167.4 mm for 2011, 102 mm for 2012 and 133.7 mm for 2013, with 5.3%, 9.5% and 8.9% falling as snow, respectively. A complete random block design was applied (Fig. S1). Three precipitation treatments, with six

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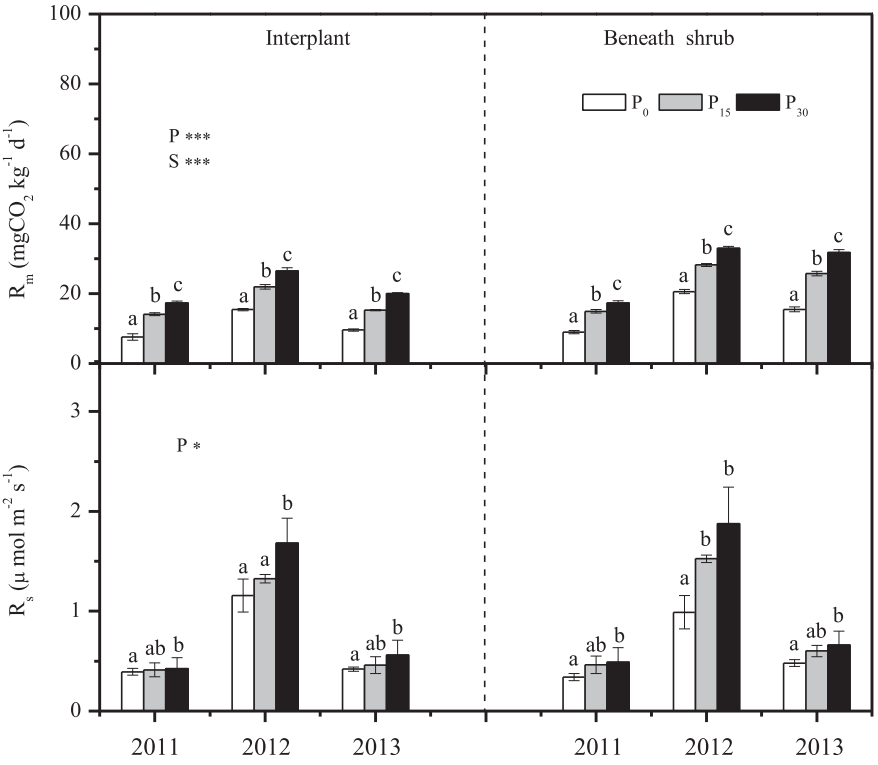

Fig. 1. Mean by year (mean ± S.E., n = 6, main panels) of microbial respiration (R_m) and soil respiration (R_s) in interplant (IP) and beneath shrub of *H. ammodendron* (BS). Significant results of the repeated-measures ANOVA on the effects of year (Y), precipitation addition (P), site (S), and their interactions on microbial respiration (R_m) and soil respiration (R_s) are shown. Significance: $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$ and $\wedge p < 0.1$. Bars with different letters within years represent significant differences based on post hoc two-way ANOVA testing with Bonferroni corrections at $p < 0.05$. IP: interplant, BS: beneath shrubs, P_0: control, P_{15}: 15% increase in precipitation, P_{30}: 30% increase in precipitation.

replications, were randomly distributed in six blocks across six interlands between sandy dune belts. Each plot was 10 × 10 m, with at least a 10 m buffer between adjacent plots. Two subplots of 'interplant' and 'beneath shrubs of *H. ammodendron*' were set up in each plot.

Precipitation was increased by 15% (P_{15}) and 30% (P_{30}) based on predictions for northern China over the next 30 years (Liu et al., 2010), and the third precipitation treatment was a control (P_0). The extra 15% and 30% precipitation was collected using precipitation collection pans. Immediately after a precipitation event, the collected rain was evenly sprayed into the plots. Given the ecological significance of snow in this site (Fan et al., 2014), collected snow was also evenly added before snow melting.

On August 10th in 2011, 2012 and 2013, soil respiration (R_s) was measured using the LI-6400-09 soil chamber (Li-Cor, Inc., Lincoln, Nebraska, USA). In each plot, three polyvinyl chloride collars (inner diameter: 10.4 cm; height: 5.8 cm) were randomly placed beneath *H. ammodendron* and in interplant soils, and then permanently installed 2 cm into the soil. For each measurement, the chamber was placed on each collar. R_s was measured between 9:00 h and 12:00 h and each subplot was repeated three times and averaged for data analysis. R_s measurement was accompanied by soil volumetric water content (SVWC) measurement at the top 5 cm using a portable TDR (HH_2-Delta T Device moisture meter, UK). On the same day of R_s measurement, five soil cores (5 cm in diameter, 5 cm in depth) were taken in each plot and mixed as a composite sample, yielding a total of 18 soil samples in interplant soil and beneath *H. ammodendron* for all treatments. After removing plant roots and large stones using a 2-mm sieve, soil samples were packed into a portable refrigerated box and transported to the laboratory for microbial measurements. Soil microbial biomass carbon (MBC) and nitrogen (MBN) were measured using the chloroform fumigation extraction method (Brookes et al., 1985). Microbial respiration (R_m) was measured using alkali absorption method (Page et al., 1982). Microbial community composition was evaluated using phospholipid fatty acid (PLFA) analysis (Bossio and Scow, 1998; Liu et al., 2013).

All statistical analyses were performed using R software version 3.0.2 (http://www.r-project.org). Due to the significant effects of year on tested parameters, a two-way ANOVA was performed to analyse the yearly impacts of the increased precipitation and site on soil microbial biomass, the ratio of MBC:MBN, R_m, R_s and total PLFAs, fungal and bacterial PLFAs, and Fungal:bacterial PLFAs ratio (F:B ratio). Multiple comparisons of treatments were performed to test for differences in soil properties among precipitation treatments. The default 'cor.test' function (Pearson correlation) was used to test the significance of correlations between MBC, MBC:MBN, total PLFAs and F:B ratio with R_s and R_m. Multivariate comparisons of microbial community composition were conducted from 2011 to 2013. Nonmetric multidimensional scaling (NMDS, 'metaMDS' function of vegan package) analysis was used to analyse changes in microbial community composition. The PLFAs using presence–absence of PLFAs as response variables were considered present only when >0.5 mol% (individual lipid percentage of total lipids) was detected, for the purpose of reducing noise in the ordination analysis.

Increasing precipitation led to a greater R_m (24.3 ± 0.6 $mgCO_2\ kg^{-1}\ d^{-1}$) and R_s (0.9 ± 0.2 μmol $m^{-2}\ s^{-1}$) in P_{30} compared to the control (R_m: 12.9 ± 0.5 $mgCO_2\ kg^{-1}\ d^{-1}$; R_s: 0.6 ± 0.1μ mol $m^{-2}\ s^{-1}$), with intermediate values of, R_m and R_s were 20.0 ± 0.4 $mgCO_2\ kg^{-1}\ d^{-1}$ and 0.8 ± 0.1μ mol $m^{-2}\ s^{-1}$ in P_{15} (Fig. 1, R_m: $p < 0.001$, R_s: $p < 0.05$). These results are consistent with other desert ecosystems (Gallardo and Schlesinger, 1992, 1995; Schwinning and Sala, 2004). The close relations between R_m and