Scaling Rhizosphere Respiration and Priming Effect from Single Plants to Field Ecosystems

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Objectives

As commonly recognized, rhizosphere processes regulate major fluxes of energy, nutrients, and water in terrestrial ecosystems. However, mostly because of methodological limitations, our understanding of rhizosphere processes at the ecosystem level is limited. Most existing results in the literature have been obtained from individual laboratory studies using single plant species. It is widely recognized that extrapolating these existing results from laboratory-scale studies to field ecosystems can be highly unrealistic and potentially erroneous. One approach to address this issue is to search for general patterns across different experimental scales. **The main objective of the project has been to address the key research question: are rhizosphere processes scalable among different plant species, different growth conditions in various soil types, and at different temporal and spatial scales?** We have aimed to find the answer to this research question by testing two hypotheses: (1) rhizosphere respiration rate scales isometrically with live root N content, and this scaling relation is independent of plant taxonomic groupings or growth conditions; and (2) there exists an invariant scaling relationship between the rate of rhizosphere-primed soil organic matter decomposition and live root N content, live root biomass, and /or plant productivity when plants are grown in similar soils.

Approach and Procedures

The experimental plan of the project includes three experiments: (1) a pot experiment in a continuous ^{13}C-labeling greenhouse; (2) a field experiment using natural ^{13}C-tracers by growing C_4-plants a C_3-soil; and (3) a field continuous labeling experiment. As planned, we have carried out the greenhouse experiment and the natural ^{13}C-tracer experiment in the field during this funding period. The field continuous labeling experiment will be executed during the next funding period.

The greenhouse experiment had the following treatments: monocultures of six plant species (three grassland species: wild oats, maiden clover and a forb; and three tree species: ponderosa pine, California blue oak, and aspen) grown in pots of two sizes (15- and 30-cm diameters) filled with either coastal grassland soil taken from a field near the UC Santa Cruz campus for the herbaceous species or soil taken from a ponderosa pine plantation near the Blogett Forest Research Station for the tree species. Unplanted controls and a mixture of the three grassland species in bigger pots were also included. The continuous ^{13}C-depleted labeling method of Cheng and Dijkstra (2007) and Dijkstra and Cheng (2007) was used in this greenhouse experiment. Because the three tree species require longer time to grow, we did not destructively

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sample those treatments during this period. We only report some results on the herbaceous species this time.

The natural ^{13}C tracer experiment in the field had these treatments: two C_4 plant species (corn and Sudan grass) grown in an organic farm field with C_3-soils both in field plots and in buried pots near the field plots. Unplanted controls also were included. The method of Cheng (1996) and Cheng et al. (2000) was used in this experiment. Both experiments had four replicates.

Results and Discussion

We are enthused by the data obtained so far. Initial results indicated that some of the rhizosphere processes could be scaled spatially. In the greenhouse experiment, there was no significant pot-size effect on total soil respiration per unit of soil mass, even though the two kinds of pot differed by approximately three times in volume (fig. 1). Furthermore, the rates of total soil respiration per unit of soil mass were similar among different plant species in the greenhouse experiment, except for the forb which tended to respire less than other plant species. This might have been caused by the lower root biomass under the forbs.

In the field natural ^{13}C tracer experiment, we measured total soil respiration both in buried pots and in field plots. The rate of total soil respiration in the field plots without planting was largely comparable to the rate in the buried pots without plants (fig. 2), indicating that the respiration rates can be reliably scaled across spatial scales using our methods. Similar soil respiration rates also were found between the two plant species in the field natural ^{13}C tracer experiment. However, soil respiration rates in buried pots were significantly higher than the rates in the field plots, most likely due to the much higher root densities found in the buried pots.

Our initial results also indicated that there would be adequate ranges in root density and plant biomass for our scaling analysis once we have the ^{13}C data. The shoot biomass values in the greenhouse experiment ranged from 0.5 to 1.4 g/kg of soil, and the amounts of root biomass ranged from 0.1 to 1.5 g/kg of soil. In the field natural ^{13}C tracer experiment, the amounts of shoot biomass ranged from 90 to 680 g/m2, and the amounts of root biomass ranged from 10 to 150 g/ m^2.

Results in this report represent "work in progress" during the initial year. We are processing samples and expecting to have the following data soon: (1) ^{13}C abundance of respired CO_2 from both experiments, (2) ^{13}C abundance of shoots, roots and soils from both experiments, (3) contents of C and N in shoots, roots and soils, (4) soil enzyme activities, and (5) soil microbial biomass C and N. We plan to carry out the continuous labeling experiment in the field and finish all sample processing and data analysis during the coming year. The final testing of the two main hypotheses and final report will be accomplished in the coming funding period.

Figures

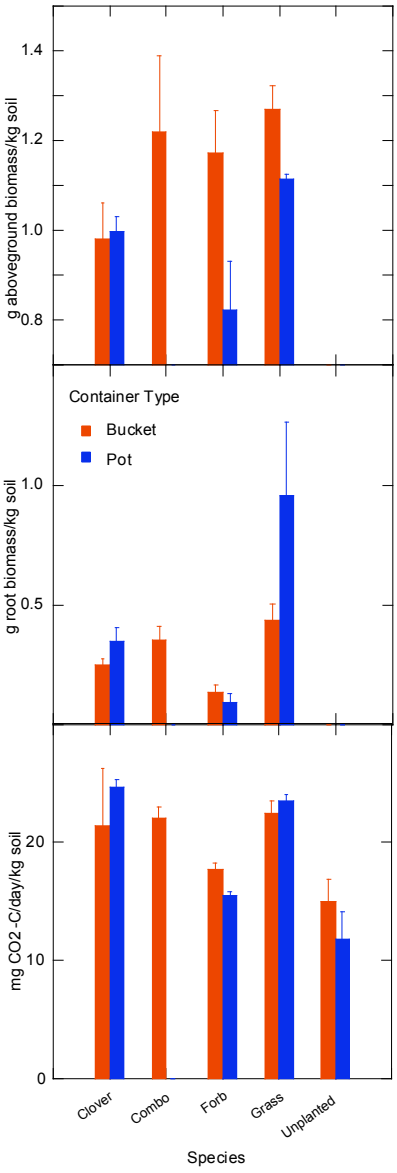
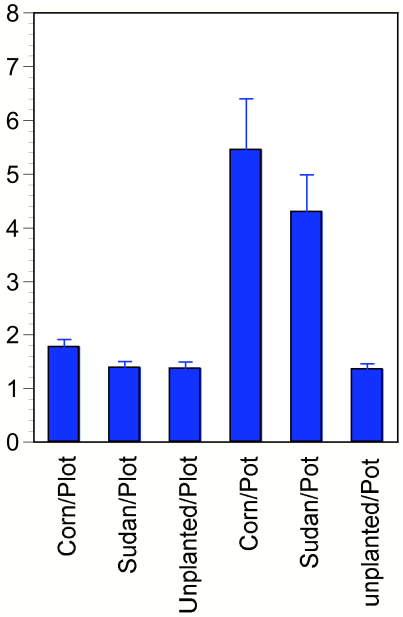


Figure 1 (left). Biomass of shoots and roots, and total soil respiration in the greenhouse experiment with clover, forb and grass grown in plastic containers of two different sizes (10 liters for the pots and 30 liters for the bucket), and mixture of the three plant species grown in buckets only. Each error bar represents one standard error.

Figure 2 (below). Total soil respiration in the field natural tracer experiment with treatments of two plant species (corn and Sudan grass) and two spatial scales (buried pot of 15-cm diameter and 40-cm tall, and field plot). Each error bar represents one standard error.



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