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Soil Respiration and Litter Decomposition Increased Following Perennial Forb Invasion into an Annual Grassland

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ABSTRACT

Exotic plant invasions may alter ecosystem carbon processes, especially when native plants are displaced by plants of a different functional group. Forb invasions into grasslands are common, yet little is known about how they impact carbon cycling. We conducted a field study over 2 years from April 2010 to March 2012 in China to examine changes in soil respiration (R_{soil}) following invasion of exotic perennial forb species (*Alternanthera philoxeroides* or *Solidago canadensis*) into an annual grassland dominated by a native annual graminoid (*Eragrostis pilosa*). Measurements of R_{soil} were taken once a week in stands of the native annual graminoid or one of the forb species using static chamber-gas chromatograph method. Aboveground litterfall of each of the three focal species was collected biweekly and litter decomposition rates were measured in a 6-month litterbag experiment. The monthly average and annual cumulative R_{soil} increased following invasion by either forb species. The increases in cumulative R_{soil} were smaller with invasion of *Solidago* (36%) than *Alternanthera* (65%). Both invasive forbs were associated with higher litter quantity and quality (*e.g.*, C:N ratio) than the native annual graminoid. Compared to the native annual graminoid, the invasive forbs *Alternanthera* (155%) and *Solidago* (361%) produced larger amounts of more rapidly decomposing litter, with the litter decay constant k being 3.8, 2.0 and 1.0 for *Alternanthera*, *Solidago* and *Eragrostis*, respectively. Functional groups of the invasive plants and the native plants they replaced appear to be useful predictors of directions of changes in R_{soil}, but the magnitude of changes in R_{soil} seems to be sensitive to variations in invader functional traits.

Key Words: carbon cycling, exotic plant, functional group, functional traits, invasive plants, litterfall, native plants

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INTRODUCTION

Exotic plant invasions profoundly alter ecosystem element processes (Ehrenfeld, 2003; Liao *et al.*, 2008; Laungani and Knops, 2009). Carbon cycling is one of the processes that experience much alteration following plant invasions (Liao *et al.*, 2008). Studies on the impacts of plant invasions on ecosystem carbon cycling have increased rapidly in number, particularly on soil carbon sequestration and soil respiration (R_{soil}) (Ehrenfeld, 2003; Liao *et al.*, 2008; Tamura and Tharayil, 2014). Soil respiration plays a major role in carbon loss from terrestrial ecosystem carbon pools, exceeding all other terrestrial-atmospheric carbon exchanges, and it is estimated to be an order of magnitude greater than the combination of carbon emitted by fossil fuel combustion and deforestation (Schlesinger and Andrews, 2000). Therefore, a slight shift in R_{soil} due to plant invasions may lead to significant changes in atmospheric composition and related pools (*e.g.*, soil organic carbon pools).

Successful plant invaders may be from a different functional group rather than the native plant community. Indeed, impacts of plant invasions on R_{soil} are various, suggesting that carbon cycling alteration following plant invasions may be ecosystem dependent (Litton *et al.*, 2008; Strickland *et al.*, 2010). For instance, invasive plants generally have a higher net primary production that leads to higher litter input after each growing season (Liao *et al.*, 2008; Wolkovich *et al.*, 2010). Woody plants are characterized by deep roots and may have slower litter decomposition rates than herbaceous plants (Jobbagy and Jackson, 2000; Jackson *et al.*, 2002; Funk, 2005). Differences in these traits would underlie changes in R_{soil} with grass invasions into woody communities (Jackson *et al.*, 2002; Knapp *et al.*, 2008; Litton *et al.*, 2008; Strickland *et al.*, 2010; Wolkovich *et al.*, 2010; Cable *et al.*, 2012).

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Even if invasive plants are from the similar functional groups with the native plant community, differences in growth traits between the invasive plants and the native plants may also alter carbon cycling following plant invasions (De Deyn *et al.*, 2008). Some studies showed that introduced grasses had a different rooting depth compared to native grasses, leading to alteration of belowground carbon input in cases of grass invasions (Wilsey and Polley, 2006; Adair and Burke, 2010). Grass invasions into grasslands may also lead to variations in R_{soil} *via* different growth forms, life spans or litter properties (Adair and Burke, 2010; Scharfy *et al.*, 2011). Therefore, studying multiple combinations of invaded ecosystem types and functional types of invasive species would help to fully understand how plant invasions impact R_{soil}. To date, considerable attention has been paid to herbaceous invasions into woody ecosystems, while very few studies have focused on forb invasions into grassland dominated by native annual grasses, despite their widespread abundance and known impacts on ecosystem processes (Scott *et al.*, 2001; Hook *et al.*, 2004; Drenovsky and Batten, 2007; Weber *et al.*, 2008; Adair and Burke, 2010).

Besides differences in functional traits between invasive and native plants, abiotic factors such as soil microclimate (*i.e.*, soil temperature or soil moisture) could be altered by increased litter coverage at the soil surface in invaded areas (Smith and Johnson, 2004; Wolkovich *et al.*, 2009). Because soil microclimate and carbon substrate availability can be important factors controlling R_{soil}, such litter-related changes in invaded plots might alter R_{soil} (Raich and Schlesinger, 1992; Wan and Luo, 2003; Scott-Denton *et al.*, 2006; Litton *et al.*, 2008; Wolkovich *et al.*, 2010).

In this study, we examined an annual grassland that had experienced serious exotic perennial invasions in Southeast China. A 2-year field experiment was conducted to understand impacts of perennial forb invasions on R_{soil}. We hypothesized that perennial forb invasions might increase R_{soil} due to the higher litter production and faster litter decomposition rate of invasive perennials than those of the native annual grass.

MATERIALS AND METHODS

Study site

This study was conducted in an annual grassland at the Nanjing Agricultural University Experimental Station (32°0′ N, 118°3′ E, 6 m above sea level) in Jiangsu Province, China. The study area has a typical monsoonal climate. The plant growing season is generally from March to November and winter season covers through December to February of the next year. Mean annual temperature is 25.0 °C with monthly mean temperature ranging from −10 °C in January to 32.5 °C in July. The mean annual precipitation is about 980 mm, 90% of which is distributed in the plant growing season from March to November. The soil is classified as a Gleysol or a hydromorphic soil with high clay content.

Focal species and stand selection

The grassland studied was flooded by the Yangtze River and cultivated to paddy rice until the early 20th century. Since the termination of paddy rice cultivation, some parts of the grassland have been dominated by one native annual graminoid, *Eragrostis pilosa* (L.) P. Beauv., before invasions of two perennial forbs, *Alternanthera philoxeroides* (Mart.) Griseb. and *Solidago Canadensis* L., which occurred approximately 5 years ago before this study. Currently, the remaining native annual grass is still threatened by these two range-expanding invasive forbs. The present distributions of these two forbs are just where they have advanced to so far.

The native annual graminoid *Eragrostis* is a broadly distributed temperate bunchgrass native to China. In this region, *Eragrostis* has been the dominant plant species prior to recent exotic plant invasions. Moreover, the global distribution of *Eragrostis* species makes it a good model plant to study carbon cycling change in grasslands after perennial forb invasions. The invasive perennial forb *Alternanthera* is native to South America and it was introduced to China *via* Japan in the 1930s. This perennial forb is classified as one of the most aggressive invaders in China and has been detected in at least 19 provinces in China (Weber *et al.*, 2008). It is commonly found in agricultural areas, wetlands and disturbed areas in Australia, North America and Asia. The other invasive perennial forb *Solidago*, another widely distributed perennial forb, was introduced into China from North America and has been reported as a serious invasive plant species that is still expanding its range (Liu *et al.*, 2006).

We surveyed the study site to locate stands dominated by the native species (*Eragrostis*) and by either of the two exotic perennial forb species (*Alternanthera* or *Solidago*) in December 2009. Stands with at least 80% of the coverage occupied by one focal species were considered dominated. Three stands (16 m × 30 m) dominated by one of the three species (*Eragrostis*, *Alternanthera* or *Solidago*) were selected.