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Short Note

The potential of naturally occurring fallow weeds to scavenge nitrogen in rice cropping systems

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ABSTRACT

Environmental costs from nitrogen (N) loss have been substantial in Chinese rice cropping systems. Naturally occurring fallow weeds may provide a similar ecosystem service as cover crops in scavenging N with the advantage of no inputs. In this study, an on-farm experiment and ^{15}N-tracing micro-plot experiment were conducted to: (1) investigate the aboveground biomass and N uptake by fallow weeds; and (2) quantify the sources of N uptake by fallow weeds in the rice cropping system. Results showed that fallow weeds produced an average aboveground biomass of 245 g m^{-2} across a wide range of regions, with the highest values of 305 g m^{-2} at the regional level and 474 g m^{-2} at the field level. Fallow weeds had an average N uptake of 2.46 g m^{-2}, with the highest values of 2.97 g m^{-2} at the regional level and 4.93 g m^{-2} at the field level. N uptake by fallow weeds increased 59% from N fertilization during the rice-growing season (18 g N m^{-2}, the national average N rate of China), and about 90% of this increase was driven by an increase in soil N uptake. Our study suggests that naturally occurring fallow weeds have great potential for providing the ecosystem service of reducing potential N loss by scavenging inorganic N (primarily N mineralized from soil organic matter) in the rice cropping system.

1. Introduction

Nitrogen (N) is the major limiting nutrient for rice productivity (Cassman et al., 1998). Increases in chemical fertilizer N input has made a significant contribution to the improvement of rice yields in China over the past five decades (Fan et al., 2012). At present, the average N application rate for rice production in China is 180 kg ha^{-1}, about 75% higher than the world average (Peng et al., 2002; Chen et al., 2014). However, at the same time, the yield increment relative to N fertilizer input has declined sharply from 15–20 kg kg^{-1} in the 1950 s to 5–10 kg kg^{-1} in the 2000 s (Peng et al., 2010). In addition, due to the high rate of N application, only 20–30% of N is taken up by the rice plant and a large proportion of the N applied is lost to the environment (Peng et al., 2009). As a result, substantial environmental costs are being observed including enhanced N deposition, soil acidification, and surface water eutrophication (Guo et al., 2010; Le et al., 2010; Liu et al., 2013).

To cope with the above problems, several improved N management practices, such as real-time N management, fixed-time adjustable-dose N management and regional mean optimal N rate management, have been developed for rice production in China (Peng et al., 2006; Ju et al., 2009). However, in addition to N loss during the rice-growing season, N loss in the fallow season also largely contributes to the environmental impacts. Liang et al. (2007) observed that nitrous oxide (N_2O) emission during the fallow season accounted for up to 40–50% of the total annual emissions from rice fields in Northeast China. Moreover, it has been documented that N loss in the fallow season can be affected by N fertilization during the rice-growing season. Lu et al. (2008) reported that N fertilization during the rice-growing season could significantly increase nitrate loss from rice fields in the fallow season and create the potential for groundwater nitrate pollution.

There are two sources of N loss in the fallow season in rice agroecosystems: (1) residual N (inorganic form) in soil from chemical fertilizers applied to rice; and (2) N mineralized from soil organic matter. Because both of these N sources can be directly absorbed by plants, one potential strategy to reduce N loss during the fallow season is the use of cover crops (David et al., 2013). However, because the expansion of cities has led to a labor shortage and an increase in labor wages in rural areas in China (Peng et al., 2009), there is little interest in growing winter crops that can serve as cover crops in many rice cropping regions.

In recent years, we observed that winter weeds, dominated by Japanese foxtail (*Alopecurus japonicus*), were very abundant in the fallow season in many rice fields in Hunan Province, China (Fig. 1). Natural growth of fallow weeds may be an alternative strategy to using cover crops to reduce N loss by scavenging the inorganic N. Moreover,

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Fig. 1. Japanese foxtail (*Alopecurus japonicus*) in a rice field in Changsha, Hunan Province, China. The photo was taken on 31 January 2015.

this alternative strategy may have great potential for widespread adoption because it does not require any inputs including labor, which is a critical barrier to cover crop adoption. The objectives of this study were to: (1) investigate the aboveground biomass and N uptake by fallow weeds in rice agroecosystems using on-farm experiments; and (2) quantify the sources of N uptake by fallow weeds in a rice cropping system using a ^{15}N-tracing micro-plot experiment.

2. Materials and methods

2.1. On-farm experiment

On-farm studies were carried out in six regions (Yueyang, Yiyang, Changsha, Xiangtan, Hengyang, and Yongzhou) of Hunan Province, China in 2015 (Table 1). The regions were selected according to two main criteria: (1) they were major rice producing areas; and (2) they provided a broad geographical distribution covering northern (Yueyang and Yiyang), central (Changsha and Xiangtan), and southern areas (Hengyang and Yongzhou) of the province.

Thirty rice fields with a dense vegetation of fallow weeds dominated by Japanese foxtail were selected in each region. Rice crops were cultivated following the local standard practices in these fields and harvested in late October. Six sampling points were chosen along the diagonal of each field. Weed plants were sampled from an area of 0.24 m^2 (0.6 m long × 0.4 m wide) at each sampling point on 10–15 April. Aboveground biomass was determined after oven-drying at 70 °C to a constant weight. The dried samples were ground and passed through a 100-mesh sieve. A sub-sample of 0.50 g was digested with H_2SO_4-H_2O_2 for determining N content with a Skalar SAN Plus segmented flow analyzer (Skalar Inc., Breda, The Netherlands). Aboveground N uptake was calculated by multiplying biomass and N content.

2.2. Micro-plot experiment

A ^{15}N-tracing micro-plot experiment was conducted in a rice field at the research farm of Hunan Agricultural University (28°11′ N, 113°04′ E), Changsha, Hunan Province, China during 2014–2015. The field was chosen because it had numerous Japanese foxtail in the last several fallow seasons. The soil of the experimental field was a tidal clay with the following soil properties: pH = 5.83, organic matter = 27.7 g kg^{-1}, total N = 1.59 g kg^{-1}, available P = 54.5 mg kg^{-1}, and available K = 63.2 mg kg^{-1}. The soil characteristics were based on samples taken from the 0–20 cm soil layer. Twenty micro-plots were established in the field by inserting PVC cylinders (40-cm long, 40-cm inner diameter) into the soil at a depth of 20 cm with a collar of 20 cm aboveground.

In 2014, the hybrid rice cultivar Y-liangyou 1 was grown under two N application rates: 0 and 18 g m^{-2} (equivalent to the Chinese national average N rate of 180 kg ha^{-1}). The N rates were arranged in a randomized complete block design with 10 replicates (micro-plots). Y-liangyou 1 is a representative of the high-yielding cultivars developed

Table 1
Geographical position and climatic condition of regions selected in the on-farm experiment.

Region	Geographical position		Climatic condition		
	Latitude (N)	Longitude (E)	Mean annual temperature (°C)	Mean annual rainfall (mm)	Mean annual sunshine duration (h)
Yueyang	28°31′–29°32′	112°39′–113°02′	16.9	1423	1656
Yiyang	28°27′–29°01′	112°18′–112°25′	16.5	1465	1560
Changsha	28°12′–28°18′	113°13′–113°49′	17.7	1451	1542
Xiangtan	27°45′–27°55′	112°13′–112°38′	17.1	1350	1670
Hengyang	26°32′–27°02′	112°13′–112°47′	17.9	1250	1669
Yongzhou	25°46′–26°36′	111°29′–111°59′	18.1	1550	1520