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Changes in weed community with different types of nitrogen fertilizers during the fallow season

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ABSTRACT

Manipulation of crop fertilization may be an important part of integrated weed management systems. The objective of this study is to investigate the responses of weed community and composition in the fallow season to the different types of nitrogen fertilization. Six treatments were conducted over four consecutive years, including no N fertilizer (N0), conventional prilled urea (PU), polymer coating of sulfur-coated urea (PSCU), urea with nitrification inhibitor (UNI), urea-formaldehyde (UF), and controlled-release bulk blending N fertilizer (70% full dosage of PSCU plus 30% full dosage of prilled urea, BBF). Weed species composition, dominant species biomass, and soil properties were investigated, and indices of weed species diversity were calculated. The results indicated that *Mazus japonicus* (Thunb.) Kuntze and *Alopecurus japonicus* Steud. dominated the N0 treatment, whereas *Alopecurus japonicus* Steud. dominated all N–fertilized treatments. The PSCU treatment produced the greatest shoot biomass (657 $g\,m^{-2}$) of *Alopecurus japonicus* Steud. The N0 treatment had the highest total weed density (365 plants m^{-2}) and Shannon-Wiener index (1.39). Application of PSCU or UF led to significantly lower Shannon-Wiener and higher Simpson indices than did the PU treatment due to high residue soil N contents. The UNI treatment not only produced the highest 4-year average grain yield of double rice, it also maintained a relatively diverse weed community in the fallow season.

1. Introduction

Weeds are an important component in agroecosystems, providing functions such as nutrient cycling and reduction of soil erosion (Altieri, 1999; Marshall et al., 2003). The performance of weed species is affected by several factors, such as the competition from the crop and other weeds on nutrients, fertilizer usage, crop rotation and tillage (Andersson and Milberg, 1996; Lehoczky et al., 2012). Additionally, climatic conditions and soil fertility can have a great influence (Unger et al., 1999; Andreasen and Skovgaard, 2009). Manipulation of fertilization may be an important component of integrated weed management programs (Lehoczky et al., 2015). Fertilization alters soil nutrient levels, thus affecting species composition and weed biomass (Yin et al., 2006). For example, Tang et al. (2014) reported that the PK treatment resulted in greater weed density and higher Shannon-Wiener index of weed diversity than did the NP and balanced fertilization (NPK) treatments in a 17-year field trial with a winter wheat-soybean rotation. Nitrogen is a major nutrient for plant growth. In addition, it is considered a dormancy breaker for certain weed species, and thus it may affect weed germination and establishment (Agenbag and Villiers, 1989; Blackshaw et al., 2005). Many studies have reported that weed diversity was influenced by N application methods and rate. Blackshaw et al. (2002) reported that surface broadcast N resulted in greater weed biomass than application in the surface pools or point-injected N in spring wheat. Andersson and Milberg (1996) found that an increase in N input did not cause an increase in total weed biomass, although weed

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species were strongly affected by N application rate.

Today, new types of N fertilizers such as controlled release urea (CRU) or urea with nitrification inhibitor (UNI), have been widely used by farmers in southern China because of more convenient field operation. However, the effectiveness of CRU was strongly affected by environmental conditions, such as soil temperature and moisture (Grant et al., 2012). Therefore, the content of soil nitrate (NO_3^-–N) and ammonium (NH_4^+–N) could change in the fallow season because of delayed release of N from the CRU. Many researchers have reported on the effects of nitrogen on weed communities, however, mainly focused on crop–weed competitive interactions during the cropping period (Andersson and Milberg, 1996; Blackshaw et al., 2002, 2004). To our knowledge, information regarding changes in weed community responses to different types of N fertilizers in the fallow season is limited. The weed community during the fallow season provides a number of resources for insect species and birds. Therefore, it plays an important role in the biological diversity of agroecosystems (Tang et al., 2014).

The goal of this study was to determine weed species composition and weed species abundance caused by different types of N fertilizers. By using redundancy analysis (RDA), we sought to illustrate how weed species were related to each other and to various soil properties in the fallow season. Additionally, greater knowledge of different types of N fertilizer on weed communities could aid in the development of N fertilizer management for the maintenance of a stable agroecosystem.

2. Materials and methods

2.1. Site description

The experiment was located at Xinzhu Country (29°01′N, 119°27′E), Zhejiang Province, China. This region has a middle subtropical monsoon climate with annual precipitation of 1424 mm and an annual mean temperature of 17.5 °C. The soil type is yellow clayey paddy soil, with initial properties of 26.2 g kg^{-1} organic matter, 1.96 g kg^{-1} total nitrogen, 4.43 mg kg^{-1} available P, 79 mg kg^{-1} available K, and pH (H_2O) 5.24.

2.2. Experimental design

This experiment trial was set up in April 2011 in a double rice cropping system. Six treatments with three replicates were established: (1) no nitrogen (N0), (2) prilled urea (PU, N 46%), (3) polymer coating of sulfur-coated urea (PSCU, N 34%, made by Kingenta Ecological Engineering Group Co., Ltd., Shandong, China), (4) urea with nitrification inhibitor (2-chloro-6-trichloromethyl-pyridin, 0.25%) (UNI, N 46%, made by Zhejiang Aofutuo Chemical Co., Ltd., China), (5) urea-formaldehyde (UF, N 28%) and (6) controlled-release bulk blended N fertilizer (BBF, 70% full dosage of PSCU plus 30% full dosage of PU, N 37.6%). The fertilization treatments were assigned in the same experimental plots in the continuous four studying years. P and K were used in the form of calcium superphosphate and potassium chloride, respectively, with equal amounts in all treatments. At the start of each season, the P and K fertilizers were applied as basal fertilizer at the rate of 90 kg P ha^{-1} and 120 kg K ha^{-1}, respectively. All N–fertilized treatments received the same amount, 180 kg N ha^{-1}, per season. In treatments 3–6, N fertilizer was used as a single basal application. For the PU treatment, the ratio of nitrogen application was 40%: 30%: 30% (basal: tillering: booting) in the early rice and 40%: 60% (basal: tillering) in the late rice season.

The experiment was a completely randomized design. The plots were 12.5 m^2 (5 m × 2.5 m) and isolated by ridges and plastic film covering. The rice cultivar was 'Jinzao 09' in the early season and 'Yueyou 9113' in the late season. Pregerminated seeds were sown in a seeding field. The specific seeding dates were in late-March for early rice and early-July for late rice every year. The seeding rates were 36 kg ha^{-1} for early rice and 12 kg ha^{-1} for late rice, respectively. Seedlings were transplanted in late-April for early rice and late-July for late rice every year. The fields remained fallow between the harvest and next planting. Weeds were removed manually at booting stage once per season, and no herbicide was applied during 2011–2014.

2.3. Sampling and analysis

All soil samples were collected from the 0–10 cm layer in each plot on April 2, 2015. The samples were transported to the laboratory within 24 h after sampling. One portion was sieved moist (< 2 mm) then kept at 4 °C for NH_4^+ and NO_3^-analysis. The other portion was air-dried and kept at room temperature to analyze soil organic matter (SOM), total N (TN), alkali-hydrolyzable N (AN), P, K, S, and pH (Lu, 2000). SOM was determined using $K_2Cr_2O_7$-H_2SO_4 oxidation. Total N was measured using the Kjeldahl method. Alkali-hydrolyzable N was released and transformed to NH_3 using 1 M NaOH and $FeSO_4$ powder at 40 °C for 24 h, and then absorbed with a 2% (w/v) H_3BO_3 solution and titrated with a 0.005 M H_2SO_4 solution. Available P in the soil was measured using the ammonium fluoride extraction method. Soil exchangeable K^+ was extracted using 1 M NH_4OAc and analyzed using flame photometry. Soil pH (H_2O) was measured in 1: 2.5 soil to water suspensions. The soil NH_4^+-N and NO_3^--N were extracted by 2 M KCl using a 1:5 soil to solution concentration (Pansu and Gautheyrou, 2006).

Five representative hills of rice plants were collected in late-July for early rice and early-November for late rice. All plant samples were oven dried at 70 °C for 48 h to a constant weight and weighed. The total biomass of rice was estimated. Grain yield was determined by harvesting the whole plot, and then adjusted the harvest by the standard 14% moisture content. The N cumulative release rates of PSCU were determined by a weight loss method (Wilson et al., 2009). Thirty mesh bags (15 cm × 10 cm) with 10 g PSCU were buried in the field. Three bags were randomly collected at 10, 22, 33, 47, 54, 65, 75, 85, 101, and 111 days after transplanting in 2014.

The weed community was investigated by means of three 0.5 × 0.5 m^2 quadrats randomly distributed in each plot on April 2, 2015. All weeds in the quadrat were clipped, sorted by species, counted, and oven dried at 75 °C for 72 h before weighing (Yin et al., 2005).

2.4. Statistical analysis

Data analysis was performed with STATISTICA 5.5 program. Analysis of variance (ANOVA) with Duncan's multiple range test was performed for soil organic matter, soil nutrients, soil pH, weed abundance, shoot biomass of dominant species, and rice grain yield with a probability level of 0.05. To assess weed diversity of each treatment, four diversity indices were used (Magurran, 1988). The Shannon-Wiener diversity index (H'), Pielou index (E), Margalef (D_{MG}), and Simpson index (D_S) were calculated using the following equations:

$$H' = (N \ln N - n \ln n)/N$$

$$E = H'/(\ln \mathrm{S})$$

$$D_{MG} = (S - 1)/(\ln \mathrm{N})$$

$$Ds = \sum (\mathrm{n}/N)(\mathrm{n}/N)$$

Where N is the total number of individuals in each plot, n is the number of individual per species present in each plot and S is the number of species in each plot. Redundancy analysis (RDA) was performed to investigate weed communities and environmental variables. The vector length represented the degree of correlation between soil properties and weed species. The vector direction indicated the trend of variable. Weed density data were $\log_e(x+1)$ transformed prior to analysis.