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Impacts of geese on weed communities in corn production systems and associated economic benefits

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HIGHLIGHTS

- We evaluated three corn (*Zea mays*) production methods: raising geese in corn fields; conventional corn production with weed management; and corn fields without weed management.
- The first of these (i.e. raising geese) minimized herbicide application, maintained higher weed diversity, and results in a greater overall economic benefit compared to the other two methods.
- Raising geese in corn fields should be considered more widely for sustainable crop production.

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ABSTRACT

Weed pests directly impact crop quality and yield. We compared three different treatments on weed diversity and structure, and assessed the economic benefits of each on corn (*Zea mays*) production. The treatments included: raising geese in corn fields (hereinafter referred to as RGICF), conventional corn production with weed management (CCP) and corn fields without weed management (CK). A Shannon-Wiener diversity index and richness indicated that fields with RGICF and CK had higher weed diversity than CCP fields at early growth stages (60 and 90 days after planting, hereinafter referred to as d.a.p.), but low evenness. In RGICF fields the dominance of the major weed species populations sharply decreased because of geese feeding and trampling activity. As a consequence, weed population abundances were more evenly distributed and the evenness index, richness, and Shannon-Wiener index differed from CK and CCP treatments at 120 d.a.p. The RGICF treatment resulted in a yield reduction of corn. This loss, however, was compensated by the economic gains obtained from geese production and RGICF production without herbicide application should be considered as a production approach for sustainable agriculture operations.

1. Introduction

Competition for sunlight, water, and soil nutrients between crops and weeds can reduce crop yield and quality (Kropff and Spitters, 1991). Chemical control of weeds is typically used in modern agriculture (Harker and O'Donovan, 2013). Hume (1987) reported that herbicides reduce populations of susceptible weeds while enabling resistant weed species to increase. Despite intensive use of herbicides in corn, abundances of certain weed species and yield losses due to weed competition have increased (Keller et al., 2014). On the other hand, increased awareness of the vulnerability of arable weed populations is reflected in the UK Biodiversity Action Plan (BAP), which lists 20 arable plants that are endangered by destructively weeding, of which 12 arable plant species are under prioritized protection (Storkey and Westbury, 2007).

Weeds can be viewed as primary producers within agricultural systems and they play important roles in arable system food webs. The weed community can provide food and habitats for higher trophic groups, supporting a diverse community of insects and birds (Marshall et al., 2003; Holland et al., 2006). Weeds can also add ecological value to arable systems by improving soil

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properties, facilitating soil nutrient cycling, and preventing soil erosion and nutrient leaching (El Titi, 1995; Altieri, 1994; Wortman et al., 2010). It is therefore useful to consider protecting the ecological functions of weeds if this can be done while maintaining acceptable crop yields. An alternative to herbicide weed control is Integrated Weed Management (IWM) which combines management techniques that decrease the density of weeds emerging in crops, reduce their relative competitive ability, and reduce the effects of weeds on crop yield to below the economic threshold (ET). The goal is to reduce the need for herbicide applications at the cropping system level (Deytieux et al., 2012; Mézière et al., 2013). Within the concept of IWM, many non-chemical weed control techniques have been developed. These include diversified crop rotations (Derksen et al., 2002; Murphy et al., 2006); no-tillage, minimal tillage; delayed autumn sowing, post-emergence harrowing (Rasmussen, 2004), competitive cultivars and competitive crop species (Blubaugh and Kaplan, 2015). These methods usually require more labor than chemical weed management, resulting in greater cost (Rask et al., 2013). It is therefore important to explore alternative methods to control weeds while maintaining some weeds for economic benefit.

Raising geese in cornfields is a compound production model based on the principle of "Agro-pastoral Integration," first proposed in 2011 (Guan and Wang, 2011). It is a production model that uses waste resources such as weeds, lower leaves of crops from the tillage system to raise poultry (Guan et al., 2013a,b). This study evaluated three treatments: Raising Geese in Cornfield model (RGICF), weed-unmanaged corn fields (CK), and the Conventional Corn Planting model (CCP). Our goal was to provide a comprehensive understanding of the effects of raising geese on the control of weed populations, changes of weed community structure (populations, diversity), and associated economic benefits.

2. Materials and methods

2.1. Location and study site

The study was conducted in the Niyang River valley in Southwest China near the town of BaYi, Tibet (29°33′ N, 94°21′ E). The area topography is sloping fields at 2980–3100 m elevation above mean sea level. The climate is warm and sub-humid. The annual mean temperature at the study site was 8.6 °C, with 159.2 days on average exceeding a mean daily temperature of 10 °C. Frost-free period at the study site was 177 days. Assuming a base temperature of 10 °C, the site accumulates 2225.7 degree days. The mean annual sunshine is 1989 h and the 46% of the days have sunshine.

The study was conducted in 2014. Three treatments were established. These were RGICF, CK, and CCP. Each treatment was set up in split-split plot design with three blocks, and each sub-plots covered an area of 100 m^2. The corn rows were spaced 70 cm apart. A layer of plastic film was mulched and fertilizers were applied at planting (compound fertilizer, 240 kg/ha, which consisted of N-33%, P-17%, K-17%, and organic matter-20%). The sub-plots of the RGICF production model were enclosed by nylon net of 0.5 m height. No herbicide was applied nor manual weed removal conducted in the RGICF production model. On August 7, we conducted rotational grazing of geese (ten geese, 30 d old) in the three sub-plots of the RGICF production model. The geese were captured and confined in the evening to prevent loss from predation. Additional food was provided (mixed feed, 100 g/goose, consisting of ground corn grain-70%, wheat bran-20%, soybean meal-5%, fish meal-5%).

Post-emergence herbicide, "Yudiao" (Binnong Technology Company, Binzhou city, Shandong province, China), consisting of 90% atrazine, and 10% mesotrione, was applied to eradicate weeds in the CCP. A manual backpack sprayer with single fan nozzle (XF-16B, Xiefeng Machinery Company, Binzhou city, Shandong province, China) with a fluid capacity of 16 L and a 1.4 L/min spray rate was used for apply herbicide application. The herbicide was applied 30 days after planting (corn was planted on April 28, 2014).

No weed management was conducted in CK during the entire growing season. No geese were grazed in either CCP or CK.

2.2. Weed sampling

Four weed evaluations were conducted during the 2014 corn growing season; these were on 4 July which was 60 days after planting (hereafter referred to as d.a.p), Aug. 4 (90 d.a.p), 4 September (120 d.a.p), and 4 October (150 d.a.p). On each sampling date, three 0.5 m^2 (0.5 cm × 100 cm) quadrats were established in the middle of each plot to minimize edge effects. The quadrats were positioned in the plot to avoid the re-sampling of previously sampled areas. All weeds present in the quadrat were collected and identified to species. The abundance of each weed species was counted to determine species density. Plant heights of the weeds were measured. Harvested weeds were oven dried at 80 °C for 48 h and weighed to determine the above-ground biomass of each species. Corn grain yield was determined by harvesting the entire plot, drying the corn kernals to 14% moisture, weighing, and extrapolating these data to kg ha^{-1}.

2.3. Statistical methods

Weed species richness, the Shannon-Weiner diversity index (H′) and evenness index (E) were used to characterize species diversity. Weed species richness is the number of different weed species found in each plot (Magurran, 2004). H′ is the diversity represented by the proportional abundance of species. Higher values of H′ signify a greater diversity. E is the relationship between the observed number of species and the total number of species. E values can range 0 and 1.0 where a value of 0 corresponds to a community of only one species whereas a value of 1.0 indicates a community where all species are equally abundant (Tang et al., 2014).

Rank-abundance plots were used to display the ranking distribution of the species relative abundance data. The X axis is species rank; the Y axis is relative abundance by base-10 logarithms. The relative abundance of a weed species population indicates its degree of dominance in the weed community. The greater the relative abundance of a weed population, the higher its dominance. Meanwhile, abundance distribution can comprehensively describe the community diversity and evenness (Tang et al., 2014).

Data were summarized as mean values and standard errors of the mean. Differences in the mean density, height, above-ground biomass and diversity indices of each weed population and community among the treatments were compared using One-way analysis of variance (ANOVA) followed by the Tukey tests for post hoc multiple comparison at a 5% level of significance. Before the ANOVA, all data were transformed by $\log(x + 1)$ to satisfy the assumption of homogeneity of variance and normalize distributions. Other data were not normally distributed even after transformation, and thus analyzed using non-parametric Kruskal–wallis test with Dunn's procedure for multiple comparison. Non-transformed data were presented in the paper. All statistical analyses were performed using SPSS version 21.0.