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Short Communication

Landscape pattern affects species composition and abundance of ground-dwelling predator

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ABSTRACT

Commercial wheat farms were studied in Yinchuan Plain of Northwest China to assess the effects of two agro-farming systems on ground-dwelling predators. Pitfall trap methods were employed to investigate ground-dwelling predators during a four-year study from 2009 to 2012. Results showed that 9 species of ground-dwelling predators (*Calosma maderae*, *Chlaenius pallipes*, *Dolichus halensis*, *Scarites terricola*, *Pterostichus gebleri*, *Harpalus crates*, *Pardosa astrigera*, *Erigonidium graminicolum*, and *Erigone prominens*) dominated in the total 49 species captured. The structurally complex landscape (CL) supported significantly higher species diversity of ground-dwelling predators than that in structurally simple landscape (SL). Furthermore, there were also significant differences in population density and richness of ground-dwelling predators between CL and SL system. Finally, an inventory of ground-dwelling predators associated with different agricultural management systems was developed based on experimental collection, and it will serve as the basis for the sustainable pest management in Northwest China.

Introduction

In the past decades, agricultural intensification has greatly increased to meet the grain demands of an increasingly large human population. The development of high-yield crop varieties combined with the irrigation, insecticides, fossil fertilizers, and land cover conversation has led to a rapid increase in the per unit area yield of grain (Tscharntke et al., 2007; Brewer and Goodell, 2012). At the same time, agricultural intensification has caused loss of biodiversity and biocontrol service. Additionally, landscape simplification was formed due to rapid land cover conversion of semi-natural habitats to cropland (Zhao et al., 2015). Landscape complexity was always indicated by the percent of semi-natural habitats in a particular spatial region. Ground-dwelling predators are an important group of natural enemies in many cropping systems (Brewer and Elliott, 2004), but their distribution and ecological function have not been fully investigated and exploited in biocontrol programs in different farming system (Elliott et al., 1998; Lee et al., 2001).

A growing body of evidence suggested that increasing species diversity of ground-dwelling predators could enhance biocontrol of agricultural pests by natural enemies (Schmidt et al., 2003; Tscharntke et al., 2007). In recent years, some experiments have found that farming system and agricultural management had a significant influence on distribution and species composition of natural enemies, which also affected the biocontrol of pests in the fields (Clough et al., 2005; Schmidt et al., 2008; Zhao et al., 2013). Furthermore, the effects of agricultural intensification and agricultural practices on community structure have received substantial attention of agroecologist, which had become a new paradigm in habitat management (Schmidt et al., 2008). Several researchers reported that the abundance and species diversity of ground-dwelling predators in structurally complex landscape (CL) were higher compared to structurally simple landscape (SL) (Elliott et al., 2006; Werling and Gratton, 2008), but others were unable to detect any significant differences between these two agroecosystems (Anjum-Zubair et al., 2010; Shrestha and Parajulee, 2010). Although the relationship between landscape composition and species composition of natural enemies have not come to a consistent reorganization across multiple agricultural regions or among different agroecosystems, it is well accepted that the diversified landscape and reduced-agrochemical production system could generally enhance the abundance and species diversity of ground-dwelling predators (Tscharntke et al., 2005). Despite an increased interest and significant research on ground-dwelling predator in the past decades (Brewer and Elliott, 2004), there is still a general lack of information on ground-dwelling

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predators from Chinese agroecosystems, especially in wheat fields (Zhao et al., 2012). In this experiment, we examined species composition and diversity of ground-dwelling predator in CL and SL, which were two important landscapes and agricultural patterns in Northwest China. We aimed to determine that which specific management systems could sustain high abundance and species diversity of ground-dwelling predator fauna and supply high biocontrol service.

Material and methods

The experiments were conducted on structurally complex landscape (CL) and structurally simple landscape (SL) in Yinchuan Plain, Ningxia Hui, and Autonomous Region of Northwest China. A four-year (2009–2012) study was conducted to examine the abundance and species composition of ground-dwelling predators across the landscape complexity (CL and SL). In the landscape of study area (Yinchuan plain, 1100–1200 m a.s.l.), wheat crop was the primary grain crop which accounted for 32% of the total crop area. The study region has a temperate continental climate (an average 3000 h p.a. of sunshine and an annual mean temperature of 13.1 °C) and a long history of crop production. The soil type is Chernozem, a typical type in this region. A comprehensive cropping system classification matrix was developed to characterize the range of different agricultural managements in the region. Two different agricultural landscape patterns (CL and SL) were developed in the past decades. The CL and SL systems selected in the experiments have been cultured for average of 4.5 and 12.6 years, respectively. The CL system was located in West Yinchuan Plain (Junmachang County), which had a relatively low yield and high quality, and represented a typical organic agricultural production system. The wheat fields in CL system received less insecticides or herbicides and more organic fertilizer than the SL system. This region was a semi-arid region and the rainfall was very low (about 200 mm per year), which had a high crop species diversity. Semi-natural habitats were important patches, which account >45% of the whole landscape. Additionally, the CL system was characterized by a heterogeneous landscape, which was composed of 64.6% arable land (crop production), 25.8% semi-natural areas (abandoned land and woodland), and 9.6% urban area. The SL system was located in East of Yinchuan Plain (Zhangzhen County), which had a high yield and represented a typical intensive agricultural production system, which had a low percentage of semi-natural habitat (<20%). Furthermore, chemical fertilizers, insecticides, and herbicides were frequently applied in the SL system according the standard cultivation, which was characterized by highly landscape simplification. Wheat crop was planted in early March and was harvested in early July. The SL system was characterized by a wheat-based rotation system including intensive production of wheat, corn, soybean, sunflower, and oilseed, whereas the CL system included wheat and these all crops together with many forage crops (e.g., alfalfa) and fallow. Some woodland and other semi-natural habitats were also distributed widely in the CL system. The distance between CL and SL systems was more than 30 km. However, the agricultural managements were kept the same in these two farming systems except for the chemical applications. All the experiments were conducted in these two farming landscapes. The number of crop species and habitat composition had almost no significant variation between the years.

In each wheat field of two landscape systems, seven uniform wheat fields (100 m × 100 m), at least 500 m apart, were selected for sampling of ground-dwelling predator fauna. In all the experiments, 14 wheat fields (7 CL wheat fields and 7 SL wheat fields) were subjected to arthropod investigation. In order to capture the maximum possible variation within the two agricultural landscape systems, six sampling transects were designed in each wheat field: four 50-m long transects formed a square which was 25 m from the wheat field edge plus two diagonals of the square represented the remaining two transects (Fig. 1). This sampling method was expected to capture the maximum variation

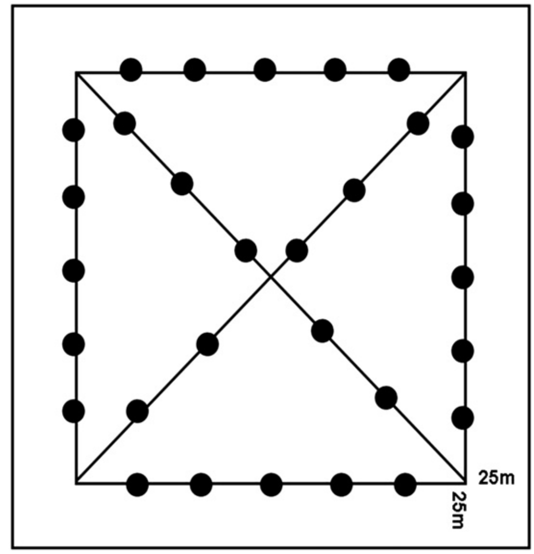

Fig. 1. Sample position and distribution of pitfall traps for ground-dwelling predator collection.

between CL and SL systems and avoid possible spillover effects due to the relatively heterogeneous wheat fields in different locations.

The pitfall trap method was used to collect ground-dwelling predators. Therefore, abundance generated from pitfall trap catches alone does not provide estimates of absolute density, rather activity density, which was a function of a species population size, activity, and ease of capture (Greenslade, 1964). Additionally, pitfall trap could continuously collect individuals over a period of days or weeks, which could also effectively estimate relative abundance of species within a habitat and permit comparison of abundance among years or seasons in that habitat (Greenslade, 1964; Baars, 1979). The trap was a 0.2-L plastic cup with 6.5 cm in diameter and 11 cm in height, filled with 60 mL mixture of vinegar, sugar, propylene glycol and water at a ratio of 2:1:1:20. To break the surface tension of the water, an odorless detergent was added to the mixture. This method has been reported as an appropriate method for sample collection of ground-dwelling predators (Zhao et al., 2013). All individuals were retrieved by emptying each trap into individual collection bottle, 120 h after the trap deployment. Individuals in five traps of each transects per experimental plot were placed in a single bottle, which indicated a sub-sample, with total six sub-samples per wheat field. In summary, total 420 traps were installed in this experiment. Furthermore, the traps were covered with plastic lids to prevent the unexpected capture of arthropods and to keep the debris and rain out of the traps when traps were not in use (Zhao et al., 2013).

The wheat fields were sampled once a month on the third week of April, May, and June of each year. All the collected individuals were preserved in 90% ethyl alcohol, and transported back to the lab for identification and counting. Then, all the individuals were fixed to insect specimens by insect needle. All adult ground-dwelling predators were identified to species level according to the morphologic and taxonomic characteristics following the identification guide of Anjum-Zubair et al. (2010), Pluess et al. (2008), Michels et al. (2010) and Liu et al. (2010).

Ground-dwelling predators per wheat field including 30 traps were summed up in each sampling period. We calculated individuals/trap/120 h as the population density of ground-dwelling predators. The individuals were also summed over the three sampling occasions in each wheat field.

Simpson diversity indices were applied to calculate the species diversity of ground-dwelling predators: $D_s = 1-\sum_{i=1}^{s} P_i^2$. We used general linear models (GLM) with the Restricted Maximum Likelihood method