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Effects of inter-annual landscape change on interactions between cereal aphids and their natural enemies

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Abstract

The agricultural intensification and the subsequent habitat changes in agroecosystem can strongly affect biological control services. We here examine the influence of inter-annual landscape change in wheat field area on interactions of cereal aphids and their natural enemies, as well as the efficacy of biological control using data collected from a 4-year experiment in Northwest China. Two hypotheses were tested. (i) Population densities decline following an inter-annual expansion of wheat crop proportion cover due to dilution and crowding effects. (ii) Species that are specialists or at higher trophic levels are more sensitive to bottom-up disturbance by inter-annual change in percent cover of wheat crop. Results showed the population densities of one cereal aphid (*Macrosiphum avenae*), one parasitic wasp (*Aphidius avenae*), two specialist predators (ladybirds: *Hippodamia variegata* and *H. tredecimpunctata*) and one hyperparasitic wasp (*Pachyneuron aphidis*) declined following the expansion of wheat crop areas, supporting the predictions of inter-annual dilution and crowding effects. In contrast, the populations of one cereal aphid (*Schizaphis graminum*), one parasitic wasp (*A. gifuensis*), two generalist predators (spiders: *Pardosa astrigera*; carabid beetles: *Chlaenius pallipes*), and two hyperparasitic wasps (*Asaphes suspensus*, and *Alloxysta* sp.) did not respond to inter-annual landscape change. The two hypotheses were partially supported but with noticeable exceptions, and the bio-control efficiency declined with the increase of the proportion cover of wheat field in agricultural landscape. Overall, different responses of cereal aphids and their natural enemies make it difficult but still possible to optimize inter-annual landscape change for enhancing the parasitism rate and predator-prey ratio.

Zusammenfassung

Die Intensivierung der Landwirtschaft und die daraus folgenden Änderungen der Habitate in Agrarökosystemen können die biologische Schädlingsbekämpfung stark beeinflussen. Wir untersuchen hier den Einfluss der jährlichen Änderungen des Flächenanteils von Weizenfeldern in der Landschaft auf die Interaktionen zwischen Getreideblattläusen und ihren natürlichen Feinden sowie auf die Effektivität der biologischen Schädlingsbekämpfung. Wir nutzten Daten aus einem vierjährigen Experiment im Nordwesten Chinas. Zwei Hypothesen wurden getestet: (1) Nach einer Ausweitung des Flächenanteils der Weizenfelder gehen die Populationsdichten zurück als Folge von Verdünnungs- und Konzentrationseffekten. (2) Spezialisten und

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Arten höherer Trophiestufen sind empfindlicher gegen die bottom-up-Störung durch die von Jahr zu Jahr wechselnden Flächenanteile der Weizenfelder.

Die Ergebnisse zeigten, dass die Populationsdichten einer Getreideblattlaus (*Macrosiphum avenae*), einer parasitoiden Wespe (*Aphidius avenae*), zweier spezialisierter Räuber (Marienkäfer: *Hippodamia variegata* und *H. tredecimpunctata*) und einer hyperparasitischen Wespe (*Pachyneuron aphidis*) in Folge der Zunahme der Weizenfelder abnahmen, was die Vorhersage von Verdünnungs- und Konzentrationseffekten unterstützt. Dagegen reagierten die Populationen einer Getreideblattlaus (*Schizaphis graminum*), eines Parasitoiden (*A. gifuensis*), zweier generalistischer Räuber (Spinnen: *Pardosa astrigera*; Laufkäfer: *Chlaenius pallipes*), und zweier Hyperparasitoide (*Asaphes suspensus* und *Alloxysta* sp.) nicht auf die alljährlichen Änderungen der Landschaft.

Die beiden Hypothesen wurden zum Teil bestätigt, aber mit auffälligen Ausnahmen, und die Effektivität der biologischen Kontrolle sank mit der Zunahme des Flächenanteils der Weizenfelder. Insgesamt machen es die unterschiedlichen Reaktionen der Getreideblattläuse und ihrer natürlichen Gegenspieler schwierig aber nicht unmöglich, die jährlichen Änderungen der Landschaft so zu optimieren, dass Parasitierungsraten und das Räuber-Beute-Verhältnis gesteigert werden.

Keywords: Crop rotation; Crowding effect; Dilution effect; Parasitism; Predator–prey ratio

Introduction

Landscape-scale agricultural activities can profoundly disturb interspecific relationships and degrade the function and service of many bio-control agents (Thies, Steffan-Dewenter, & Tscharntke 2008; Zaller, Moser, Drapela, & Frank 2009). This is because agricultural landscape change can rapidly relocate resources and affect food distribution and habitat quality for insects. To this end, agricultural landscape change can play particularly important roles in the efficiency and success of pest control (Haenke, Scheid, Scharfer, Tscharntke, & Thies 2009; Tscharntke et al. 2012).

Two effects of landscape change on insect densities have been proposed in the literature (see Appendix A: Fig. A1; Tscharntke et al. 2012). The crowding effect (Grez, Zaviezo, Tischendorf, & Fahrig 2004) predicts that the population density of insects should increase in the remaining habitat patch for a short period once a part of the patch has been removed. In contrast, the dilution effect suggests that the increase of patch size will result in the declines of insect population densities in the newly ameliorated habitat (Grez et al. 2004). Indeed, as Otway, Hector, and Lawton (2005) put it, both the crowding and dilution effects on insect populations are important mechanisms to be considered for improving crop yield.

In Northwest China spring wheat is an important economic crop which has experienced severe outbreaks of cereal aphids since the 1980s. Due to the high number of pests and plant diseases, spring wheat is cultivated at an interval of 1–2 years. The rotation of cultivated wheat has driven rapid compositional changes in the agricultural landscape and results in a mosaic pattern of crop fields (Bianchi, Booij, & Tscharntke 2006), not only affecting the dynamics of cereal aphids and their natural enemies but also the structure and function of regional insect food webs (Gagic et al. 2011).

Two cereal aphid pests are dominant in the region: *Macrosiphum avenae* and *Schizaphis graminum*, sharing the same natural enemies (including parasitoids and predators). Specialized *Aphidius* parasitic wasps are used as bio-control agents to suppress the cereal aphids. However, the existence of a large number of hyperparasitic wasps has discredited the bio-control efficiency of these parasitic wasps. Moreover, both polyphagous generalist predators (e.g. spiders and carabid beetles) and oligophagous specialist predators (*Hippodamia* ladybirds) can also suppress cereal aphid populations by attacking immature and adult aphids (Brewer & Elliott 2004). These predator–prey interactions combined with host–parasitoid interactions will further complicate our understanding of the biological control of cereal aphids (Schmidt, Thies, Nentwig, & Tscharntke 2008; Thies et al. 2011).

A quantitative assessment of the effects of crop patch structure changes on the biotic interactions in the agricultural landscape and the efficacy of the biological control is still lacking and urgently needed (Wäckers, van Rijn, & Heimpel 2008). Here, we report the results from a 4-year experiment that examines the effect of inter-annual change in percent cover of wheat fields on interactions between cereal aphids and their natural enemies. Two hypotheses were specifically tested. First, in a mosaic landscape with rotating wheat crops, the local densities of insects within field patches are expected to decline when the wheat area increases inter-annually (i.e. the dilution effect) and to increase when the wheat area is reduced inter-annually (i.e. the crowding effect) (Grez et al. 2004). Second, species at higher trophic levels or specialists could be more susceptible and sensitive to bottom-up disturbance, whilst species at lower trophic levels or generalists could be more robust against these landscape disturbances. Our research thus highlights the complexity of the bottom-up effect of landscape disturbances on food-web sensitivity and bio-control efficacy.