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Landscape effects of transgenic cotton on non-target ants and beetles

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Abstract

Transgenic crops producing toxins from *Bacillus thuringiensis* (Bt) can be planted in the same field for many years, and many insects exploiting such crops must disperse to other habitats to persist. Accordingly, effects of transgenic crop farming could accumulate through time and affect insect populations across agricultural landscapes. We monitored the population density of seven ant genera and beetle families and of rare ants and beetles in 84 non-cultivated sites abutting agricultural fields in Central Arizona. We assessed the short-term (during planting year) and long-term (over 5–6 years) landscape effect of farming Cry1Ac cotton on ant and beetle density in non-cultivated sites, in addition to several local and regional variables. Landscape variables (e.g., sequence of crops planted in neighbouring fields, crop diversity, and abundance) were more frequently associated with insect density than local variables (e.g., plant productivity and diversity in non-cultivated sites). In the short-term, use of Bt relative to non-Bt cotton in neighbouring fields was positively associated with density of one ant and two beetle groups in non-cultivated sites. However, acreage of Bt cotton located within 1 km from non-cultivated sites had more negative effects than acreage of non-Bt cotton on density of one ant and one beetle group. In the long-term, the proportion of years that Bt cotton was planted in neighbouring fields was positively associated with ant density but not beetle density. Results suggest that the farming of Bt cotton in neighbouring fields frequently resulted in positive short- and long-term landscape effects on ants and beetles in non-cultivated sites, while Bt cotton planted farther away had less frequent negative short-term impacts.

Zusammenfassung

Transgene Kulturpflanzen, die Toxine von *Bacillus thuringiensis* (Bt) produzieren, können über viele Jahre auf denselben Ackerflächen angebaut werden, so dass viele Insekten, die diese Kulturpflanzen nutzen, in andere Habitate ausweichen müssen, um zu überleben. Infolgedessen könnten sich die Auswirkungen des Anbaus von transgenen Kulturpflanzen über die Zeit akkumulieren und Insektenpopulationen in Agrarlandschaften beeinflussen. Wir untersuchten die Populationsdichten von sieben Ameisengattungen und Käferfamilien und von seltenen Ameisen und

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Käfern auf 84 nichtkultivierten Flächen an der Grenze zu landwirtschaftlichen Flächen in Zentralarizona. Wir schätzten die kurzfristigen (während des Pflanzjahres) und die langfristigen (über 5–6 Jahre) Landschaftseffekte des Anbaus von Cry1Ac-Baumwolle auf die Ameisen- und Käferdichte in den nichtkultivierten Flächen sowie einige lokale und regionale Faktoren ab. Die Landschaftsvariablen (d. h. die Reihenfolge der Kulturpflanzen, die auf den benachbarten Flächen angebaut wurden, die Kulturpflanzendichte und -abundanz) waren häufiger mit der Insektendichte assoziiert als lokale Variablen (d. h. Pflanzenproduktivität und -diversität in den nichtkultivierten Flächen). Kurzfristig war die Nutzung von Bt-Baumwolle im Vergleich zur einfachen Baumwolle auf den benachbarten Flächen positiv mit der Dichte einer Ameisen- und zweier Käfergruppen in den nichtkultivierten Flächen assoziiert. Der Flächenanteil der Bt-Baumwolle im Umkreis von 1 km zu den nichtkultivierten Flächen hatte jedoch einen größeren negativen Effekt als der Flächenanteil der normalen Baumwolle auf die Dichte einer Ameisen- und einer Käfergruppe. Langfristig war der Anteil der Jahre, in denen Bt-Baumwolle in den benachbarten Flächen gepflanzt wurde, positiv mit der Ameisendichte aber nicht mit der Käferdichte assoziiert. Die Ergebnisse lassen vermuten, dass der Anbau von Bt-Baumwolle in den benachbarten Flächen regelmäßig zu positiven kurz- und langfristigen Landschaftseffekten auf die Ameisen und Käfer in den nichtkultivierten Flächen führt, während die Bt-Baumwolle, die in größeren Entfernungen gepflanzt wird, weniger regelmäßige, negative und kurzfristige Auswirkungen hat.

Keywords: *Bacillus thuringiensis*; Landscape effects; Herbicide tolerance; Nontarget arthropods; Regional effects; Remote sensing; Risk assessment; Transgenic crops

Introduction

Most transgenic crops engineered to produce toxins from *Bacillus thuringiensis* (Bt) or tolerance to herbicides (Ht) are grown as annual plants in monocultures. Such monocultures represent ephemeral and simplified environments that often do not allow for persistence of insect species (Duelli & Obrist 2003; Tscharntke, Klein, Kruess, Steffan-Dewenter, & Thies 2005; Tscharntke, Rand, & Bianchi 2005). Because many insects exploiting transgenic crops must disperse to other agricultural fields or non-cultivated habitats to persist within and between cropping seasons, fields of transgenic crops may affect insect populations locally as well as across agricultural landscapes. Yet, most studies assessing impacts of transgenic crops on insect biodiversity have focused on in-field effects (Marvier, McCreedy, Regetz, & Kareiva 2007).

Non-cultivated habitats embedded in agro-ecosystems can be important sources of biodiversity for agricultural fields (Duelli & Obrist 2003; Tscharntke, Klein et al. 2005). Nevertheless, highly productive agricultural fields may also represent significant sources of arthropods for less productive non-cultivated areas. Accordingly, agricultural fields may alter biodiversity of non-cultivated habitats through spillover effects, defined as movement of agriculturally subsidised insects to non-cultivated habitats (Rand, Tylianakis, & Tscharntke 2006; Tscharntke, Klein et al. 2005; Tscharntke, Rand et al. 2005). While theory suggests that spillover effects often have negative impacts on biodiversity, empirical investigations are needed to understand how they affect non-cultivated habitats (Hunter 2002; Tscharntke, Klein et al. 2005).

Here, we compared landscape effects of transgenic and non-transgenic cotton on insect density in non-cultivated habitats embedded in a patchwork of agricultural fields in the Sonoran Desert of Central Arizona. We focused on ground-dwelling ants and beetles, because their life history provides a useful contrast to understand landscape effects, they are major contributors to biodiversity, and play important roles in structuring communities (Duelli & Obrist 2003; Roth & Perfecto 1994). Single-season spillover effects were evaluated by comparing population density of ants and beetles in non-cultivated sites contiguous to non-Bt, Bt, or BtHt cotton fields. Impacts of transgenic and non-transgenic cotton located in more distant parts of the landscape were also investigated. Cumulative spillover effects were investigated by assessing ant and beetle density in non-cultivated sites adjacent to cotton fields, where Bt cotton had been used at different frequencies over several years.

Materials and methods

Study area and sampling

Non-cultivated sites directly adjacent to cotton fields were arbitrarily selected within a region of ca. 6600 km^2 in Central Arizona. The region was delimited by frames of Landsat Enhanced Thematic Mapper Plus (ETM+) satellite images overlaid on Geographical Information System (GIS) maps with the position and identification (non-Bt or Bt cotton) of all cotton fields grown in the region (Cattaneo et al. 2006). GIS and remotely sensed