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Maize pollen foraging by honey bees in relation to crop area and landscape context

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Abstract

The increasing demand for insect pollinated crops and high recent losses of honey bee colonies raise concerns about food security. Systemic insecticides are recognized as one of the drivers of worldwide honey and wild bee declines. Particularly honey bees in agricultural environments are exposed to pesticides when they collect crop pollen and nectar. However, landscape scale studies which analyze pollen use and foraging distances of honey bees on mass-flowering crops like maize to evaluate potential exposure risks are currently lacking. In an experimental approach on a landscape scale we took advantage of intra-colonial dance communication to gather information about the location of utilized pollen resources. During maize flowering, four observation hives were placed in and rotated between 11 different landscapes which covered a gradient from low to high maize acreage. A higher frequency of dances for foraging locations on maize fields compared to other land use types shows that maize is an intensively used pollen resource for honey bee colonies. Mean foraging distances were significantly shorter for maize pollen than for other pollen origins. The percentage of maize pollen foragers did not increase with maize acreage in the landscape. The proportion of grassland area providing alternative pollen sources did not reduce the percentage of maize pollen foragers. Our findings allow estimating the distance-related exposure risk of honey bee colonies to pollen from surrounding maize fields treated with systemic insecticides. Similarly, the results can be used to estimate the exposure to transgenic maize pollen, which is relevant for honey production in European countries. Provision of alternative pollen resources within agri-environmental schemes could potentially reduce exposure risk to pesticide contaminated crop pollen.

Zusammenfassung

Der zunehmende Bedarf an insektenbestäubten Kulturen und die hohen Verluste von Honigbienenvölkern gefährden potentiell die Sicherung der Nahrungsmittelversorgung. Systemische Insektizide gelten als eine der Ursachen des weltweiten Rückgangs von Honig- und Wildbienen. Besonders Honigbienen in landwirtschaftlicher Umgebung sind durch das Sammeln von Nektar und Pollen Pestiziden ausgesetzt. Es fehlen jedoch Landschaftsstudien, die Pollennutzung und Sammeldistanzen von Honigbienen auf Massentrachten wie Mais untersuchen, um potentielle Expositionsrisiken einzuschätzen. In einem experimentellen Ansatz auf Landschaftsebene nutzten wir die Tanzsprache der Bienen, um Informationen über die Lage genutzter Pollenressourcen zu erlangen. Während der Maisblüte wurden vier Beobachtungsstöcke in 11 Landschaften, die einen Maisflächengradienten abdeckten, platziert und zwischen diesen rotiert. Die höhere Tanzfrequenz für Maisflächen im Vergleich zu anderen Landnutzungstypen zeigt, dass Mais eine intensiv genutzte Pollenquelle ist. Die mittleren Sammeldistanzen für Maispollen waren kürzer als für anderen Pollen. Der Anteil an Maispollensammlerinnen war nicht mit der Maisfläche in der Landschaft korreliert.

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Der Anteil an Grünland als alternative Pollenquelle reduzierte nicht den Anteil an Maispollensammlerinnen. Unsere Ergebnisse erlauben eine Abschätzung des distanzbezogenen Expositionsrisikos von Honigbienenvölkern gegenüber Pollen von insektizidbehandelten Maisfeldern in ihrer Umgebung. Sie können ebenso genutzt werden, um die Exposition gegenüber transgenem Maispollen abzuschätzen, was für die Honigproduktion in Europa relevant ist. Die Bereitstellung alternativer Pollenressourcen im Rahmen von Agrarumweltmaßnahmen könnte das Expositionsrisiko vermindern.

Keywords: *Apis mellifera*; *Zea mays*; Resource use; Foraging distances; Bee decline; Exposure risk

Introduction

The honey bee (*Apis mellifera* L.) is a globally distributed pollinator and plays an important role in maintaining the ecosystem service of pollination in agricultural landscapes (Klein et al., 2007; Potts et al., 2010). Pollination and the survival of pollinators are at risk since bees face a number of potential threats from agricultural intensification, such as exposure to pesticides (Henry et al., 2012; Pettis et al., 2013; Stokstad, 2013), pesticide/bee-pathogen interactions (Blacquiére, Smagghe, Gestel, & Mommaerts, 2012; Pettis et al., 2013), lower immunocompetence due to monofloral pollen diets (Alaux, Ducloz, Crauser, & Le Conte, 2010) or temporal gaps in pollen availability due to monocultures, habitat loss and fragmentation (Potts et al. 2010). On the other hand, the proportion of agricultural production that depends on pollinators shows a strong increase in the last two decades (Aizen, Garibaldi, Cunningham, & Klein, 2009).

The few studies that have used the spatial information provided by bee dances to analyze the foraging ecology of this major pollinator indicate that landscape structure, resource availability and season impact foraging distances (Steffan-Dewenter & Kuhn, 2003). However, the way how crops and landscape composition shape the spatial distribution of used floral resources is still unknown, despite its general relevance for maintaining pollination services and protecting honey bees from potentially negative impacts of intensive agriculture, including pesticide applications and their interaction with pathogens (Härtel & Steffan-Dewenter, 2014).

In central Europe the demand for biofuels as renewable energy is resulting in a constantly increasing proportion of maize acreage (Meissle, Mouron, Musa, Bigler, & Pons, 2009). On a global scale, maize cultivation is increasingly dominated by genetically modified (GM) varieties and characterized by intensive pesticide application including systemic neonicotinoids. Being a wind-pollinated mass flowering crop, maize provides huge amounts of pollen within a flowering period of 2–5 weeks on a landscape scale. It was reported to be a pollen source for honey bees (Keller, Fluri, & Imdorf, 2005; Odoux et al., 2012) despite its visually unattractive flowers compared to most insect pollinated plants.

Feeding on pollen and nectar exposes larvae and adult bees directly to the environment (Babendreier, Kalberer, Romeis, Fluri, & Bigler, 2004; Hendriksma et al., 2013; Krupke, Hunt, Eitzer, Andino, & Given, 2012). Mass-flowering crops are a potential exposure pathway to chemicals applied in agriculture. Particularly neonicotinoid pesticides which are used for crop seed dressing and distribute within the plant can be detected in maize pollen (Bonmatin et al., 2003). Neonicotinoids are highly toxic for honey bees (Krupke et al., 2012) and synergistic interactions with spreading honey bee diseases are reported (Blacquiére et al., 2012). In agricultural landscapes the exposure to neonicotinoids is thought to contribute to the observed declines of honey bee colonies (vanEngelsdorp, Hayes, Underwood, & Pettis, 2008). In Europe seed coating with three commonly used neonicotinoids was banned in 2013 for two years, but in many other countries of the world the application is still agricultural practice.

The potential harm of honey bees through crop pollen contaminated with pesticides is proven while for GM pollen no detrimental effects have been found (Duan, Marvier, Huesing, Dively, & Huang, 2008; Malone & Burgess, 2009). However, there is another reason why the exposure to GM pollen is a relevant issue at least within Europe. Pollen is an inherent compound of honey and bee keepers are highly interested to produce GM pollen free products. In view of the observed detrimental effects of neonicotinoids on pollinators (Henry et al., 2012) and the expansion of GM crops, it is astonishing that the resource use of crop pollen including maize has never systematically been analyzed to estimate exposure risks in agricultural environments.

In this study we address pollen foraging of honey bee colonies in selected landscapes that cover a gradient from low to high percentage of maize acreage. In order to investigate the importance of maize as a pollen source on a landscape scale with its implications on bee health we test the following hypotheses:

(1) Maize is a frequently used pollen resource for honey bee colonies.
(2) Foraging distances differ between maize pollen and other pollen species.
(3) The proportion of maize pollen foragers increases with the amount of maize acreage in the landscape.
(4) In landscape with alternative pollen sources the proportion of maize pollen foragers is reduced.