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The potential impacts of insecticides on the life-history traits of bees and the consequences for pollination

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Abstract

Maintaining the relationships between plants and pollinators is vital to ecosystem stability. Insecticides may disturb these interactions with poorly understood consequences for pollination. Community level research is essential, if we are to understand the wider effects of insecticides on a variety of pollinating taxa and the impacts on the plants they pollinate. In this article we discuss the potential effects of both the lethal and sub-lethal impacts of insecticide use in agro-ecosystems on pollination services by bees. In particular, we consider how particular life-history traits of pollinators, such as sociality and floral specialisation may be differentially affected by insecticides. We discuss how this might translate through to pollination services. We propose that a trait-based approach can give insight into the potential impacts of insecticides on plant–pollinator communities.

Zusammenfassung

Die Beziehung zwischen Pflanzen und Bestäubern aufrechtzuerhalten ist lebensnotwendig für die Stabilität von Ökosystemen. Insektizide können jedoch Auswirkungen auf diese Interaktion haben, mit bis heute noch unbekannt Auswirkungen auf die Bestäubung. Untersuchungen auf der Ebene von Lebensgemeinschaften sind notwendig, wenn wir die Effekte von Insektiziden auf unterschiedliche Bestäubungsarten und deren Einflüsse auf die zu bestäubenden Pflanzen verstehen wollen. In dieser Studie diskutieren wir die möglichen Effekte von lethalen und sublethalen Auswirkungen des Insektizideinsatzes in Agrarökosystemen auf die Bestäubungleistungen durch Bienen. Insbesondere betrachten wir, wie sich Insektizide auf die Eigenschaften einer Biene im Laufe ihres Lebens auswirken können, wie z.B. auf ihr soziales Gefüge und ihre Spezialisierung auf bestimmte Pflanzen beim Blütenbesuch.

Wir diskutieren, wie sich diese Veränderungen auf die Bestäubungsleistung auswirken könnten und damit auch auf die Pflanzenlebensgemeinschaften. Wir nehmen an, dass ein Forschungsansatz, der die einzelen Merkmale von Bienen berücksichtigt, uns gute Einblicke bietet, welchen Einfluss Insektizide auf die Pflanzen-Bestäuber-Lebensgemeinschaften haben.

Keywords: Biodiversity; Disturbance; Ecosystem service; Environmental chemicals; Pesticide pressure; Pollinator

Introduction

The production of food in agro-ecosystems often involves the application of insecticides which may harm the many insect species providing pollination services to agriculture. Trends in the global area of land devoted to agriculture

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in recent decades show an increase, not only in the area of land devoted to agriculture, but also in the relative importance of pollinator dependent crops in both the developed and developing world (16.7% and 9.4% increase in the developed and developing world, respectively, in cropped land devoted to pollinator dependent crops from 1961 to 2006) (Aizen, Garibaldi, Cunningham, & Klein 2008; see also Aizen & Harder 2009). It is important to understand the threat insecticides pose to pollination given our increasing requirements for this ecosystem service in agro-ecosystems and its importance for the reproduction of wild plants (Tepedino 1979) as well as for crop plants.

Global pesticide production has increased for several decades and is predicted to more than double by 2050 to around 10 million metric tonnes (Tilman et al. 2001; Wagner, Rauf, & Schwarze 2010). Agro-chemical use along with land use practices have been highlighted as key pressures on pollinators (Kuldna, Peterson, Poltimäe, & Luig 2009). Insecticides are the group of pesticides that pose the most direct risk to pollinators and negative impacts of insecticides have been demonstrated for the honeybee *A. mellifera* (Greig-Smith et al. 1994; Shires, Murray, Debray, & Le Blanc 2006; Desneux, Decourtye, & Delpuech 2007) and several non-*Apis* bees (Tasei 2002; Gels, Held, & Potter 2002). Pollinators can be exposed to insecticides during their application, by contact with residues, or from the ingestion of pollen, nectar or guttation fluid (appearance of drops of xylem sap on the tips or edges of leaves) containing insecticide. The increasing use of neonicotinoids means there is a greater potential for pollinators to be exposed over longer periods as systemic insecticides can be found in the pollen and nectar of plants throughout their blooming period (Ellis 2010). Exposure to insecticides may have lethal (e.g. Kevan 1975; Greig-Smith et al. 1994) or sub-lethal behavioural or physiological effects (e.g. Morandin, Winston, Franklin, & Abbott 2005; Desneux et al. 2007).

There is a growing body of evidence describing the impacts of insecticides on pollinators (for a review see Tasei 2002; Desneux et al. 2007) and so here we do not aim to give an in depth review of this literature. Rather we consider how the life-history traits of bees and pollination services may be affected. Most investigations of the impact of insecticides on pollinators are conducted on *Apis mellifera* L., but bees are not uniformly sensitive across species (Torchio 1973; Thompson & Hunt 1999). Differences in the relative toxicities of insecticides (measured by LD50, lethal dose causing 50% mortality) between (Scott-Dupree, Conroy, & Harris 2009) and even within species (Danka, Rinderer, Hellmich, & Collins 1986) are not consistent. Here we take a new approach, considering how life-history traits of bees (such as body size, sociality, flight season, voltinism, floral specialisation, and nesting behaviour) can be linked to their sensitivity to insecticides, and how this may translate through to changes in the community structure of bees and the flowers they pollinate.

Insecticides and pollination

Lethal effects on bees

One of the best documented examples of an insecticide application affecting pollination is the reductions in the blueberry crop in New Brunswick, Canada which were linked with a decline in pollinator populations and diversity due to the application of the insecticide fenitrothion to nearby forests (Kevan 1975, 1999). An increase in mortality due to the impact of insecticides may reduce visitation frequency by bees to flowering plants and the number of flower-visiting bees has been shown to be positively associated with plant seed set (Steffan-Dewenter & Tscharntke 1999). A reduction in the diversity of visitors may in some cases such as strawberries, reduce the quality of a crop (Chagnon, Gingras, & de Oliveira 1993). The flowering plant species that are likely to be most at risk from negative impacts of insecticides on pollinators are those that are specialist on specific pollinating taxa to set fruits, such as passion fruit that is dependent on carpenter bees or vanilla on specific Euglossinae bees (Klein et al. 2007) or many orchids (Pemberton 2010).

Sub-lethal effects on bees

Concerns over sub-lethal effects of insecticides have been highlighted, due to their potential contributory role in recent losses of honey bee colonies (Frazier, Mullin, Frazier, & Ashcraft 2008). Insecticides can have a range of sub-lethal effects on bees (see Desneux et al. 2007 for a review). Some of these impacts are likely to affect their efficiency as pollinators but these impacts are difficult to quantify under field conditions. Bees need to orient for foraging trips and in the case of honey bees, to be able to communicate the location of food sources to other colony members. Reduction in the orientation abilities of *A. mellifera* have been observed after exposure to insecticides (Vandame, Meled, Colin, & Belzunces 1995; Desneux et al. 2007). Yang, Chuang, Chen and Chang (2008) found that *A. mellifera* fed imidacloprid, a neonicotinoid, showed abnormal foraging behaviour with delays in foraging trips, and Ramirez-Romero, Chaufaux, and Pham Delègue (2005) found reductions in foraging of ca. 20–60% with exposure to insecticides (imidacloprid and deltamethrin (a pyrethroid)). Ramirez-Romero, Desneux, Decourtye, Chaffiol, and Pham-Delègue (2008) also found negative effects of imidacloprid on feeding behaviour and olfactory learning in *A. mellifera*. Sub-lethal doses of imidacloprid and fipronil (a phenyl pyrazole) reduced *A. mellifera* activity and feeding respectively (Colin et al. 2004). Learning performance was reduced in *A. mellifera* after chronic exposure to imidacloprid with the time of year affecting the sensitivity of the bees (Decourtye, Lacassie, & Pham-Delègue 2003). In addition, a reduction in the life expectancy of exposed pollinators (Mackenzie & Winston 1989) may