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Exposure of native bees foraging in an agricultural landscape to current-use pesticides

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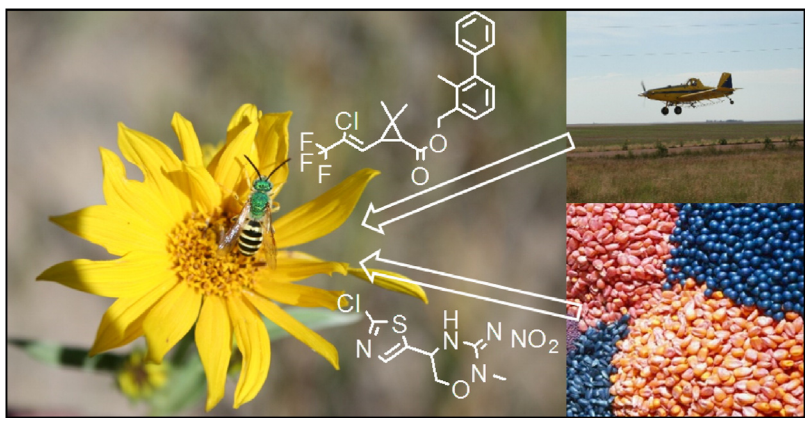
HIGHLIGHTS

- 19 current-use pesticides and degradates were detected in native bees.
- Neonicotinoid insecticides were some of the most frequently detected pesticides.
- Detected other insecticides (pyrethroid, organophosphate), fungicides and herbicides
- Surrounding land cover influences pesticide detections.

GRAPHICAL ABSTRACT



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ABSTRACT

The awareness of insects as pollinators and indicators of environmental quality has grown in recent years, partially in response to declines in honey bee (*Apis mellifera*) populations. While most pesticide research has focused on honey bees, there has been less work on native bee populations. To determine the exposure of native bees to pesticides, bees were collected from an existing research area in northeastern Colorado in both grasslands (2013–2014) and wheat fields (2014). Traps were deployed bi-monthly during the summer at each land cover type and all bees, regardless of species, were composited as whole samples and analyzed for 136 current-use pesticides and degradates. This reconnaissance approach provides a sampling of all species and represents overall pesticide exposure (internal and external). Nineteen pesticides and degradates were detected in 54 composite samples collected. Compounds detected in >2% of the samples included: insecticides thiamethoxam (46%), bifenthrin (28%), clothianidin (24%), chlorpyrifos (17%), imidacloprid (13%), fipronil desulfinyl (7%; degradate); fungicides azoxystrobin (17%), pyraclostrobin (11%), fluxapyroxad (9%), and propiconazole (9%); herbicides atrazine (19%) and metolachlor (9%). Concentrations ranged from 1 to 310 ng/g for individual pesticides. Pesticides were detected in samples collected from both grasslands and wheat fields; the location of the sample and the surrounding land cover at the 1000 m radius influenced the pesticides detected but because of a small number of temporally comparable samples, correlations between pesticide concentration and land cover were not significant. The results show native bees collected in an agricultural landscape are exposed to multiple pesticides, these results can direct future research on routes/timing of pesticide exposure and the design of future conservation efforts for pollinators.

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1. Introduction

Pollinator services provided by commercial honey bees (*Apis mellifera*) and native bees are essential for modern agricultural practices. Today approximately 75% of crop species worldwide benefit from insect pollination (Klein et al., 2013) but farmers typically rely on the honey bee to provide these services worth approximately $200 billion to food production (Gallai et al., 2009; USDA, 2015a). However, due to loss in abundance and diversity of habitat (i.e., flowering plants) and exposure to pesticides and parasites (e.g., varroa mites [*Varroa destructor*] in honey bees), bee populations are on the decline (Goulson et al., 2015). Native bees have the potential to provide pollination services as a number of biotic and abiotic factors have decreased healthy honey bee colonies worldwide (Dainat et al., 2012). However, to provide these services, an abundance of florally diverse areas within flight distance is necessary for sources of pollination and nectar (Garibaldi et al., 2011; Kremen et al., 2002). How the contribution of native bees to pollination is influenced by land management practices is not well understood and continued modification of the landscape (agricultural and natural) can have negative effects on the benefits provided by these species.

Native pollinators foraging in grasslands and crop fields provide ecosystem services at a local scale, but it is unclear how the widespread use of pesticides may affect native bees as they move across the broader agricultural landscape. Studies have shown impacts to honey bees from exposure to pesticides, including neonicotinoid insecticides and certain classes of fungicides, but the effects of these compounds on native pollinators at the field scale are largely unknown. Neonicotinoids are the most widely used class of insecticides worldwide (Jeschke et al., 2011), and their use is increasing as seed treatments become more prevalent (Douglas and Tooker, 2015). Environmentally relevant concentrations of neonicotinoids have been reported to cause a variety of effects to native bees including reduction in population densities and reproduction, impairment of foraging success and development, and increased susceptibility to disease and parasites (Lundin et al., 2015; Rundlof et al., 2015; Sandrock et al., 2013; van der Sluijis et al., 2013). The agricultural use of fungicides has increased dramatically over the past decade to control fungal outbreaks (USGS, 2015). Fungicide use both as seed treatment and foliar application throughout the growing season increase the chance of potential exposure to pollinators. Although fungicides are not considered acutely toxic to honey bees, a recent study observed an increased probability of parasitic fungal infection in bees that consumed pollen with high fungicide loads (Pettis et al., 2013). Fungicide exposure, could in turn, reduce the biodiversity and richness of native pollinators and the ecosystem services they provide.

Larger assemblages of grasslands within agriculturally dominated landscapes contribute permeability through the surrounding matrix (Cane, 2001), providing refuge for native pollinators (Park et al., 2015) and acting as a source of healthy bee populations. The Food, Conservation and Energy Act of 2008 introduced language recognizing the importance of pollinators and allowed for measures to address targeting the conservation of pollinator habitat. US Geological Survey scientists have been monitoring native pollinator habitat, diversity, and richness in the Conservation Reserve Program (CRP) fields in eastern Colorado to evaluate the extent to which CRP grasslands provide floral food sources for native pollinators in large-scale agroecosystems (NPWRC, 2015). Management strategies to benefit pollinators include planting strips or fields with pollinator-friendly plants or hedgerows in and around crop fields to improve floral diversity and nutritional options for pollinators (Hannon and Sisk, 2009). These efforts, as well as grassed corners of center pivot irrigation fields, roadsides, and fallow fields may also provide refuge and ideal nesting substrate for native bees. In agricultural landscapes dominated by row crops not meeting the nutritional demands of bees as well as monoculture grasslands lacking floral diversity, there may be a cost-distance tradeoff for the bees where they incur greater chemical exposure as they seek floral resources outside their habitat. Ongoing research has focused on the value grasslands provide for native bees, but little has been done on broader landscape comparisons involving intensively farmed landscapes interspersed with grasslands. Native bees are limited in maximum foraging distance (typically <1000 m) (Gathmann and Tscharntke, 2002; Zurbuchen et al., 2010) and frequently have spatially separated nesting and foraging habitats. Access to suitable nesting and habitat resources necessitates flight between the two, often across a fragmented landscape (Cane, 2001) that includes grassland and cropland.

The objective of this study was to understand which current-use pesticides native bees are exposed to within their foraging range in an agriculturally dominated landscape in northeastern Colorado, USA. It is hypothesized that native bees collected from areas with a greater percentage of surrounding cropland will be exposed to more pesticides than those residing in areas with a higher percentage of grassland. Determining the exposure of native bees to pesticides is the first step in understanding the benefits of conservation efforts on the landscape to increase pollinator habitat in areas of intense crop production and how these efforts may or may not influence pesticide exposure.

2. Experimental

2.1. Site information and field collection

Native bees were collected from fields in Logan County in northeastern Colorado, USA (Fig. 1). The exact locations of the grasslands and wheat fields are proprietary and written permission was obtained from the landowners prior to the start of sampling. Fields were located in the transitional zone between the western Great Plains and the central high tableland regions. Precipitation occurs as high-intensity rainfall from spring through early autumn (average 455 mm) but fluctuates widely across the region. Between 93% and 97% of the land in this region is privately owned cropland and grassland. Dryland winter wheat is the primary crop and typically grown in a wheat-fallow rotation. Native bees were collected in four grassland sites in 2013 and 2014 (sites Grasses 1–4). In 2014, native bees were also collected from an additional six sites located in wheat fields (sites Wheat 0–5). Springstar™ blue vane bee traps were deployed bi-monthly from May to September in all fields from each land cover type. Traps were set at a fixed location at each site from morning until early afternoon (0800–1300) and were collected the following day (0800–1300), for a total of 24 h per trap. Each vane trap was attached to a conduit pipe and moved to the appropriate height level of the nearest vegetation (Stephen and Rao, 2005). Trapped bees were collected in individual labeled bags and put on ice for transport back from the field. In the lab, bees were separated and grouped by body size. Native bee abundance had an average (± standard deviation) of 22 ± 3 genera per field and were similar between 2013 and 2014 (22 ± 2 and 22 ± 4, respectively) while wheat fields had an average of 18 ± 2 genera per field. About half of the traps deployed (48%) had enough bees collected during each trapping for pesticide analysis (see Table SI-3). Bees were stored frozen at −20 °C and held for no longer than 9 months prior to extraction. Field locations were mapped in geographic information systems (GIS) using the USDA CropScape-Cropland Data Layer (USDA, 2015b), the buffer radius for each sampling location was set based on known foraging distances of captured native bees (<200 m, <500 m, <1000 m); the 1000 m radius was selected for final interpretation of the data.

2.2. Sample extraction

For each individual sample (total of 54 samples) approximately 10 bees were composited (actual numbers per composite ranged from 4 to 15 in 2013 and 6 to 10 in 2014). Species of bees were not identified for this portion of the study and all bees were composited as whole samples to include residues on external as well as internal parts of the bees