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Effects of land-use change and fungicide application on soil respiration in playa wetlands and adjacent uplands of the U.S. High Plains

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HIGHLIGHTS

- Examined effects of fungicides Headline® and Quilt® on soil respiration in playas/watersheds
- Also measured ergosterol levels in cropland and native grassland playas/watersheds
- Grassland playas/watersheds had higher soil respiration rates than those in cropland.
- Fungicides had no effect on soil respiration at any concentration in either land use type or playa/watershed.
- Grassland playas/watersheds had 3 and 1.6 times higher ergosterol content than those in cropland.

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ABSTRACT

With the increased use of fungicides in cultivated regions such as the southern High Plains (SHP), U.S., unintentional runoff and drift as well as direct overspray during aerial application lead to environmental exposures that may influence soil microbial communities and related biogeochemical functioning. Our goal was to examine the effects of two popular fungicides Headline® (pyraclostrobin) and Quilt® (azoxystrobin/propiconazole) on respiration from soil microbial communities in playa wetlands embedded in cropland and native grassland and their adjacent watersheds. We monitored fungicide effects (at levels of 0, .1×, 1× and 10× the label rate) by measuring respiration from plant matter amended soils collected from 6 cropland and 6 grassland playas and uplands. In addition, differences in microbial community structure among land use types were determined by measuring ergosterol levels in cropland and native grassland playas and uplands. Native grassland playas and their associated watersheds had up to 43% higher soil respiration rates than cropland playas and watersheds, indicating higher soil microbial activity. Application of either fungicide had no effect on soil respiration at any concentration in either land use type or habitat type (playa/watershed). Native grassland playas and watersheds had 3 and 1.6 times higher ergosterol content than cropland playas and watersheds. The lack of soil respiration response to fungicide application does not necessarily suggest that fungicides used in this study do not affect non-target soil microbial communities due to potential compensation by other biota. Future studies should further elucidate existing microorganism communities in playas and their watersheds.

1. Introduction

The bulk of terrestrial carbon (C) is stored in soils, making them important components to the global climate system (Swift, 2001). The amount of C that is stored in soil or released into the atmosphere is the balance between organic matter production, primarily photosynthetic life, and microbial decomposition (Singh and Gupta, 1977). Because heterotrophic respiration from microbial activity has an integral role in C emissions from natural ecosystems (Raich and Schlesinger 1992), it is becoming increasingly important to identify potential disruptors to soil microbial communities.

In recent years, pesticide expenditures in the U.S. reached nearly $12 billion annually (Fernandez-Cornejo et al. 2014). Although effects of pesticides on soil microbes are considered a part of the guidelines for pesticide approval, knowledge is limited on their influence to microbial community structure and soil respiration (Lo, 2010). Multiple studies have demonstrated responses of microbial communities to pesticide exposure (Gonzalez-Lopez et al. 1993; Patnaik et al. 1995; Min et al. 2001). Changes in soil respiration rates upon pesticide application can suggest a decrease or stimulation of microbial biomass as well as microbial diversity shifts, depending upon the properties of the pesticide and biochemical behaviors of affected microbes (Hussain et al., 2009). The variability of pesticide

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influence to the soil environment can have important implications at the landscape level, where land conversion influences regional soil microbial dynamics and diversity (Buckley and Schmidt, 2003).

Pesticides are most commonly applied in heavily cultivated regions where soil microbial communities are already impacted by mechanical disturbance and nutrient additions, often resulting in higher bacteria and lower fungal abundance (Six et al., 2006). Because the High Plains region of the U.S. is one of the most heavily cultivated landscapes in the world (Bolen et al., 1989), it is likely that changes in basic soil processes have altered some of the regions ecosystem functions including nutrient cycling and decomposition that regulate services such as C sequestration. Playa wetlands are the predominant water feature of the High Plains and their ecosystem service delivery capabilities have been greatly diminished due to land use change (Smith et al., 2011). Playas are isolated, depressional wetlands and pesticides can accumulate in their basins via spray drift from aerial applications, agricultural runoff, or direct overspray (Haukos and Smith, 2003; Belden et al., 2010). Pesticides have the potential to accumulate in playa surface water and influence water quality but little is known about the potential compounding impacts of land conversion and pesticide exposure to the microbial communities driving playa functions and services.

The use of fungicides has increased substantially in the United States (Russell, 2005; Fernandez-Cornejo et al. 2014). Fungicide application on 81 million hectares of corn, soybean and wheat in the United States has increased from 2% in 2004 (National Agricultural Statistics Service; http://www.pestmanagement.info/nass/app_usage.cfm) to 25–30% in 2009 (letter from universities regarding the strobilurin, pyraclostrobin, supplemental label, 2009, http://www.epa.gov/pesticides/regulating/headline-letter.pdf). Strobilurins bind to the Qo site on cytochrome b and effectively inhibit mitochondrial respiration (Russell, 2005). In addition, fungicides containing strobilurins are often labeled to increase plant yield and health (BASF Headline® label, Syngenta Quilt® label), increasing chances of spraying at times other than when necessary to combat fungal disease.

Because of their role in ecosystem functioning, soil fungal diversity and abundance may influence provisioning of multiple ecosystem services. For example, plant community composition and primary productivity can be influenced by soil fungal populations (van der Heijden et al., 1998), which can impact biodiversity maintenance and C sequestration services. Fungi also have a high C assimilation efficiency (Sylvia et al., 2005) and aid in forming stable C aggregates with longer mean residence time (MRT) in the soil (Six et al., 2002), making them beneficial to climate mitigation. However, in some soils, fugal communities are the dominant contributor to C effluxes through soil respiration (Anderson and Domsch, 1973), thus their prevalence across landscape types is important to understanding potential fungicide effects on soil respiration.

Our objective was to examine the effects of two popular fungicides Headline® (pyraclostrobin) and Quilt® (azoxystrobin/propiconazole) on respiration from soil microbial communities in playa wetlands and their adjacent watersheds embedded in active cropland land use compared to playas/watersheds in unaltered, reference condition native grasslands. In addition, differences in microbial community structure among land use types were measured using ergosterol levels in cropland and native grassland playas and uplands.

2. Materials and methods

2.1. Materials

Solvents were pesticide-analysis grade or better (Burdick and Jackson Brand, Honeywell, Morristown, New Jersey). Other reagents including extraction supplies were obtained from Sigma-Aldrich (St. Louis, MO). Analytical standards for ergosterol and the fungicide active ingredients were obtained from Alfa Aesar (>96% purity; Ward Hill, MA). Quilt® fungicide (EPA Reg. No. 100-1178, Syngenta Crop Protection) and Headline® fungicide (EPA Reg. No. 7969-186, BASF) were purchased through a local distributor.

2.2. Soil sampling

Soil samples were collected from 7 counties (Briscoe, Castro, Crosby, Floyd, Gray, Lubbock, and Swisher) in the High Plains of Texas in June 2011 (Fig. 1). This area is highly cultivated (Bolen et al., 1989), particularly for cotton, wheat and corn (Haukos and Smith, 1994). The dominant upland soils in the region are fine sandy loams or clay loams in the Amarillo or Pullman series, respectively (Luo et al., 1999). Randall clays are most common in playa wetland basins and although they have higher clay content than their adjacent upland soils, the clay mineralogy of playas and their watersheds are similar (Allen et al., 1972). Due to rapidly fluctuating wet/dry cycles and frequently aerobic soil conditions, organic carbon content in playas in the southern High Plains is typically less than 2% (Luo, 1994; O'Connell, 2011).

Twelve playas and adjacent upland watershed sites were selected throughout the SHP; six were in cropland and six were in native prairie landscapes that had never been cultivated. Soils were collected using a 2.54 cm × 60 cm soil probe up to a depth of 15 cm. Nine samples were collected within the playa basin (one at the center and eight equidistant points surrounding the center) and nine samples around the perimeter of the playa basin in the adjacent watershed. The nine samples collected from each habitat (playa/upland) were composited together to have a single representative playa sample and upland sample for each collection site. All sampling locations were dry at the time of collection and samples were sieved through a 2 mm mesh to remove large particles upon arrival at the lab. Soil was kept in the dark at 4 °C until commencement of biomass and respiration analyses (approximately 1–3 weeks; Blume et al., 2002). Previous research has demonstrated that within one month of cold storage biomass changes less than 25% on average and substrate induced respiration does not change as compared to freshly tested soil (Stenberg et al., 1998).

2.3. Soil amendment

Soil amendments were done on both wetland and upland soil samples. Just prior to the beginning of each test, soils were amended with finely ground plant matter that had been heat sterilized at 180 °F for 9 h. Wetland soils were dried and amended with matter Pennsylvania smartweed (*Polygonum pensylvanicum*; 125 mg/g), collected on site to provide a substrate for microbial populations and increase measureable response. *P. pensylvanicum* is a facultative wetland plant species that is widely distributed throughout the Great Plains (Anderson and Smith, 2002). Because direct cultivation changes the vegetation providing inputs for upland soil fungi, two upland experiments were conducted on upland soil samples. The first study used vegetation from croplands and grasslands in their respective soil sites; the second study used the same vegetation for both croplands and grasslands to minimize potential differences between decomposition rates of different plants. During summer 2011, soils were amended with plant matter that had been homogenized. Cropland soils were amended with annual ryegrass (*Lolium multiflorum*), a facultative upland species common to disturbed areas and used for winter grazing (Redmon et al., 1995). The grassland soils were amended with western wheat-grass (*Pascopyrum smithii*), a facultative upland, perennial species that is found throughout the High Plains.

The second study was performed in August 2011 with the same upland soils; however, both grassland and cropland soils were amended with the same carbon source, blue grama (*Bouteloua gracilis*). Blue grama is an upland, perennial species that is widely distributed throughout the High Plains. No fungicides were used in the second study; the study was used to test whether there was a difference in microbial activity based on the two different plant species in the first experiment.