Applied Soil Ecology 100 (2016) 81–90

Contents lists available at ScienceDirect

Applied Soil Ecology

journal homepage: www.elsevier.com/locate/apsoil

# Conservation agriculture affects arthropod community composition in a rainfed maize–wheat system in central Mexico

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ARTICLE INFO

*Article history:*
Received 14 August 2015
Received in revised form 17 November 2015
Accepted 13 December 2015
Available online 29 December 2015

*Keywords:*
Conservation agriculture
Crop residue
Soil arthropods
Predation
Biological control

ABSTRACT

As a system of practices involving crop rotations, reduced soil disturbance, and the retention of organic matter at the soil surface, conservation agriculture (CA) increases soil quality, reduces erosion, and provides a favorable habitat for beneficial soil-dwelling organisms which may provide improved pest control. To determine the effect of CA on generalist arthropod predators and pests, we assessed the ground-dwelling arthropod assemblage prior to crop planting and shortly after crop emergence in a long-term CA trial at the International Maize and Wheat Improvement Center (CIMMYT) in central Mexico. We used pitfall traps and in-field sentinel insect assay arenas to evaluate arthropod activity-density and predation, respectively, in a maize–wheat rotation, planted under CA (zero tillage, retention of residues) and conventional agriculture (tillage and no surface residue). In maize, activity-density of generalist predators (excluding ants) was higher in conventional agriculture treatments than in CA treatments prior to crop planting ($P = 0.03$), but no significant differences were apparent in arthropod activity-densities at the treatment level at any other time. In multivariate analyses, the arthropod community was affected by tillage in maize at both sampling dates ($P \leq 0.05$), and by residue after crop emergence in wheat ($P = 0.03$). Spiders trended toward a greater association with no-till treatments in maize and treatments with residue retained in wheat. In wheat, predation (biological control potential) was significantly lower in conventional compared with CA treatments ($P \leq 0.05$). According to multiple linear regressions, higher levels of soil cover significantly explained predation before and after planting in maize, and before planting in wheat ($P \leq 0.05$). Our results indicate that the type and amount of residue that remains at the soil surface may influence arthropod community dynamics. This first report of the effects of CA on arthropods in this long-term trial indicates that CA in central Mexico may contribute to conservation of certain arthropod predators and biological control of insect pests.



## 1. Introduction

Globally, soil degradation is one of the many constraints contributing to low yields in subsistence agriculture, and thus a significant contributor to food insecurity (Greenland and Nabhan, 2001; Lal, 2009). Conventional agricultural practices involving frequent and intensive tillage and crop residue removal have been associated with degradation of soil resources by causing erosion and compaction, reducing nutrient and water holding capacities, and reducing habitat for beneficial soil organisms (Henneron et al., 2015; Nyamangara et al., 2014; Thierfelder and Wall, 2010). As an alternative to conventional agricultural production, conservation agriculture (CA) includes the retention of crop residues on the soil surface, an increase in crop diversity through rotations, and minimizing tillage used for various cultural practices, such as weed management (Erenstein et al., 2012; Hobbs et al., 2008; Knowler and Bradshaw, 2007; Palm et al., 2014; Verhulst et al., 2010). These practices together augment soil quality and reduce erosion, increase and stabilize yields, and provide a more complex and favorable habitat for soil-dwelling organisms (Govaerts et al., 2005; Henneron et al., 2015; Nyamangara et al., 2014; Pineda et al., 2012; Rendon et al., 2015), but many challenges within regional contexts still need to be addressed in CA systems.

Decreasing the frequency and intensity of tillage and retaining crop residues on the soil surface can contribute to an increase in herbivorous insects, some of which may be crop pests of economic importance (Brévault et al., 2007; Hammond, 1991; Henneron et al., 2015; Kladivko, 2001). An increase in the prevalence of insect pests may be a risk factor associated with CA, but arthropod natural enemies, e.g., generalist predators, may help to suppress these

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http://dx.doi.org/10.1016/j.apsoil.2015.12.004
0929-1393/

insect pests (Henneron et al., 2015; Schmidt and Rypstra, 2010; Wyckhuys and O'Neil, 2007). Generalist predators, such as spiders (Araneae) and carabid beetles (Coleoptera: Carabidae) non-selectively feed on other arthropods, and have been cited as contributing to lower plant damage and a reduced number of herbivores in vegetable systems, for example (Riechert and Bishop, 1990). In CA, the practices that may contribute to increased numbers of insect pests, namely residue retention and reduced tillage, may also contribute to the conservation of generalist predators (Rendon et al., 2015; Schmidt and Rypstra, 2010). Any potential increases in pest numbers because of these practices may then be mitigated by an increase in the abundance of generalist predators, but the total effect of CA on the interactions between herbivorous and predatory arthropods is an area that warrants further study. An understanding of the arthropod community at the soil surface is also important in informing interactions beyond plant–herbivore–predator, as some non-predatory and non-herbivorous arthropods present in the system may serve as supplemental prey to retain generalist predators in the field prior to pest outbreaks (Memmott et al., 2007).

Since 1991, the International Maize and Wheat Improvement Center (CIMMYT) has maintained a long-term trial in El Batán, Mexico, to evaluate and refine CA-based practices. As compared to practices considered conventional for the area (the removal of crop residues from the field and the use of inversion tillage for soil preparation and weed control), a maize–wheat rotation and retention of crop residues in combination with no-till management have contributed to stabilizing yields (Govaerts et al., 2006; Verhulst et al., 2011). Additionally, CA practices, in particular no-till and crop residue retention in combination, resulted in higher numbers of bacteria and fungi indicative of soil health, low to moderate prevalence of root rot and plant-parasitic nematodes, and maintenance of a high level of soil microbial biomass as compared to the treatments classified as conventional (Govaerts et al., 2008, 2007, 2006).

The risk of increased insect pests with CA, coupled with the high use of pesticides in Mexico and the significant damage caused annually by the fall armyworm in maize, *Spodoptera frugiperda* (J.E. Smith) (Blanco et al., 2014; Bolaños-Espinoza et al., 2001; Wyckhuys et al., 2013), are reason to study the effects of CA on the arthropod community in the long-term trial located at CIMMYT, where such research has not previously been a focus. By determining how CA and conventional tillage and residue management practices affect the beneficial arthropod community and predation rates in this agroecosystem, we can gain a better understanding of how these practices could contribute to in-field biodiversity and biological control potential (Wyckhuys et al., 2013). Specifically, we hypothesized that in a no-till system where the previous year's crop residue had been retained in the field (full CA), we would observe the following as compared to a tilled system with the residue removed (full conventional agriculture): (1) higher activity-densities and a greater diversity of generalist arthropod predators at the soil surface; (2) fewer herbivores at the soil surface; (3) higher in-field predation (and thus, biological control potential); and (4) lower crop damage caused by chewing insects early in the cropping season.

## 2. Materials and methods

### *2.1. Site description*

We conducted our research during the May–November, 2013 growing season at CIMMYT's experimental station in El Batán, Mexico (19°31′55″N, 98°50′51″W). El Batán is located in the central Mexican highlands at an elevation of 2250 masl, with a mean annual precipitation of 625 mm between 1991 and 2013, and a mean of 542 mm of precipitation during the growing season of May through October. Rainfall during the growing season in 2013 was above average, at 645 mm. Mean monthly minimum and maximum temperatures were 6.3 and 24.4 °C, respectively, in the years 1991 through 2013 (data recorded from CIMMYT's on-site weather station). According to the Food and Agriculture Organization of the United Nations (FAO) soil classification system, the soil is a Haplic Phaeozem, described as a moderately well drained, light clay (FAO et al., 2012).

### *2.2. Experimental design and field operations*

In the long-term, rain-fed trial, conservation and conventional agricultural practices have been implemented at various levels at the same site since 1991 (Govaerts et al., 2005). The trial consists of a randomized complete block design, with two repetitions, and each plot measuring 7.5 m by 22 m. Of the 32 total treatments in the long-term trial, 8 were selected for the research reported here: a full entry, maize (*Zea mays* L.) and wheat (*Triticum aestivum* L.) rotation, with either no-till or tilled plots, and retention or removal of the previous years' crop residues. Tillage consisted of a single pass with a chisel plow after harvest in the previous year, to a depth of 30 cm, followed by a disk harrow at a depth of 20 cm. Residue was incorporated into the soil when retained in tilled plots, and left on the soil surface in no-till plots. For the purposes of this research, we consider the residue retained, no-till treatments as full CA treatments, and tilled plots with residue removed as full conventional agriculture treatments.

Both crops were planted in the first week of June; maize at a rate of 25 kg seed ha$^{-1}$ in 75 cm rows, and wheat at a rate of 110 kg seed ha$^{-1}$, in 20 cm rows, both with recommended crop cultivars commonly used in the area. All treatments received the same rate of fertilizer (150 kg N ha$^{-1}$ as urea), which was disked into the soil at the time of planting in maize. In wheat, urea was disked into the soil prior to planting in zero tillage, and incorporated through tillage in conventional tillage. Maize seed was treated with an insecticide with an active ingredient of clothianidin prior to planting, at a rate of 0.3 mg/kernel of active ingredient. Both crops received 20 mm of sprinkler irrigation after planting to ensure uniform germination, and both crops emerged during the second week of June. Weeds were controlled with applications of a post-emergence herbicide as appropriate. On July 3 and again on July 24, maize received an insecticide treatment with an active ingredient of chlorpyrifos (240 g of active ingredient per hectare) in response to high numbers of *Spodoptera frugiperda* J. E. Smith (Lepidoptera: Noctuidae) and a weevil pest complex (*Nicentrites testaceipes* Champion and *Geraeus senilis* Gyllenhal, Coleoptera: Curculionidae) (Blanco et al., 2014; Bolaños-Espinoza et al., 2001). Historically, the experiment has received similar treatments of insecticides in response to pest incidence as needed, typically once or twice per growing season.

The two center maize rows of each plot were hand-harvested on November 26, and the 8 center rows (1.6 m width) were harvested in wheat on October 8 with a combine. Grain was dried and shelled, and yield is reported as dry weight of grain in kg ha$^{-1}$.

### *2.3. Characterization of ground-dwelling arthropods*

#### *2.3.1. Pitfall traps*

To characterize the local assemblage of ground-dwelling arthropods, we employed pitfall traps (at a depth of 129 mm, and with a 114 mm diameter), using ethylene glycol as a killing agent. Traps remained open in the field for 72 h (Bestelmeyer et al., 2000). Arthropods were preserved in 70% ethanol, counted and identified to at least order, with some groups identified to family, and species in the case of ants, according to established keys. We