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Tillage as a driver of change in weed communities: a functional perspective

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ABSTRACT

The adoption of non-inversion tillage practices has been widely promoted due to their potential benefits in reducing energy consumption and greenhouse emissions as well as improving soil fertility. However, the lack of soil inversion usually increases weed infestations and changes the composition of the weed community. Weed management is still a main drawback for the wider adoption of reduced tillage practices. However, it is not entirely clear whether these changes in weed communities are a consequence of non-random filters on the functional attributes of weed species and may thus affect the potential weed-crop competition relationship.

Here, we analyse the changes in weed diversity, community composition, and the functional attributes of weed communities under reduced (non-inversion) and conventional (inversion) tillage. We discuss their potential effects on the competitiveness against crop production using data from two crops of seven on-going organic and low-input field trials in different climatic regions across Europe. Weeds were evaluated after post-emergence weed control methods. We used the community weighted mean values of the life form (annuals versus perennials), specific leaf area, seed weight, canopy height, seed bank longevity, soil nutrient conditions affinity, beginning of flowering and flowering span. Moreover, the effect of the crop type on the functional attributes was also evaluated.

Overall, the tillage system affected the composition and functional attributes of the weed communities. Weed community changes may imply a reduction in weed-crop competition under both tillage systems. For instance, weed communities under reduced tillage were potentially less competitive because they were shorter and had less affinity to nutrients. On the other hand, weed communities under conventional tillage had potentially less seed production and a lower abundance of perennial species. Our study thus supports tillage as an important driver of the functional attributes of weed communities, but both tillage systems can have their downside. However, the crop type was overall more relevant than the tillage in determining most of the trait values of the weed communities.

1. Introduction

The adoption of reduced tillage practices, e.g., non-inversion tillage, has increased worldwide in recent years (Kassam et al.,

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2010). Reduced tillage has been promoted by international institutions such as the Food and Agriculture Organization of the United Nations and the Common Agricultural Policy in the European Union due to their potential benefits in improving soil fertility, increasing biodiversity, and reducing soil erosion, energy consumption and the emissions of greenhouse gases (Basch et al., 2011; Berner et al., 2008; Hobbs et al., 2008; Holland, 2004).

One of the main concerns of farmers in adopting reduced tillage practices is weed infestation. Tillage is considered to be a key strategy for weed control, particularly under organic farming, where the use of herbicides is prohibited. The lack of soil inversion may increase weed infestation, although this trend is usually crop-specific and not constant over time (Armengot et al., 2015; Légère et al., 2013; Vakali et al., 2011). However, a higher weed infestation under reduced tillage does not always lead to increased yield losses compared to conventional tillage because weed abundance may not reach the level for significant yield loss reduction (Armengot et al., 2015; Sans et al., 2011).

Studying weed communities under both conventional and reduced tillage systems is crucial for overcoming what is perceived as one of the main drawbacks of reduced tillage by farmers. Until now, most studies have focused on the role of the tillage system on weed abundance, community composition, and diversity. The reduction in the intensity of the soil tillage commonly increases the abundance of perennial and grass species (Armengot et al., 2015; Melander et al., 2013; Peigné et al., 2007; Santín-Montanyá et al., 2013), but the trends are less clear in relation to weed diversity (Armengot et al., 2015; Hernandez Plaza et al., 2011; Santín-Montanyá et al., 2013). However, in spite of the evidence that the tillage system may differently affect each species in relation to its attributes such as life form (annual and perennials), trait-based approaches have been neglected in disentangling the effect of reduced and conventional tillage practices on the weed flora (but see Fried et al., 2012; Trichard et al., 2013).

In contrast to the taxonomic approach, the functional attributes of the species allow for the interpretation of shifts in community composition beyond the changes that may be related to the geographic context or to the high variability in the local occurrence of weeds (Gunton et al., 2011). Shifts in weed communities result from non-random filters acting on the local pool of species depending on their functional attributes (Garnier and Navas, 2012; Shipley et al., 2006). Thus, researchers have recently focused their efforts on identifying which farming practices are the most significant filters for weed community assemblies (Gaba et al., 2014; Fried et al., 2012; Trichard et al., 2013). Among others, crop type, fertiliser and herbicide inputs have been found to have a strong influence on weed communities (Fried et al., 2012; Gunton et al., 2011; Storkey et al., 2010). More interestingly, this approach has the potential to identify the expected impacts of weed community shifts on the functionality of agroecosystems (Garnier and Navas, 2012). For instance, shifts in weed communities may result in changes in the competiveness against crops as well as in certain services that weeds provide, such as the provision of food for beneficial fauna.

In this study, we aim to evaluate whether the tillage system (conventional compared with reduced tillage) affects weed communities and their functional attributes in a predictable way, which in turn may affect the relationship of the weed flora to crop production. We analysed data on weed communities from seven European on-going trials assessing the effects of the tillage system within the framework of the TILMAN-ORG project (www.tilman-org.net). We hypothesised that (i) the type of tillage will affect weed species richness and community composition, and (ii) that these changes will lead to weed communities with different traits in response to the disturbance. These changes in weed community may have important consequences in relation to crop-weed competition and the management of agricultural systems.

2. Material and methods

2.1. Data sets

We used data from seven on-going organic or low-input field trials testing for the effect of reduced tillage practices on weed flora, within the framework of the CORE-organic TILMAN-ORG project.

Table 1
Data on the environmental conditions, crop types, tillage system and weed sampling of the seven field trials included in the study.

Country	Temperature and rainfall (annual mean)	Soil type	Tillage system (depth)	Crops	Weed sampling (samples per plot)	Timing of sampling (days after sowing)	Other factors
Austria	8.8 °C	Silty loam	Con: mouldboard plough (25 cm)	2012 Winter wheat	Two 1 m^2	244	–
	500 mm		Red: chisel plough (5–7 cm)	2013 Sugar beet	Four 1 m^2	146	
France	10.3 °C	Sandy	Con: mouldboard plough (30 cm)	2012 Winter wheat	Eight 0.25 m^2	247	–
	830 mm		Red: chisel plough (15 cm)	2013 Maize		190	
Italy	15 °C	Loam	Con: mouldboard plough (30 cm)	2012 Sunflower	Two 4 m^2	122	Fertilisation
	826 mm		Red: chisel plough (30 cm)	2013 Winter wheat	Two 1 m^2	227	
Luxembourg	9.1 °C	Loamy sand	Con: mouldboard plough (15–25 cm)	2012 Spring oat	Two 1 m^2	170	Green manures
	800 mm		Red: disc harrow (5 cm)	2013 Spring wheat		115	
Netherlands	9.5 °C	Light clay	Con: mouldboard plough (25 cm)	2012 Spring wheat	Eight 0.25 m^2	86	–
	775 mm		Red: cultivation (12 cm)	2013 White cabbage		107	
Spain	14.9 °C	Loamy clay	Con: mouldboard plough (20 cm)	2012 Spelt	Four 1 m^2	176	Fertilisation
	650 mm		Red: chisel plough (20 cm)	2013 Chickpea		94	Green manures
Switzerland[a]	8.9 °C	Clay	Con: mouldboard plough (15 cm)	2010 Sunflower	One 64 m^2	83	Fertilisation
	1000 mm		Red: chisel (5–7 cm), occasionally at 15 cm or stubble cleaner (5–7 cm)	2011 Spelt		258	

Weed cover for each species was recorded in all of the trials with the exception of the Netherlands, where density was recorded. When only one of the sampling strategies is reported, it was the same for both crops.

[a] Data from 2010 and 2011 were used because a grass clover crop was grown in 2012 and 2013.