Short-term effects of crop husbandry on the weed community of a cereal-legume rotation, "TILMAN-ORG session"

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Abstract

The aim of this experiment was to study the effects of two techniques from conservation agriculture, reduced tillage (RT) and green manure (GM) plus fertilization, on weed density and diversity and on community composition in the context of an organic Mediterranean system with a cereal-legume crop rotation. The experiment was carried out in an experimental field near Barcelona (Spain). From 2011 to 2013, weed density per species was evaluated under each crop (spelt, green manure and chickpeas). The seedbank was characterized before the rotation started. Our results showed that total weed density increased under RT, except in chickpea, where tillage had no effect. Also, weed density decreased dramatically while GM was standing, but no carry-over effects could be observed on the next crop, chickpea. GM also prevents the expression of the seedbank, as the effects of previous year tillage and seedbank could only be observed where GM was absent. As for community composition, GM seems to prevent the dominance of few species.

Introduction

The fate of weed seeds and their chances of germination are crucial for weed infestation. Thus, tillage systems which invert soil layers can be used to manage weeds. However, this intensive tillage can cause severe soil losses and alteration. Reduced tillage (RT) is an alternative, but it can increase weed density, and thus other techniques to manage weeds are needed. Green manures (GM) or cover crops can reduce the growth of weeds between main crops. In addition, these intercrops can avoid soil loss and improve soil fertility, although fertilization can seldom be avoided, since GM do not provide all necessary nutrients. RT and GM are two of the main techniques of conservation agriculture. There is little information on conservation agriculture for organic systems, and even less on the combined use of these techniques in Mediterranean agricultural systems. Our purpose is to study the effects of RT (chisel versus mouldboard plough), and of GM, plus fertilization and their interactions, on the weeds, in terms of density and of community composition, in a Mediterranean cereal-legume crop rotation.

Material and methods

A mid-term field experiment was set up in 2011 to test an organic farming system adapted to the Mediterranean conditions using techniques from conservation agriculture. It was set up in Gallecs, an agricultural area 15 km to the north of Barcelona, Spain, which is currently undergoing a conversion to organic agricultural management. The selected field had already been under organic management, with typical dryland Mediterranean crop rotation, alternating cereal and legume. The last crop before the experiment started was *Vicia ervilia*. Thirty two plots, grouped in four blocks, were set up. All plots were 13 m × 12 m, but only the central 9 m × 8 m area was sampled in order to avoid edge effects. Each block comprised the full combination of three treatments: tillage, with mouldboard or chisel ploughing; fertilization, with or without application of manure; and with or without sowing a green manure during winter months).

To study the initial weed seedbank, we collected soil samples in November 2011. Inside each plot we extracted 48 cores, 2.5 cm of diameter × 20 cm deep, regularly distributed. The samples were mixed and spread on labelled trays, kept in a non-heated greenhouse and irrigated daily with sprinklers. The trays were checked periodically to identify and count weed seedlings.

From 2011 to 2013 there have been three crops: spelt (December 2011 - July 2012); green manure (only half of the plots), consisting of a mixture of white oat, mustard, vetch and common vetch (October 2012 - March 2013); and chickpeas (April 2013 - July 2013). Field emergence of weeds was evaluated in April 2012 and February and May 2013. Weed seedlings were identified and counted in 12 randomly distributed samples, measuring 25 cm × 25 cm, on each plot.

The effects of the treatments on the weed community were tested by means of Generalized Linear Mixed Models with Poisson error distribution. Since the application of the treatments (tillage, green manure and fertilization) does not occur simultaneously, some effects are better described as direct effects (tillage and

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fertilization on the succeeding crop; green manure while it is standing on the field) or carry over effects (tillage and fertilization from the first year onto the green manure phase; the green manure on the subsequent chickpea crop). The information from the seedbank and from 2012 densities was used as covariates for weed density analysis to correct for the effects of the pre-existing weed distribution. In order to test the effects of the applied factors on the weed community, the data on specific weed abundances was analysed by means of a Permutational Multivariate Analysis of Variance using a distance matrix based on the Jaccard index.

Results

In April 2012, total weed density responded negatively to mouldboard plough ($Z=-3.43$, $p<0.01$, figure 1), but not to fertilization. Tillage also had a significant effect on the composition of the weed community (pseudo-$F=2.74$, $p<0.05$).

Weed density during the green manure phase, was very low. There was a significant negative effect on total weed density from the standing green manure ($Z=-8.86$, $p<0.01$) and a carry-over effect from plough applied in 2011 ($Z=-2.29$, $p<0.05$). A significant interaction between these factors was detected. Density was significantly higher under chisel than under plough ($Z=-2.57$, $p<0.05$), but only in the plots without green manure. In addition, we observed that the effect of previous year weed density was significant only in plots without green manure.

The most abundant species also responded negatively to the presence of green manure. The effects of tillage and fertilization applied in 2011 varied among species. Plough had a positive effect on *Diplotaxis erucoides* and fertilization had opposite effects on *D. erucoides* and *Kickxia spuria*.

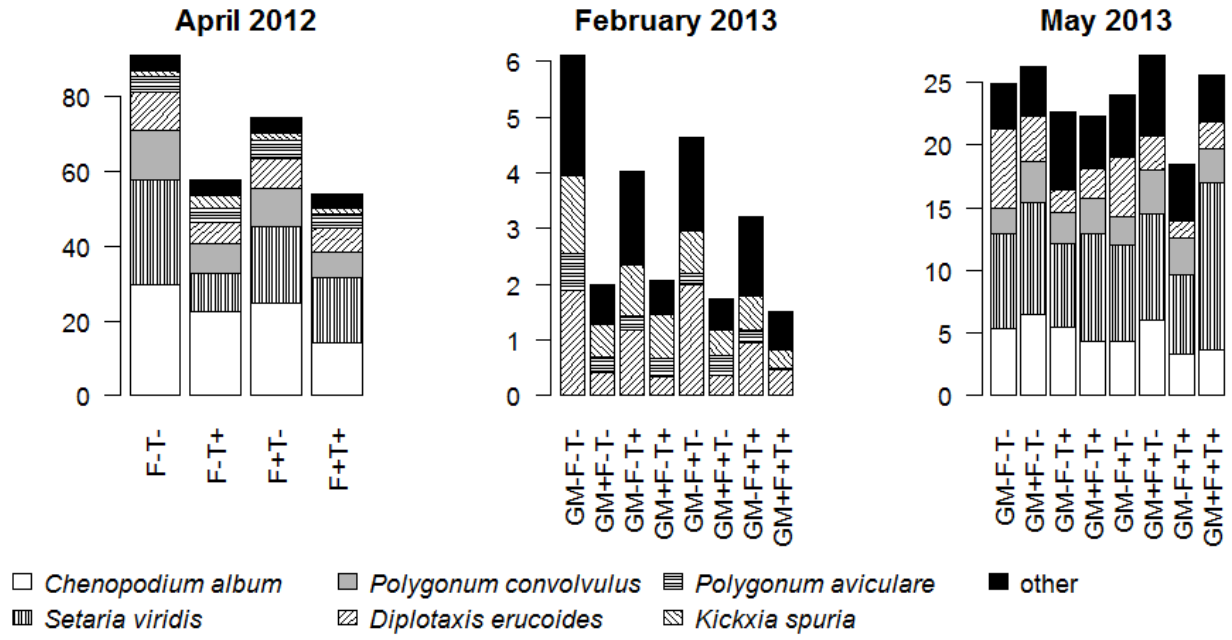

Figure 1. Weed species density (in individuals/m2) in each of the treatments and sampling periods. "Other" summarizes the species with less than 100 individuals across all samples. T: tillage (+ mouldboard, - chisel), F: fertilization (+ with manure, - without manure), GM: green manure (+ with green manure during winter, - without green manure).

Changes in the relative abundances of weeds caused strong differences in the community composition between plots with and without green manure (pseudo-$F=8.02$, p-value<0.01), although species composition was quite similar.

During the chickpea phase, total weed density was only affected by 2012 densities ($Z=5.18$, $p<0.001$), showing a null carry-over effect of the control provided by green manure. For most species, only densities from 2012 were relevant to explain density in 2013. There were some exceptions, however. *Setaria viridis*, *Polygonum convolvulus* and *Kickxia spuria* showed a positive effect of plough. *P. convolvulus* and *Convolvulus arvensis* showed a significant effect of green manure, which had a positive effect on the former and a negative effect on the other one. Finally *P. convolvulus* and *S. viridis* responded positively to the

application of fertilizer. In other species none of the fixed effects or covariates was significant. Composition analysis in May did not show any effect from treatments.

Discussion

Our results support that plough is an effective method to manage weeds, as its effects are prolonged in time, causing a reduction in weed density up to two years from its application. On the other hand, green manures standing a few months are very effective while growing, but do not seem to provide control afterwards. This is especially true if the following crop leaves much soil uncovered, allowing the development of weeds independently of the applied treatments (Dorado et al., 2006, Mirsky et al., 2010). Green manures also prevent the expression of the weed seedbank, thus, effects from previous tillage can only be observed where green manure is absent. In addition, green manures avoid the dominance of few species by changing the pattern of expression of the seedbank.

The effects of treatments are variable among species. Disturbance related species, such as *Diplotaxis erucoides*, may respond positively to intensive tillage, and fertilization seemed to favour the earliest germinating ones. Green manure had a greater negative effect on perennial species, such as *Convolvulus arvensis*, that may have used up the resources from rizomes to compete against green manures, thus being unable to resprout after tillage. Our results suggest that it may be completely necessary to adjust the crop husbandry, combining tillage, fertilization and green manures, to have better management options to specific weed problems.

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