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Weed flora in a long-term reduced tillage trial, "Tilman-org session"

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Abstract

Reduced tillage techniques are widely applied, but mainly under herbicide based cropping systems. The potential increase of weed infestation due to the non-inversion of the soil is one of the main obstacles for their adoption among organic farmers. This study analyses the weed abundance and community composition of a nine-year old experiment under conventional and reduced tillage in organic farming. The experiment was settled in Frick (Switzerland) in 2002 and the crop rotation consisted of winter wheat, sunflower, spelt, 2 years of grass-clover, silage maize, winter wheat, sunflower and spelt. The results did not show huge differences in weed infestation between both tillage systems, although they were higher under reduced tillage, mainly in crops sowed in high-spacing rows, such as the sunflower. However, an increase of the perennial species was observed in all the crops over the years under reduced tillage.

Introduction

Reduced tillage may improve the environmental and economic performance of organic farming. Reducing the intensity of soil tillage decreases the energy consumption and the emission of CO_2, and could increase carbon sequestration (Holland 2004). It also may improve water retention and reduce soil erosion (Berner et al. 2008). One drawback of the reduced tillage practices is the potential increase of weed infestation and changes in species composition, sometimes benefiting those species which are more difficult to control, such as perennials and grasses (Peigné et al. 2007, Sans et al. 2011). Organic farmers commonly control weeds by ploughing and by post-emergence mechanical methods, and by an appropriate crop rotation including e.g. grass-clover. Thus, weed management under reduced tillage is more challenging in organics systems. In this study, we present the results on weed abundance and community composition in a 9-year old long-term trial under conventional and reduced tillage.

Material and methods

Site and experimental design

In autumn 2002 a field experiment was settled in Frick (Switzerland). The field was managed organically since 1995. The mean annual temperature and precipitation are 8.9°C and 1000 mm, respectively. On average, the mineral fraction consists of 22 % sand, 33 % silt and 45 % clay. The experiment involved 3 factors: tillage (conventional vs reduced), fertilisation (slurry vs manure compost with reduced quantity of slurry) and biodynamic preparations (with vs without). The three factors and four replicates were arranged in a strip-split-plot design, with tillage as a main factor (in total, thirty-two 12 m × 12 m plots). Conventional tillage used a mouldboard plough operating at 15 cm depth. In the reduced tillage system, a chisel plough with wide sweeps or a stubble cleaner ("Stoppelhobel", German) was used, operating at 5 cm depth, and occasionally (3 times in nine years) a chisel was applied at 15 cm depth. Seedbed preparation was performed by a rotary harrow in both tillage systems. Fertilisation was applied at a level of 1.4 livestock units ha^{-1} in both fertilisation treatments. A detailed description of the experiment is given by Berner et al. (2008).

The crop rotation consisted of winter wheat (*Triticum aestivum* L. cv 'Titlis', 2003), an oat-clover intercrop (*Trifolium alexandrinum* L. and *Avena sativa* L., 2003/2004), sunflower (*Helianthemus annuus* L, cv 'Sanluca', 2004), spelt (*Triticum spelta* L. cv 'Ostro', 2005), a 2-year grass-clover ley (mixture of *Trifolium campestre* L., *T. repens* L., *Dactylis glomerata* L., *Festuca pratensis* Huds., *Phleum pratense* L., *Lolium perenne* L., 2006 and 2007), silage maize (*Zea mays* L. cv 'Amadeo', 2008), winter wheat (*T. aestivum* L. cv 'Titlis', 2009), sunflower (*H. anuus* L, cv 'Sanluca', 2010), spelt (*T. spelta* L. cv 'Ostro', 2011) and two years of grass-clover ley (2012 and 2013). Weeds were controlled mechanically by a tractor-driven flex-tine-

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weeder in cereals and by a rolling cultivator and also by hand within the sunflower and maize rows according local practice.

Data collection and statistical analyses

The percentage of cover of each species was estimated visually (1 % - 100 %) per each wheat, sunflower, spelt and maize crop within the inner 8 m × 8 m of each plot before harvest. The percentage of cover was assigned as the leaf surface projected vertically on the ground, and as integrated over all the weeds and the crop, reaching a maximum of 100 %. Data on maize was not analysed in this study because only one-year data was available.

For each crop, the effect of the tillage treatment, the year and their interaction on the total weed cover, and on the percentage of cover of perennial and grass species were analysed through mixed-effect models. Tillage and plot were introduced as random factors. Data were transformed when necessary to meet the normality and homoscedasticity requirements of the residuals. Previous statistical analysis revealed no significant differences and interactions related to biodynamic preparations and fertilisation treatments. Therefore, the results will neither be shown nor discussed. The data of these two treatments were consequently pooled. The analyses were performed in R 2.7.1 (R Development Core Team 2008), with the lme4 package (Bates et al 2008) for mixed models and language to evaluate the *P* values.

We also performed a multivariate analysis of variance using distance matrices to analyse the effect of the tillage system and the crop on weed composition. The Bray-Curtis distance was applied. Species occurring just once were removed. The significance of the explanatory variable was obtained from F-test based on sequential sums of squares from permutation of the raw data. The permutations were restricted within each plot to incorporate the hierarchical sampling. The analyses were performed in R 2.7.1 (R Development Core Team 2008), using the vegan package for R (Oksanen et al. 2009).

Results

Overall, the mean percentage of weed cover was 16.4 %, being the sunflower crop more infested than the wheat and spelt crops. The perennial species had an average cover of 6.9 %, whereas the cover of the grasses was almost negligible. In general, weed cover was higher under reduced tillage. However, the results did not show a tendency of increase of the weed infestation over the years under reduced tillage, and for the wheat crop no significant differences were observed between both systems in the two years included in the rotation.

Conversely, the cover of the perennial weeds was higher under reduced tillage in all the crops and it was always higher in the second year of each crop type in the rotation, which means an increased infestation over the years in the reduced tillage system, but not under conventional tillage. We did not observe significant differences between tillage systems or a clear trend over the years in the cover of grass species, which was probably related to the very low cover of these species in the field trial.

Weed species richness was not affected by the tillage system, except in the sunflower crop, where a significant lower value was observed under conventional tillage in 2010. However, the analysis of the weed community composition revealed significant differences between tillage systems, between crops and their interaction.

Discussion

Overall, our results showed that reduced tillage was a feasible system in terms of weed management after nine years of tillage system comparison, since not huge differences were observed in the weed infestation. However, especial attention must be paid to perennial species, which were more abundant and increased over the years under reduced tillage, potentially decreasing the performance of this tillage system at the long-term in term of yields. The results also highlighted the importance of the crop selection in the rotation, and of paying especial attention to that sowed in high-spacing rows, such as the sunflower.

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