Reduced tillage and cover crops in organic arable systems preserve weed diversity without jeopardising crop yield

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Abstract

Environmental concerns are pushing organic farmers to substitute ploughing with reduced tillage but weed management under reduced tillage can be troublesome. One objective of the TILMAN-ORG Project is to improve weed management with reduced tillage ± cover crops without reducing weed community diversity. This paper reports results obtained in 2012 in 13 long-, mid-, and short-term trials scattered across Europe including winter cereals, maize, grain pea, potato, sunflower and grass/clover or legume leys. Long- and mid-term experiments showed higher weed abundance under reduced tillage but usually without reduced crop yield. Short-term trials showed that reduced tillage system may be troublesome to manage right after the conversion from ploughing, due to higher abundance of weeds and volunteer crops and reduced yield. Interestingly, there was no overall consistent relationship between weed diversity, always higher under reduced tillage, and crop yield.

Introduction

Organic farmers commonly keep weeds under control by ploughing and post-emergence mechanical methods. However, organic farming is facing increasing pressure towards substitution of ploughing with more environmentally-friendly methods like reduced tillage. Weed management, especially of perennial species, is expected to become more challenging in organic systems based on reduced tillage. Nevertheless, diversification in the cropping system based on targeted combinations between reduced tillage, cover crops and direct weed control should reduce weed abundance to a minimum.

One of the objectives of the TILMAN-ORG Project is to improve weed management under conservation agriculture (reduced tillage and/or cover crops) in organic arable systems while maintaining weed community diversity. This paper summarises the results on (1) weed abundance, (2) weed diversity and (3) crop yield obtained in the first year of the project (2012) in 13 trials scattered across Europe.

Material and methods

The 13 trials are based on different approaches (e.g. system *vs* reductionist trials), crops, factors, treatments and histories. They include 5 long-term (>7 years), 4 mid-term (3 to 7 years) and 4 short-term (<3 years) experiments, located in Austria, Estonia, France, Germany, Italy, Luxembourg, Spain, Switzerland, the Netherlands and the UK.

The crops included in the trials are winter cereals (barley, wheat, oats and spelt), maize, grain pea, potato, sunflower and grass/clover or legume leys. Some of the trials include both tillage (usually ploughing *vs* reduced tillage) and cover crop (species comparison) factors, whereas others include only one of the two factors.

Weed data (density and/or cover by species) are collected at key growth stages in both cover and cash crops. Crop yield and yield components are collected in all trials. Both weed and crop data are collected upon a commonly agreed sampling protocol.

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Data of the 2012 growing season are here summarised by typology of trial (long-, mid- or short-term experiments). Based on ANOVA results, trials were classified in three categories, regardless of their duration: those in which data in the ploughed treatment were significantly (a) higher or (b) lower than in the reduced tillage treatment(s), and those in which (c) there was no significant difference between tillage treatments. Attribution of trials to one of these three categories was done for weed abundance, weed diversity and crop yield data. A chi-square test for equivalence of sample distribution among categories was then performed. This analysis was not done on trials including only the cover crop factor due to their limited number.

Results

Long-term trials

In the Italian system comparison trial weed cover and/or biomass were generally higher in the organic system (including a green manure crop) than in the conventional system, although this difference was not always significant. Higher weed abundance did not turn out in lower wheat yield. The Italian cover crop trial showed no significant differences in weed abundance and composition at the termination date of cover crops but cover crop species influenced weed community composition. Total weed cover and biomass before harvest did not differ among treatments.

In the Austrian trial grain yield was very low irrespective of treatments due to seasonal drought, and did not differ between tillage systems. Before harvest, weed cover and biomass were low and nearly equal between ploughing and reduced tillage. The latter showed higher weed species richness with more perennials and grasses.

Dry weather also affected the Swiss trial, where establishment of the grass-clover ley was suboptimal. In the first two cuts, the proportion of clover in the sward was higher in the plough than in the reduced tillage treatment, where weed biomass was higher.

In the French trial very superficial tillage and reduced tillage had higher weed infestation and consequently lower undersown alfalfa biomass at wheat harvest. Weed diversity was also higher in these two treatments. Wheat yield was lower in the reduced tillage system and higher with shallow than deep ploughing.

Mid-term trials

In the Estonian system experiment weed presence was strongly influenced by green manure crop, rye being the most suppressive one and ryegrass the least. This had a carry-over effect on weed density in the next pea crop. Perennial weeds dominated in red clover.

In the UK trial reduced tillage significantly improved crop establishment. There was no grain yield difference between ploughing and reduced tillage (Ecodyn) in spring crops but 50% lower winter rye yield in the latter, probably because Ecodyn performed better under dry spring sowing conditions. Weed cover was higher in reduced tillage only at an early stage. Density of dicotyledonous species was higher in reduced tillage.

In the German trial the highest weed cover was found in the reduced tillage system (stubble cleaner). Alfalfa + plough was the treatment which had the lowest weed cover and biomass. *Lolium perenne*, *Sinapis alba* and *Vicia sativa* were the most suppressive green manure crops. Wheat grain yield was significantly higher in the alfalfa + plough system and after *V. sativa*. Instead, the *L. perenne* green manure reduced wheat yield.

In the Dutch trial there were hardly any perennial weeds, even in non-inversion and minimum tillage plots, likely due to the relatively high share of root crops in the rotation, leading to intensive soil cultivation. Tillage systems did not influence neither potato nor spring wheat yield. In spring wheat, weed density did not change upon tillage system. Undersown white clover did not establish well in the plough treatment compared with minimum tillage, whilst non-inversion tillage showed intermediate values. This was probably due to suboptimal working depth of the sowing implement under looser ploughed soil.

Short-term trials

In the Luxembourg factorial trial ploughing gave highest grain yield and better weed control compared to the stubble plough and the non-inversion system (disc harrow). No significant differences were found between the two reduced tillage methods.

In the Spanish trial spelt yield was enhanced (13%) by fertilisation with composted farmyard manure but was unaffected by tillage type. Total weed density early in the season was lower with ploughing. Later in the season, and without post-emergence mechanical weed control, weed biomass was only lower in fertilised ploughed plots.

In the German trial weed cover was lower in the plough system and higher in the direct drilling system. Direct drilling and mulching + drilling had less numerous but taller weeds than chisel and plough systems. However, weed cover was so high in direct drilling and mulching + drilling (from 60 to 90%) that all plots under direct drilling x common vetch (*Vicia sativa*) and mulching + drilling x common vetch treatments could not be assessed any further. Common vetch was the only green manure species capable to suppress weeds to some extent under reduced tillage. This was also the green manure treatment which gave the highest oat yield but yields were acceptable in all plots (from 4 to 6 t ha^{-1}). Chisel + common vetch resulted in the highest yields, whilst plough + white mustard and chisel + white mustard in the lowest.

Pooled results of all trials showed that tillage system influenced all three parameters but differently (Table 1). Reduced tillage increased weed abundance but did not diminish crop yield in a significant number of trials. Weed community diversity was also significantly increased by reduced tillage.

Table 1: Number of trials in which weed abundance, weed diversity or crop yield were significantly higher, equal or lower in ploughing (PLO) *vs* reduced tillage (RED), with observed chi-square (X_2) values, number of cases (n), degrees of freedom (d.f.) and probability (P) of equal distribution among the three categories

Parameter	PLO>RED	PLO=RED	PLO<RED	X_2 (n, d.f.)	P
Weed abundance	0	2	7	8.67 (9,2)	0.013*
Weed diversity	0	1	5	7.00 (6,2)	0.030*
Crop yield	5	11	0	11.38 (16,2)	0.003**

*, **significant at P≤0.05 and 0.01 respectively

Discussion

Long- and mid-term experiments showed a trend towards higher weed abundance under reduced tillage. However, this often did not turn out into lower crop yield. Overall, it was evident that proper weed management over the whole crop rotation can compensate for suboptimum results in one course. The German mid-term trial showed that consistent good results in both weed suppression and crop yield can be attained by optimum crop sequence/tillage system/ green manure combination. Wheat yield components often differed between ploughing and reduced tillage without influencing grain yield. This indicates high phenotypic plasticity and consequent buffer capacity of the cereal crop. There was no consistent relationship between weed diversity, always higher under reduced tillage, and crop yield. Short-term trials showed that reduced tillage system are often troublesome to manage right after the conversion from ploughing, resulting in higher abundance of weeds and volunteer crops and reduced yield.

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