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Weed density and diversity in a long-term cover crop experiment background

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ABSTRACT

Cover crops (CC) are biological tools with a great potential for weed control, but the suppression level depends on the CC species and management. A 2-year study was performed in the eighth year of a long-term experiment located in Central Spain to study the effect of replacing winter fallow by barley (*Hordeum vulgare* L.) or vetch (*Vicia sativa* L.), on the weed control. Moreover, two CC termination dates were evaluated. Weed biomass, density, diversity, population composition and the seed bank were assessed. Ground cover and CC biomass, soil inorganic N and topsoil water content were determined throughout the season. Barley achieved a greater weed control compared to vetch in winter and early spring. Later in May, both CC residues decreased weed density compared to fallow (63% in 2015, 55% in 2016), and reduced the density of some broadleaf species (i.e. *Xanthium spinosum* L. reduced > 50%). The weed seedbank density was not affected by CC but the effect on specific species confirmed the control over *Xanthium* spp. (78% reduction), and also warned of the incomplete weed control by CC. The year in which the biomass and ground cover increased between termination dates, delaying the CC termination reduced weed density > 75%. Therefore, delaying the termination date was a mean to increase weed control but should be performed with caution to avoid pre-emptive competition with the cash crop. Results underline the relevance of CC species and the termination date as management tools for weed control, and must be considered to plan specific management strategies in different scenarios.

1. Introduction

The interest of replacing winter fallow by cover crops (CC) has increased in last decades mainly due to the beneficial effects on soil and water quality (Thorup-Kristensen et al., 2003). Given the economic relevance of crop losses by weeds and the negative effects of herbicides, as the environmental persistence or herbicide-resistant weeds increase (Oerke, 2006; Zimdahl, 2013), weed suppression benefits from CC have become highly relevant as well (Teasdale et al., 2007). However, there is still a need to clarify what are the best management choices to enhance weed control capabilities of CC (Schipanski et al., 2014). In addition, the result of introducing CC for weed communities may take several years to manifest (Moonen and Barberi, 2004) and information from long-term experiments may help to design strategies to optimize weed control.

As living crops or as mulch, CC compete for resources as light, water and nutrients (Teasdale and Mohler, 1993). Also, chemical control has been reported in CC that release allelopathic substances that reduce weed density (Sturm et al., 2016). However, CC impact on weed density and diversity is still not clear as it depends on CC type and management, among other factors (Campiglia et al., 2012; Radicetti et al., 2013).

Cover crop biomass is an important factor in weed control (Teasdale and Mohler, 2000) and can explain differences between CC species performance (Campiglia et al., 2012; Buchanan et al., 2016). Further, the impact of the CC on the soil N and water content must be considered. The soil N depletion by the growing CC might contribute to weed control, but the N release from residue after CC termination might enhance weed emergence (Blackshaw et al., 2003). As legumes incorporate atmospheric N to the soil, they should be considered as another variable leading to differences between CC (Blum et al., 1997). Likewise, under no-tillage practices, CC mulch preserves soil moisture that may promote weed density (Teasdale and Mohler, 1993). However, few field experiments connected soil N availability and moisture with the weed control by CC residues.

The CC termination date is crucial for weed control (Mirsky et al.,

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2011). In some experiments the termination date delay increased CC biomass and led to better weed control and changes in the composition of the weed population (Mirsky et al., 2011). However, other authors did not observe an impact of termination date (Duiker and Curran, 2005). The termination date effect on water and N availability has been reported (Alonso-Ayuso et al., 2014) but few studies related the termination date effect on weed control with soil water and N. Only the study by Wayman et al. (2015) focus in the correlation between CC termination date, soil N availability and weed density in a field experiment, but results were not conclusive. In addition, none of previous studies integrating CC termination date and weed control were performed in semiarid regions in which the termination date delay could entail a pre-emptive competition risk (Nielsen and Vigil, 2005). Therefore, more comprehensive research is needed to understand the impact of CC and management practices on environmental variables that affect weed control.

The objectives were to study the effect on weed density and diversity of i) replacing fallow by a grass or a legume winter CC in a long-term field experiment, and ii) terminating the CC in two dates in spring. Topsoil water and N availability were periodically measured to explain weed control. The study was conducted in an irrigated area with intensive crop management. Weed competition is a major concern in the area, but relying only on chemical control could lead to environmental pollution of a shallow aquifer (≈5 m bellow surface). The use of CC is not widespread in the region and its use could contribute to control weeds and diminish herbicide application.

2. Materials and methods

2.1. Field experiment

The study was performed in a field experiment located in Aranjuez (Central Spain) that was established in 2006. Year after year a winter CC-irrigated cash crop rotation was carried out in the same plots. Two CC species, barley (*Hordeum vulgare* L.) and common vetch (*Vicia sativa* L.), were compared with a fallow treatment. Then, the cash crop – maize (*Zea mays* L.) or sunflower (*Helianthus annuus* L.) were sowed through CC residues. The design corresponded to 4 replications randomly distributed in 12 plots (12 × 12 m^2). Detailed information can be found elsewhere (Garcia-Gonzalez et al., 2016). The soil is classified as a *Typic Calcixerept* (Soil Survey Staff, 2014) and had a silty clay loam topsoil (pH ~8.1; soil organic matter ~1.9%). The climate of the area is Mediterranean semiarid (Papadakis, 1966). Weather measurements during the experiment were recorded by aCR23X micrologger in a Campbell Scientific station located less than 100 m from the field experiment.

The current study was performed eight years after the establishment of that long-term experiment to show the legacy of CC treatments on the weed assembly over two seasons (2014–2015, 2015–2016). Cover crop species (barley, 180 kg ha^{-1}; vetch, 150 kg ha^{-1}) were sown in early October each year and buried with a shallow cultivator (~5 cm). Fallow plots received as well a shallow cultivator pass. None of the plots received fertilization, irrigation, or any type of weed control during the autumn-winter period. Cover crops were terminated in spring with glyphosate (1.07 kg a. e. ha^{-1}) and chopped when dry. The termination date, was considered a second factor to study. Both years, a 4 m^2 microplot was established and corresponded to the first termination date (FT, March 13th, 2015; March 17th, 2016). At this time barley was at the end of the booting, and vetch at the stem elongation stage, and the herbicide was applied by a backpack sprayer in the microplot. The rest of the main plots corresponded to the second termination date (ST, April 20th, 2015; April 14th, 2016), when barley was at the middle of heading and vetch at the stem elongation stage. The herbicide was applied with a tractor sprayer, after covering microplots. Both termination dates, glyphosate was sprayed as well over fallow plots.

Cash crops, sunflower in 2015, and maize in 2016, were sown (April 29th, 2015; April 18th, 2016) by direct drilling through the CC mulch (80,000 plants ha^{-1}). On May 29th, 2015, tribenuron-methyl (18.5 g a. e. ha^{-1}) was applied over sunflower (5 extended leaves). On May 18th, 2016, a mix of mesotrione (12 g a. i. ha^{-1}) and S-metolachlor (120 g a. i. ha^{-1}), was applied over maize (3 unfolded leaves).

Irrigation was applied from May to July for sunflower, and from May to September for maize. A sprinkler delivery system was used and irrigation water applied was ≈80% of cash crop evapotranspiration calculated by the FAO method (Allen et al., 1998) due to water scarcity.

Sunflower did not receive fertilizer application, while maize received two split application of N-fertilizer (at the end of May and June). Each CC treatment received a different rate according to the N available in the soil, the expected maize N uptake, and the estimated N mineralized from barley and vetch residues. Therefore, 196, 110 and 150 kg N ha^{-1} were applied on barley, vetch and fallow plots respectively.

In 2015, sunflower heads were damaged by birds. Thus, at early September 3 rows $plot^{-1}$ were hand harvested and the seed yield was estimated through the head diameter, as the head diameter and the seed weight were highly correlated in a calibration obtained from seed-full sunflower heads (R^2 = 0.99). No differences between CC treatments were found in sunflower commercial grain yield (1528 ± 161 kg ha^{-1}). For maize, at early October 2016, two 8-m stripes of the central rows in each plot were harvested with an experimental combiner and maize yield was recorded. No differences were found between CC treatments in commercial grain yield (8.0 ± 0.8 Mg ha^{-1}). A timeline with the main field labors and sampling performed from 2014 to 2016 is presented in Fig. 1.

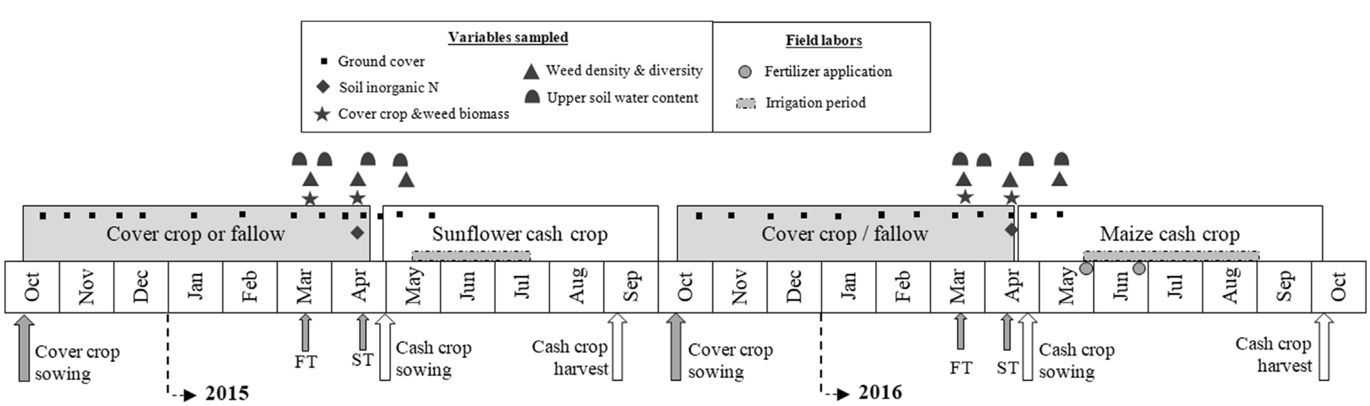

Fig. 1. Schematic timeline showing the field works and sampling performed on the experimental site from 2014 to 2016.