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Impact of managing cover crop residues on the floristic composition and species diversity of the weed community of pepper crop (*Capsicum annuum* L.)

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ABSTRACT

The decline of farmland biodiversity is mainly attributed to the intensive use of chemical inputs in agriculture. Cover crop residues may contribute to improve weed management while maintaining a high level of weed diversity. A 2-year field experiment was carried out in central Italy to study the effect of cover crop species and their residue management on weed community composition and weed species diversity in a winter cover crop – pepper sequence. Hairy vetch (*Vicia villosa* Roth.), oat (*Avena sativa* L.) and canola (*Brassica napus* L.) were sown in September 2009 and 2010 and grew undisturbed during the winter season until spring when they were suppressed one week before pepper transplanting. Cover crop residues were: (i) green manured at 30 cm depth (conventional tillage, CT), (ii) green manured at 10 cm depth (minimum tillage, MT), and (iii) left on the soil surface as mulch strips covering 50% of the ground area in no-tilled soil (NT). A winter weedy fallow and a bare soil without cover crop in NT, MT and CT were also included as controls. Weed plant density data in pepper were used for calculating weed species richness. Compared to weedy fallow, oat, hairy vetch and canola consistently reduced the weed density and weed aboveground biomass by the time of their suppression (on average 3.6, 21.5, and 41.3 plants m^{-2} and 11.0, 49.2, and 161.8 g m^{-2} of DM, respectively). In pepper, oat residues generally determined a higher reduction of weed density and species richness compared to hairy vetch and canola regardless the residue management treatments. Converting cover crop aboveground biomass into mulch strips greatly reduced weed species density but did not always imply a reduction of weed species diversity in pepper compared to MT and CT. The weed species richness was reduced inside the mulch strips, while a richer and more diverse weed community was found outside the mulch strips in NT. Weed community in pepper was mainly composed of annual dicot weeds such as *Amaranthus retroflexus*, *Chenopodium album*, *Solanum nigrum*, *Polygonum aviculare* which were mostly associated with MT and CT tillage systems, while in NT an increase of perennial species such as *Rumex crispus* was observed. These results suggest that it is possible to manage cover crop residues in NT in order to obtain a lower weed density and consequently a higher yield in pepper compared to MT and CT while maintaining a high level of weed diversity.

1. Introduction

Using a great amount of external inputs in intensive agriculture such as intensive tillage, fertilizers and pesticides has caused a dramatic reduction in biodiversity in cultivated fields (Clements et al., 1994), therefore conserving farmland biodiversity has become a fundamental issue for maintaining ecological functions in the agro-ecosystems (Tscharntke et al., 2005). The weeds are part of biodiversity and are able to support biodiversity in agro-ecosystems in many ways. They can provide food for insects and birds (Marshall et al., 2003), and they can affect insect herbivore population dynamics by influencing their natural predators which are generally more abundant in weedy crops (Schellhorn and Sork, 1997). Weeds may also help to contain pest outbreaks by maintaining populations of predators and parasites (Marshall et al., 2003). However weeds are considered one of the main factors limiting agricultural production systems (Oerke, 2006) and the large use of herbicides in modern agriculture plays an important role in determining weed diversity in cropping systems and may differently affect species richness in relation to their selectivity patterns (Tomkins and Grant, 1977). A growing list of herbicide-resistant weeds (Powles et al., 1997) reinforces the concept that the repeated use of herbicides for weed control may not only facilitate the selection and the following infestations of the most

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problematic weed species, but may fundamentally change population genetics towards a reduction of biodiversity (Vandermeer et al., 1998).

Loss of farmland biodiversity can be counteracted by adopting appropriate farming managements that preserve species richness within fields and the nearby uncultivated areas (Marshall, 2009). Integrated Weed Management Strategy (IWMS), which involves the combination of two or more weed control practices, has been identified as a viable alternative for both reducing the use of chemicals to control weeds and increasing biodiversity in agro-ecosystems (Bastiaans et al., 2008). Cover crops and their residue managements have the potential to be an important component in IWMS, since their inclusion in crop rotations could disadvantage the development of weed populations (Kruidhof et al., 2008). In fact, cover crops can reduce weed growth and weed development throughout the cover crop growing season (Campiglia et al., 2010), filling gaps in cropping systems that would otherwise be occupied by weeds (Liebman and Staver, 2001), while after their suppression, the cover crop residues could retard and/or suppress weed emergence and growth due to their chemical and physical effects (Teasdale and Mohler, 1993). Cover crop residues could be tilled into the soil as green manure or left on the soil surface as organic dead mulches in no-tillage systems (Campiglia et al., 2011; Shrestha et al., 2002). Since disturbance caused by tillage is one of the most important factors influencing the composition of the weed flora within cropping systems (Shrestha et al., 2002), the type of cover crop residue management could play an important role in determining the weed community shift (Kruidhof et al., 2009). Understanding how cover crop species and cover crop residue management can affect weed communities may reduce the need of herbicides and may improve the sustainability of the cropping system. The objectives of this study were: (1) to evaluate the influence of some cover crop and soil management practices on weed species composition; (2) to assess associations between cover crop residue management and weed community; (3) to identify suitable cover crop species and residue management practices in order to obtain both an efficient weed management strategy and to maintain a high level of weed species diversity; (4) to determine the effects of cover crop residue management on pepper yield.

2. Materials and methods

2.1. Study site

Two field experiments were carried out during the 2009–2010 and 2010–2011 growing seasons at the experimental farm “Nello Lupori” of Tuscia University (lat. 42°26′ N, long. 12°40′ E), Viterbo, Italy. The experimental site has a typical Mediterranean climate, altitude of 310 m a.s.l, mean annual temperature of 14.5 °C, 342 frost-free days, and mean annual rainfall of 750 mm falling mainly from October to May. The soil type is a deep well-drained andosol with the following characteristics: sand 76.3%, silt 13.3%, clay 10.4%, organic matter (Lotti) 1.32%, total nitrogen (Kjeldahl) 0.094%, and pH 6.9 (water, 1:2.5).

2.2. Experimental design

Each experiment consisted in a winter cover crop – pepper sequence. Cover crop treatments were: three cover crops [hairy vetch (*Vicia villosa* Roth., var. Capello), oat (*Avena sativa* L., var. Donata), canola (*Brassica napus* L., var. Licapo)], and a control plot with no cover was included (hereafter called bare soil). Furthermore, in order to evaluate the weed suppressive ability of each cover crop species, a weedy fallow, where the weeds were allowed to grow undisturbed until cover crop suppression, was included. Before pepper transplanting the cover crops were mechanically suppressed and the cover crop residue managements were: conventional tilled (hereafter called CT), minimum tilled (hereafter called MT), and no-tilled (hereafter called NT). Pepper was grown at two weed levels: weed free (hereafter called WF) and weedy (hereafter called W). The experimental design was a split-split-plot with three replications, where the main plots were represented by the cover crops [size 144 m^2 (18 m by 8 m)], the sub-plots were the cover crop residue management treatments [size 48 m^2 (6 m by 8 m)], and the sub-sub-plots were the levels of weed management in the pepper crop [size 24 m^2 (6 m by 4 m)].

2.3. Experimental procedures

Field experiments were carried out in two adjacent fields previously cropped with durum wheat (*Triticum durum* Desf.). In each field the soil was ploughed in the late summer at a depth of 30 cm, and fertilized with 100 kg ha^{-1} of P_2O_5 as a triple super phosphate. It was then harrowed twice (about 10 cm depth) for seed bed preparation. The cover crop species were sown manually and the seed rate was 60, 100, and 15 kg ha^{-1} for hairy vetch, oat, and canola, respectively. They were seeded on 24 September, 2009 and 13 September, 2010 and the seeds were slightly buried approximately 2 cm deep. The bare soil plots were managed similarly to cover crop plots and were kept weed free throughout the cover crop growing season by hand weeding whenever necessary. All cover crops were suppressed at the same time on 21 May, 2010 and 4 May, 2011, the cover crop residues were treated as follows: (i) chopped by means of a straw chopper and immediately incorporated into the soil using a mould-board plough to a depth of 30 cm and then the soil was disked twice (deep soil tillage, CT); (ii) chopped as CT and incorporated into the soil by means of a rotary hoe to a depth of approximately 10 cm (shallow soil tillage, MT); (iii) mowed about 5 cm above the soil surface and placed in mulch strips by means of a hay-conditioner farm machine (no-tilled soil, NT). The mulch strips in NT were 50 cm wide and placed 1 m from one another (from centre to centre of each strip), consequently only 50% of the total ground area was covered in mulch. The following treatments were applied at the same time as cover crop suppression in the bare soil: in NT the soil was left untilled; in MT it was tilled with a rotary hoe; in CT it was mould-board ploughed and disked.

One month old pepper seedlings cv. Cleor were transplanted on 27 May, 2010 and 12 May, 2011 in rows 50 cm apart at 33 cm in the row between two consecutive pepper plants with a density of 3 plants m^{-2}. In NT the pepper seedlings were transplanted in the centre of the mulch strips. Just after transplanting, the pepper seedlings were over irrigated for avoiding moisture stress by means of a single line of drip irrigation tape with 30 cm spaced emitters laid over the mulch in NT and the soil surface in MT and CT. From one week after pepper transplanting to 10 days before the last pepper harvesting, the water input was determined by evapotraspiration estimated by class A pan evaporimeter and converted by crop coefficients (Allen et al., 1998). In weed-free treatments, the weeds were hand weeded whenever necessary, while in weedy plots, the weeds grew undisturbed throughout the pepper cropping seasons. No chemical fertilizer was applied throughout the pepper season. Three and four copper treatments were applied during the pepper cultivation to control disease in 2010 and 2011, respectively. In both years, the pepper fruits were harvested twice on 20 September and 4 October, 2010, and on 25 August and 13 September, 2011.

2.4. Data collection

Just before cover crop suppression, weed species, weed density and aboveground biomass samples were collected in the middle of