Scientia Horticulturae 166 (2014) 97–104

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Do cover crop species and residue management play a leading role in pepper productivity?

E. Campiglia, E. Radicetti*, P. Brunetti, R. Mancinelli

Dipartimento di Scienze e Tecnologie per l'Agricoltura, le Foreste, la Natura e l'Energia, Università della Tuscia, via S. Camillo de Lellis, 01100 Viterbo, Italy

ARTICLE INFO

Article history:
Received 24 April 2013
Received in revised form 6 December 2013
Accepted 17 December 2013

Keywords:
Green manure
Mulch
Hairy vetch
Oat
Weeds
Nitrogen

ABSTRACT

There is a growing interest in improving sustainability in Mediterranean vegetable cropping systems by using winter cover crops. A 2-year field experiment was carried out with the aim of assessing the effect of cover crops and their residue managements on the following pepper (*Capsicum annuum* L.) crop productivity. Treatments consisted of factorial combinations of cover crops [hairy vetch (*Vicia villosa* Roth.), oat (*Avena sativa* L.) and no cover], residue management systems [tilled (as green manure, GM), or mowed and placed in strips in the crop row (as dead mulch, M)]. Cover crops were sown in early September and mechanically suppressed in May about one week before pepper transplanting. The pepper was transplanted in paired rows which were placed in the middle of the mulch strips in M treatments, the same geometry was maintained in the other treatments. The pepper crop was not fertilized and mechanically weeded twice only in the inter-row space between the paired rows in order to minimize agronomical inputs. At cover crop suppression, hairy vetch showed the highest aboveground biomass and total nitrogen content (712 g m^{-2} of DM and 197 kg of N ha^{-1}, respectively), while oat exerted the strongest weed reduction. The marketable pepper yield was higher in hairy vetch than oat and no cover regardless of residue management (on average 25.4, 9.9 and 12.0 t ha^{-1}, respectively) probably due to an abundant availability of soil nitrate throughout the pepper growing season. This was confirmed by high and constant values of SPAD readings of pepper plants grown in hairy vetch. Cover crop residues placed in strips suppressed weeds more effectively than incorporated residues. A better nitrogen nutrition and weed control led to an increase in pepper productivity cultivated in vetch mulch strips. Therefore combining legume cover crops and a strip mulching technique to manage cover crop residues could contribute to effectively increasing the crop productivity and consequently the yield of the following pepper crop. This management package could be considered an important option for organic and conventional growers seeking a way to reduce the agronomical inputs in a winter cover crop–pepper sequence.

1. Introduction

Winter annual legume and non-legume species have been used for centuries as cover crops in many agricultural systems, but their use over the past decades has been minimal (Hartwig and Ammon, 2002). In fact, modern external inputs such as synthetic fertilizers and pesticides have replaced some cover crop functions (Liebman and Davis, 2000), although the use of chemicals is often associated with environmental and human health risks (Kropff and Walter, 2000; Schroeder et al., 1993). More sustainable agricultural practices are required in order to reduce the occurrence of these problems (Uchino et al., 2011). Therefore, in recent years cover crops have gained popularity as part of modern sustainable agricultural systems (Picard et al., 2010). Although they can provide several benefits (Sarrantonio and Gallandt, 2003; Hartwig and Ammon, 2002), cover crops are often used primarily for providing nutrients and supporting weed control in the subsequent cash crop (Kruidhof et al., 2008). In fact, nitrogen fertilization and weed control are crucial issues in agricultural production systems as a good availability of nutrients and low weed competition enhance the crop biomass and productivity (Blackshaw et al., 2004). However, the quality and quantity of cover crop residues and their management affect nutrient dynamics (Ruffo and Bollero, 2003) and weed establishment in different ways (Kruidhof et al., 2009). Grass cover crop residues show a strong weed suppressive ability partly due to allelophatic potential (Hooker et al., 2008; Weston, 1990), nevertheless they are the most resistant to decomposition mainly due to the high C:N ratio which causes nitrogen immobilization (Ranells and Wagger, 1996) and competition with the following cash crop for the available nitrogen in the soil (Döring et al., 2005). The use of legume cover crops represents a potentially valuable source of nitrogen for replenishing soil nitrogen pools (People and Craswell,

* Corresponding author. Tel.: +39 0761 357538; fax: +39 0761 357558.
E-mail address: radicetti@unitus.it (E. Radicetti).

0304-4238/$ – see front matter
http://dx.doi.org/10.1016/j.scienta.2013.12.018

1992), and their residues mineralize rapidly releasing nutrients for the following main crop (Radicetti et al., 2013; Rocecrance et al., 2000). However, the release of nutrients by cover crop residues may favor both crops and weeds depending on their relative growth rate and earliness of competitors (Teasdale and Pillai, 2005). In order to maximize the beneficial effects obtained by the potential release of nutrients, it is important to seek cover crop residue management practices which favor crop competitiveness and reduce weed aggressiveness, resulting in increased productivity of the crop.

When cover crops are incorporated into the soil as green manure (hereafter called GM), their residues mineralize rapidly and release nutrients and allelochemicals (Kuo and Jellum, 2002; Putnam et al., 1983). When cover crops are used in no-tillage systems and their residues are left on the soil surface, as dead mulches (hereafter called M), the residues mineralize more slowly but they make a physical barrier which negatively affects the emergence of weeds (Teasdale and Mohler, 2000).

In the Mediterranean environment, cover crops are usually grown during the winter season and killed in spring prior to planting the summer crop (Teasdale, 1996). The most widely used winter cover crops are grasses which are considered the most suitable catch crops, and legumes are appreciated for their nitrogen supply to the cropping system. Due to the cold growing period, the winter cover crop residues are usually not abundant and they cannot effectively suppress the weeds when left uniformly on the soil surface (Teasdale and Mohler, 2000). Due to the hot growing period of the subsequent cash crop, cover crop residues can mineralize too fast when incorporated into the soil (Ruffo and Bollero, 2003). Therefore, in order to maximize the positive effects associated with their use, it is important to improve cover crop residue management. The objectives of this study were: (i) to identify the best cover crop residue management for improving weed control and nitrogen availability in the subsequent crop; (2) to quantify the influence of cover crop species and their residue management on pepper productivity; (3) to find a management package to minimize the agronomical inputs in a winter cover crop–pepper sequence.

2. Materials and methods

2.1. Experimental site and design

The study was carried out at the experimental farm of the University of Tuscia in Viterbo (upper Latium, 85 km NW of Rome, lat. 42°26′ N, long. 12°40′ E, alt. 310 m a.s.l.). The region has an attenuate thermo-Mediterranean climate (UNESCO-FAO classification) with a mean annual precipitation of 780 mm, mostly concentrated during the autumn and spring seasons, minimum temperatures a little below 0 °C in the winter and about 36 °C as maximum temperatures in the summer. A winter cover crop–pepper sequence was carried out for two growing seasons (2010/2011 and 2011/2012) in two nearby and homogeneous fields previously cropped with durum wheat (*Triticum durum* Desf.). Average soil characteristics at cover crop sowing (0–30 cm layer) were: 76.3% sand, 13.3% silt, and 10.4% clay; pH 6.9 (water, 1:2.5); 1.32% organic matter (Lotti) and 0.094% total nitrogen (Kjeldahl). Each year, a split–split plot experimental design with three replications in randomized blocks was used, the experimental factors were: (i) two cover crop species [hairy vetch (*Vicia villosa* Roth., var. Capello) and oat (*Avena sativa* L., var Donata)] and a no covered soil – (hereafter called no cover); (ii) two different cover crop residue managements [residues mowed and left in strips on the soil surface as organic dead mulch in no-tillage (M treatment) and residues finely chopped and incorporated into the soil in a layer 0–30 cm deep in conventional tillage (GM treatment)]; (iii) two different levels of weed management applied to pepper crop [weed free (hereafter called WF) and weedy (hereafter called W)]. The experimental main plot size was 128 m^2 (16 m × 8 m), the sub-plot size was 64 m^2 (8 m × 8 m) and the sub-sub-plot size was 32 m^2 (8 m × 4 m).

2.2. Cover crop and pepper establishment

In early September of each year (2010 and 2011), the soil was plowed to a depth of 30 cm and fertilized with 100 kg ha^{-1} of P_2O_5 as triple super phosphate. The soil was disked twice (about 15 cm depth) for seed bed preparation. Cover crop seeds were broadcast manually and lightly buried by gentle harrowing on 13 September 2010 and 26 September 2011. The seed rates were the same in both years (60 and 100 kg ha^{-1} for hairy vetch and oat, respectively). After seed bed preparation, the soil in the no cover plots was kept bare by chemical means (glyphosate) until cover crop suppression. On 4 May 2011 and 8 May 2012, hairy vetch and oat cover crops were suppressed as follows: (i) the aboveground biomass was mowed at about 4–5 cm above the soil surface, and arranged in strips by a hay-conditioner farm machine with a cut front of 200 cm (M treatment); (ii) the aboveground biomass was chopped with a straw chopper and incorporated into the soil using a mold-board plough to a depth of 30 cm and then the soil was disked twice for pepper seedling bed preparation (GM treatment). In M treatment, the mulch strips were 80 cm wide, about 10 cm high, and placed 2 m from center to center of each strip, covering 40% of the total ground area (Campiglia et al., 2012). At the same time in no cover treatment the soil was: (i) left untilled; (ii) mold-board ploughed and disked.

On 12 May 2011 and 15 May 2012 one month old pepper seedlings (*Capsicum annum* L.) of the Cleor variety were transplanted by hand. The pepper seedlings were arranged in paired rows at a distance of 40 cm between them and distance of 160 cm between the paired rows. The distance between the pepper plants in the rows was 33 cm, and pepper density was 3 plants m^{-2}. In M treatment the pepper paired rows were placed in the middle of the mulch strips so that the pepper plants were surrounded by a minimum of 20 cm of mulch (Campiglia et al., 2012). The pepper seedlings were over irrigated immediately after transplanting in order to avoid moisture stress. Irrigation water was supplied by drip irrigation tape with 30 cm spaced emitters laid over the mulch layer (in M plots) and the soil surface (in GM and no cover plots) in the middle of paired rows parallel to crop rows. The water input was calculated by evapotranspiration estimated by class A pan evaporimeter and converted by crop coefficients during the pepper growing cycle (Allen et al., 1998), returning 100% of the evapotranspirated water. Irrigation was stopped one week before the final pepper harvesting. All plots were maintained weed free by mechanical means (rotary hoe) applied twice at 25 and 50 days after pepper transplanting (here after called DAT) between the paired rows. All rotary-hoeing operations were carried out in the same orientation with the same driving speed and setting along the pepper rows. Inside the paired pepper rows, the weeds were removed manually whenever necessary (weed free) or left to grow undisturbed throughout the pepper cropping season (weedy). In order to control pepper diseases, repeated copper treatments were applied during the pepper growing cycle. In both years the pepper was harvested twice, on 25 August and 13 September 2011, and 5 and 20 September 2012.

2.3. Sampling and measurements

Cover crop and weed aboveground biomass was separately collected before cover crop suppression. The plants were hand-clipped at the soil surface and sampled using a 50 cm × 50 cm quadrat (0.25 m^2) randomly placed four times in the middle of each plot.