Europ. J. Agronomy 50 (2013) 11–18

Contents lists available at SciVerse ScienceDirect

European Journal of Agronomy

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

Conservation tillage strategy based on the roller crimper technology for weed control in Mediterranean vegetable organic cropping systems

Stefano Canali[a,*], Gabriele Campanelli[b], Corrado Ciaccia[a], Fabrizio Leteo[b], Elena Testani[a], Francesco Montemurro[c]

[a] Consiglio per la Ricerca e la Sperimentazione in Agricoltura, Centro per lo studio delle relazione tra pianta e suolo (CRA-RPS), Via della Navicella, 2 – 00184 Roma, Italy
[b] Consiglio per la Ricerca e la Sperimentazione in Agricoltura, Unità di ricerca per l'orticoltura (CRA-ORA), Via Salaria, 1 – 63030 Monsampolo del Tronto, AP, Italy
[c] Consiglio per la Ricerca e la Sperimentazione in Agricoltura, Unità di ricerca per lo studio dei sistemi colturali (CRA-SSC), SS 106 Jonica, 75010 Metaponto, MT, Italy

ARTICLE INFO

Article history:
Received 18 October 2012
Received in revised form 29 March 2013
Accepted 5 May 2013

Keywords:
Organic farming
Cover crop
Green manure
Zucchini
N use efficiency
Energy saving
Soil water content
Soil temperature

ABSTRACT

A two-year field experiment was carried out at the MOVE (MOnsampolo VEgetables) organic long-term experiment, Monsampolo del Tronto – Central Italy – growing transplanted zucchini (*Cucurbita pepo* L.) to compare the effect of different tillage strategies and cover crop management (no cover crop; green manured barley; in-line till/roller crimped barley) on zucchini yield, zucchini yield quality, weed control and N dynamic in the soil–plant system. Energy consumption for mechanical operations, soil temperature and water content was also evaluated. Zucchini cultivated by the in line tillage/roller crimper technique yielded 69% more than the zucchini preceded by the green manure and similarly to the control. Moreover, zucchini yield quality did not differ among the treatments. Weed above ground biomass was 22 and 91% lower than the control in the green manure and in the roller crimper treatments, respectively. The in line-tillage/roller crimper (ILRC) also increased the N system use efficiency (yield N ratio) of twofold respect to the control and of 29% respect to the green manure treatment. Despite the additional tillage needed to sow and manage the cover crop, the ILRC treatment allowed 10% of work hours and 24% of energy saving respect to the control (no cover crop). Moreover, the in-line tillage/roller crimper technology used 46% of work hours and 56% of energy less than the green manure treatment, which is – so far – the most widely used system by organic farmers to manage cover crops. Our results demonstrated that the adoption of the novel ILRC technology would considerably contribute to enhance the sustainability of the organically managed vegetable cropping systems.

1. Introduction

In the last years the no-till organic production systems that use the roller-crimper technology have been receiving increasing interest for their capability to control weeds, to respect soil quality, to reduce soil erosion as well as labor costs and fossil fuel origin energy consumption (Altieri et al., 2011; Luna et al., 2012; Carr et al., 2012a).

Most of the studies reported in the current scientific literature have been carried out on cover-crop based organic rotational no-till grain production systems located in different regions of USA (Carr et al., 2012b; Delate et al., 2012; Mirsky et al., 2012; Reberg-Horton et al., 2012), northern great plains of Western Canada (Halde et al., 2011) and Southern America (Lana, 2007). Conversely, fewer papers report outcomes about vegetable crops (Altieri et al., 2011; Leavitt et al., 2011; Delate et al., 2012; Luna et al., 2012). Furthermore, as recently reported by Carr et al. (2012a) and Peigné et al. (2007), results obtained in Central and Mediterranean Europe regarding the use of killed cover crop mulch for weed suppression are not available so far.

With specific regard to the Mediterranean regions of Europe, North Africa and Middle East, the conservation no-till or minimum tillage systems based on the use of a roller crimper to terminate cover crops could have a great potential to control weeds and provide additional relevant ecosystem services (i.e. soil temperature control, energy and water saving) either in grain production systems and in organically managed vegetable cropping systems which are widely widespread in Mediterranean areas and provide

* Corresponding author. Tel.: +39 06 7005413x242; fax: +39 06 7005711.
E-mail address: stefano.canali@entecra.it (S. Canali).

1161-0301/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.eja.2013.05.001

great share of farmer revenues. Raviv (2010) reports that the most important field of research in organic horticulture should be the identification of novel and efficient methods for weed control that have no negative effects on the system sustainability, especially on soil quality parameters. The Author also put in evidence as part of the improved energy efficiency gained by the organic cropping systems is often offset by the increased tillage for weed control and, consequently, energy saving strategies to control weeds need to be further developed.

Despite the no-till roller crimper approach to terminate cover crops and obtain a natural mulch able to obstacle the development of natural plants has been identified as a valuable option to control weeds since a decade, agronomic constrains and risks facing this technique are well known. The most relevant issues have been recently reconsidered and deeply discussed by Altieri et al. (2011) and Luna et al. (2012). These issues are mainly related to (i) the production of proper amount of cover crop biomass before rolling, (ii) the cover crops re-growth during the subsequent main crop cycle, (iii) the nitrogen (N) immobilization and the encumbered fertilizers application due to the mulch and (iv) the poor quality of planting. Obviously, these constrains could even more limit the success of the no till roller crimper technology in the organic vegetable cropping systems because of the low competitive ability of vegetable species toward other plant species (i.e. cover crop and weeds) and their high nutrients demand (Mortensen et al., 2000). Furthermore, most of the vegetable crops are often transplanted and not sowed, thus, in these circumstances, the no-till approach is not feasible.

In order to overcome the constrains of the no-till roller crimper technology, alternative conservation tillage solution based on “hybrid” systems have been proposed. For example, Loy et al. (1987) and Luna et al. (2012) described the so called zone tillage system (or strip tillage system) in which a narrow zone of soil, about 0.25–0.30 m wide, is tilled to control weeds, loosening the soil and prepare the sowing/transplanting bed. The till zone is spaced out with a less intensive tilled (or no-tilled) area, where the mulch is not disturbed. Clearly, this system is a compromise between different strategies (till vs no-till) and the overall evaluation of its sustainability resulted in a trade-off between advantages and limits of the two approaches. However, in these systems, weed control often remains poor, as well as soil disturbance and energy consumption are still high.

A promising, extremely reduced tillage system relying with the concept of the in-line tillage and the use of the roller crimper has been recently developed. It is based on the use of a novel machinery obtained slightly modifying a roller crimper. In particular, a sharp vertical disk and a coulter (or chisel) were in-line installed at front and rear of the roller, respectively (Fig. 1). This machinery allows to flatten the cover crops and, simultaneously, to obtain a 0.2–0.3 m deep and few centimeters wide transplanting furrow, without disturbing the mulch layer which, remaining in place, covers the soil surface, thus providing the expected agronomic and ecological services (i.e. weed control, soil protection). At the same time, since the tillage zone is extremely reduced, soil disturbance and energy consumption are thought to be very low.

In order to establish the feasibility of the above described in-line tillage/roller crimper (ILRC) system in organically managed, specialized, vegetable cropping systems in Mediterranean conditions, a two-year field experiment was carried out in Central Italy, growing transplanted zucchini (*Cucurbita pepo* L.). In more depth, the study was addressed to evaluate the effect of different tillage strategies and cover crop management (i.e. green manuring vs in-line till/roller crimping) on zucchini yield, zucchini yield quality, weed control, N dynamic in the soil–plant system. Energy consumption for mechanical operations, soil temperature and water content in the compared treatments were also evaluated. Furthermore, since information about the agronomic performances of different

Fig. 1. Modified roller crimper for transplanting bed preparation (in-line tillage/roller crimper).

zucchini cultivars cropped in organic farming under different tillage strategies are missing, a comparison between two of the most widespread and farmer's accepted zucchini hybrid in the area was carried out.

2. Materials and methods

2.1. Site, climate and soil properties

A two years field experiment was carried out in 2010 and 2011 at the MOVE (MOnsampolo VEgetables) organic long-term experiment of the Vegetable Research Unit of the Research Council for Agriculture (CRA), located in Monsampolo del Tronto (AP) (latitude 42° 53′ N, longitude 13° 48′ E), in the coastal area of the Marche Region, Central Italy.

The MOVE organic long term experiment was established in 2001 and it is based on a 4-year crop rotation with 6 main crops (namely: tomato, *Solanum lycopersicon* L.; melon, *Cucumis melo* L.; fennel, *Foeniculum vulgare* M. var. *azoricum*; lettuce, *Lactuca sativa* L.; cauliflower, *Brassica olaracea* L. var. *botrytis* and bean, *Phaseolus vulgaris* L.) and 3 different cover crops, namely: hairy vetch (*Vicia villosa* R.), cropped before the tomato, barley (*H. vulgare* L.), cropped before the melon, and radish (*Raphanus sativus* L.), cropped before the lettuce. In order to carry out the present study, in the summer 2010 and 2011, the zucchini crop replaced the melon in the rotation. The two crops have a very similar cropping cycle and, according to the market requests, farmers of the area commonly interchange them in the rotation. According to the rotation, barley, which preceded the zucchini, was used as cover crop.

The climate at the MOVE organic long-term experiment is “thermomediterranean”, as classified by UNESCO-FAO (1963). Mean monthly temperatures and the rainfall during the summers 2010 and 2011, compared to the average long term values (30 years), are shown in Fig. 2. According to Soil Taxonomy of the U.S. Department of Agriculture (USDA, 1996), the soil at the field trial site was Typic Calcixerepts fine-loamy, mixed thermic.

Additional information about the long term experiment site, the system management and its agronomic and environmental performances are reported in Campanelli and Canali (2012).

2.2. Experimental design

The experimental design was a strip-plot with three replicates where two factors, the cover crop management and the cultivar, were tested. The strips (21 m × 8 m) were used to test the cover crop management factor and the following three different