Europ. J. Agronomy xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

European Journal of Agronomy

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

Original research paper

Effect of input management on yield and energy balance of cardoon crop systems in Mediterranean environment

Paola A. Deligios[a], Leonardo Sulas[b], Ester Spissu[a], Giovanni Antonio Re[b], Roberta Farci[a], Luigi Ledda[a,*]

[a] Dipartimento di Agraria, Sezione di Agronomia, Coltivazioni erbacee e Genetica, Università di Sassari, Viale Italia 39, 07100 Sassari, Italy
[b] CNR-ISPAAM, Istituto per il Sistema Produzione Animale in Ambiente Mediterraneo, Traversa La Crucca 3, località Baldinca, 07100 Sassari, Italy

ARTICLE INFO

Article history:
Received 22 June 2016
Received in revised form 24 October 2016
Accepted 28 October 2016
Available online xxx

Keywords:
Cynara cardunculus var. *altilis*
Biomass production
Calorific value
Energy efficiency
Energy yield

ABSTRACT

Sustainable cardoon (*Cynara cardunculus* L. var. *altilis* DC.) production system need to be developed to become a large-scale dedicated energy crop. Two field experiments were carried out in Italy to investigate the effects of management intensities and crop age on yield (biomass and seed), thermochemical traits, and energy efficiency of cardoon crops. The first experiment (Exp. 1) was based on the comparison of two crop management intensities (conventional chemical inputs and tillage, CT; reduced chemical inputs and tillage, LI), and it lasted five years. The second experiment (Exp. 2) lasted three years and evaluated two crop densities (standard density, SD; high density, HD). In Exp. 1, CT system performed better than LI for all analyzed agronomic traits. The average net energy yield of CT (157.7 GJ ha^{-1}) was significantly higher compared with LI (103.1 GJ ha^{-1}). The different crop densities in Exp. 2 did not influence seed yield and plant survival in the first and third year. Higher energy surpluses were found for HD than SD, due to the relatively high energy output. Our results also indicate that in less favorable soils at the Exp. 1, conventional management ensures better crop growth and energy budget, whereas in deep soils (Exp. 2), promising results could be obtained combining no N input with adjusted crop density.
© 2016 Elsevier B.V. All rights reserved.

1. Introduction

In EU, the Renewable Energy Directive (Directive 2009/28/EC) requires that 20% of the total energy comes from renewable sources by 2020, and the biomass is an important component of this plan, both in the heating and power sector and in the transport fuels. The Fuel Quality Directive (Directive 2009/30/EC), also calls for a 6% reduction in greenhouse gases in the transport sector by 2020, and it does so by encouraging fuels from renewable sources.

To date, the growing demand for energy is primarily satisfied from dedicated crops but generating the food *vs* fuel debate. Within these considerations, it takes place the deep change that is affecting traditional agriculture in the less fertile and subjected to land abandonment Mediterranean areas. Indeed, we are witnessing to the transition from traditional farming systems to more remunerative agro-energetic ones (Solinas et al., 2015). However, the development of these new cropping systems is not free from the issues related to the use of production inputs such as water, fertilizer or pesticides; thus, their development cannot ignore a careful energy efficiency evaluation of the entire lasting of growing cycle. In the case of annual energetic species, energy efficiency evaluation is somewhat simple to carry on, for perennials would be necessary to evaluate it by considering the entire lasting of multi-year cycle (e.g. at least three years or more).

Perennial energetic species show a series of advantages as a more efficient use of sunlight, water, and nutrients in addition to the ability to give good biomass productions even in minimal management conditions (Pedroso et al., 2014; Mauromicale et al., 2014). Therefore, the perennial species growing on the same field for more than one year could ensure inevitable benefits in terms of economic and environmental sustainability (Blanco-Canqui, 2010; Mishra et al., 2013; Pedroli et al., 2013; Smith et al., 2013; Deligios et al., 2014). Furthermore, the cultivation of dedicated perennial species for energy purposes, in marginal and abandoned lands with fewer negative effects (Bouriazos et al., 2014; Searle and Malins, 2014), is a source of many recommendations in policies support strategies (EEA, 2011).

Among perennials, cardoon (*Cynara cardunculus* L. var. *altilis* DC.) is considered by several authors as an important bioenergy species showing valuable characteristics (e.g. perenniality, good

* Corresponding author.
E-mail address: lledda@uniss.it (L. Ledda).

http://dx.doi.org/10.1016/j.eja.2016.10.016
1161-0301/© 2016 Elsevier B.V. All rights reserved.

Please cite this article in press as: Deligios, P.A., et al., Effect of input management on yield and energy balance of cardoon crop systems in Mediterranean environment. Eur. J. Agron. (2016), http://dx.doi.org/10.1016/j.eja.2016.10.016

biomass production and drought tolerance) that make it particularly suited to semi-arid environments (Fernández et al., 2006; Vasilakoglou and Dhima, 2014; Christodoulou et al., 2014). Concurrently, cardoon crop is also gaining interest for its multipurpose uses and as feedstock for novel industrial bio-based products obtained from third generation biorefinery (Raccuia and Melilli, 2007, 2010; Cravero et al., 2012; Centi and Perathoner, 2012; Ramos et al., 2013).

In the last years, some studies on cardoon were focused on lowering agronomic inputs and on the impacts of these inputs reductions in terms of yield performance (Vasilakoglou and Dhima, 2014). Apart from water supply that has a clear positive effect, the application of N fertilizer is considered one of the main energy input and source of greenhouse gases emissions during perennial grasses cultivation for biofuel purposes (Angelini et al., 2009; Mantineo et al., 2009). Furthermore, the response of cardoon to N fertilizer is not clear and results are conflicting due to variations in soil, crop management, and stand age (Ierna et al., 2012; Mauromicale et al., 2014). Some studies have reported limited to no yield response to N fertilization (Mantineo et al., 2009; Ierna et al., 2012) while others reported significant yield responses (Fernández et al., 2002, 2006; Archontoulis, 2011).

Accurate estimates of agricultural efficiency, calculated using energy balance tools, could provide insights into how society can meet food and fuel security needs while minimizing fossil fuel impacts. Indeed, according to Nassi o di Nasso et al. (2010), among criteria accounting for the selection of suitable energy crops, energy balance is a very important tool to evaluate the energy sustainability of crop systems and as support to policy strategies, in order to identify the best agricultural practices able to guarantee the bioenergy production sustainability. As regard cardoon, few empirical studies comparing 'whole-system-multiyear' energy balances are available so far (Angelini et al., 2009; Mantineo et al., 2009).

However, their results did not show the variation in energy balances between different management of soil tillage, zero N input and no water supply for the entire lasting of the crop cycle, and/or by varying plant density.

In particular, Mantineo et al. (2009) considered two different water supply treatments, but consumption of freshwater resources for bioenergy production is a great concern at present time and for future. Bioenergy systems are little sustainable if they occupy irrigable land and consume limited freshwater resources that are needed for human and industrial uses. In fact, for semi-arid areas such as Mediterranean, where water supplies in certain regions are already under constraints, water use becomes a critical issue for the success of the bioenergy industry.

Moreover, from an energy balance perspective, there is a general tendency to consider the entire aboveground biomass as a single output instead of splitting into biomass and seed yield in order to consider cardoon a dual-purpose bioenergy crop (providing both biomass and oil-rich seeds).

Furthermore, in the previous cited energy balance studies, the cardoon crop was cultivated in small plots (25–50 m^2), the typical ones for agronomic purpose investigations. Comprehensible indicators for the evaluation of sustainable development should be based on real and representative farm data by considering the diversity of agricultural production. Since cardoon cultivation in Mediterranean regions shows a wide variation, representative energy balances should preferably relate to data from at least large scale cultivation.

In our studies we set up two integrated experiments since large plots more closely mimic real farm conditions. Our research questions, aimed to fill the gap in knowledge regarding cardoon crop management and energy efficiency, were: what happens if (i) soil tillage is simplified; (ii) water and N fertilizer are not supplied; (iii) plant density shifts from a standard to a high level.

Therefore, the objectives of this study were to calculate energy balances for different cardoon management, analyze the crucial factors for the energy balances and identify optimal cultivation methods for an energy efficient cardoon cultivation.

2. Materials and methods

2.1. Experimental sites and treatments

In order to derive additional information useful to improve the performances of multiannual cardoon cropping systems, two independent field experiments were carried out in North-West Sardinia (Italy). As shown in previous researches (Dono et al., 2012; Cocco et al., 2014; De Menna et al., 2016), the studied area is representative for a large share of sites in the Mediterranean region. The climate is attenuated thermo-Mediterranean (Emberger et al., 1962) with a four months drought period in summer coinciding with the highest temperatures. Long-term (l958–2004) average crop year (September–August) precipitation in this area is about 550 mm (Tables A.1 and A.2). Agriculture in the study region is generally rainfed, cereal-based and extensively managed, with low crop yields due to the low and especially fluctuating rainfall. For both experiments, plants were grown without supplemental irrigation in all the growing seasons.

2.1.1. Experiment 1

The first experiment (Exp. 1) was conducted at the 'Mauro Deidda' Experimental Farm (Lat. 41° N, Long. 9° E, 81 m a.s.l.) of the University of Sassari, from 2007 to 2012. The soil is classified as Eutric Leptosols and Vertic Cambisols (FAO, 2006). The soil is a clay-loam overlaid on limestone with an average N content of 1.12 g kg^{-1} (Table A.3), a phosphorous content of 38 ppm, and organic matter and organic carbon contents of 1.65% and 0.21%, respectively (Table A.3). Soil depth ranges from 50 to 80 cm according to the occurrence of a limestone layer. The experiment studied the effect of two different management intensities (i) with conventional chemical inputs and tillage (CT); and (ii) with reduced chemical inputs and tillage (LI) combined with plant age (i.e., years from 1st to 5th of the cardoon crop cycle). The experimental design for perennials crops was a randomized complete block with four replicates and repeated overall years. Each plot in the experiment had the size of 625 m^2. In the year of planting, primary tillage included ploughing and harrowing. In CT treatment, after primary tillage, seedbed preparation was adjusted to give a satisfactory seedbed with one pass of a roller. For both treatments, sowing was performed with a precision pneumatic seed drill using a seed rate of 4 kg ha^{-1} of the 'Bianco Avorio' cultivar. At planting, both CT and LI treatments received 80 kg nitrogen (N) fertilizer ha^{-1} and 100 kg phosphorus (P_2O_5) fertilizer ha^{-1}. In the following years, CT was fertilized with 100 kg N fertilizer ha^{-1} y^{-1} split in two applications at re-growth stage (BBCH code 00) and at floral elongation stage (BBCH code 55) (Archontoulis et al., 2010). In the years subsequent to planting, the LI treatment received N fertilizer at a rate equivalent to 50% of the CT treatment applied at re-growth stage of the crop. For both treatments, to take into account soil P_2O_5 depletion due to crop residues removal, 65 kg phosphorus (P_2O_5) fertilizer ha^{-1} were applied each year at re-growth stage of the crop. Weed control in the CT was provided at year of planting in order to ensure a better plants establishment. No weed control was provided to LI treatment.

2.1.2. Experiment 2

The second experiment (Exp. 2) was carried out at the experimental station of CNR at Leccari, Sassari (Lat. 40° N, Long. 8° E; 27 m a.s.l.) from 2013 to 2015. The soil, classified as a Eutric, Calcaric and Mollic Fluvisol (FAO, 2006), is sandy-clay-loam, alkaline

Download English Version:

https://daneshyari.com/en/article/5761335

Download Persian Version:

https://daneshyari.com/article/5761335

Daneshyari.com