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Sustainability evaluation of Sicily's lemon and orange production: An energy, economic and environmental analysis

M. Pergola[a], M. D'Amico[b], G. Celano[a,*], A.M. Palese[a], A. Scuderi[b], G. Di Vita[b], G. Pappalardo[b], P. Inglese[c]

[a] Università degli Studi della Basilicata, Via Nazario Sauro, 85, 85100 Potenza, Italy
[b] Università degli Studi di Catania, Via Santa Sofia, 100, 95123 Catania, Italy
[c] Università degli Studi di Palermo, Viale delle Scienze, 90128 Palermo, Italy

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ABSTRACT

The island of Sicily has a long standing tradition in citrus growing. We evaluated the sustainability of orange and lemon orchards, under organic and conventional farming, using an energy, environmental and economic analysis of the whole production cycle by using a life cycle assessment approach. These orchard systems differ only in terms of a few of the inputs used and the duration of the various agricultural operations. The quantity of energy consumption in the production cycle was calculated by multiplying the quantity of inputs used by the energy conversion factors drawn from the literature. The production costs were calculated considering all internal costs, including equipment, materials, wages, and costs of working capital. The performance of the two systems (organic and conventional), was compared over a period of fifty years. The results, based on unit surface area (ha) production, prove the stronger sustainability of the organic over the conventional system, both in terms of energy consumption and environmental impact, especially for lemons. The sustainability of organic systems is mainly due to the use of environmentally friendly crop inputs (fertilizers, not use of synthetic products, etc.). In terms of production costs, the conventional management systems were more expensive, and both systems were heavily influenced by wages. In terms of kg of final product, the organic production system showed better environmental and energy performances.

1. Introduction

In 2010 the worldwide production of citrus was around 124 million tons. Italy is the eighth biggest producer with 3.2 millions tons and 172,618 ha, 60% of which are made up of orange orchards (103,313 ha) and 16.7% of lemon orchards (28,854 ha) (FAOSTAT, 2010). The areas of cultivation are mainly in Southern Italy, particularly in Sicily, where the production of red oranges, such as 'Tarocco', 'Moro', 'Sanguinello' and 'Sanguigno' is concentrated in the foothills of the Etna volcano and where along the coast 90% of the Italian lemon industry is located, based on three major cultivars: 'Femminello' (95%), 'Monachello' (2%) and 'Interdonato' (3%).

Over the last few decades, Italian citrus fruit producers have been losing their competitive edge to both the foreign and domestic markets (Baldi, 2011). Organic farming may represent a positive factor for the revival of citrus production, overcoming the negative factors that are currently weighing on the sector: lack of organization, small-sized farms, increasing input costs, and strong competition from other Mediterranean countries. In Italy, organic citrus growing represents 14% (23,424 ha) of the total acreage dedicated to citrus orchards. Of this 14%, organic orange groves account for 55% and lemon orchards for 19% (SINAB, 2010).

According to Madge (2009), citrus is well suited to organic production. It is considered by some (Kaval, 2004) as one of the more profitable crops using organic methods. As Kaval (2004) said, the quality of the end product benefits a lot from this technology.

The agro-food sector is one of the most significant contributors to energy consumption and thus to Global Warming Potential (GWP) (Gan et al., 2010) for the increase of greenhouse gases

Abbreviations: CL, Conventional Lemon; OL, Organic Lemon; OO, Organic Orange; CO, Conventional Orange; EA, Energy Analysis; LCA, Life Cycle Assessment; GWP, Global Warming Potential; AD, Abiotic Depletion; OLD, Ozone Layer Depletion; AA, Air Acidification; PO, Photochemical Oxidation; EU, Eutrophication.

* Corresponding author. Università della Basilicata, Viale dell'Ateneo Lucano, 10, 85100 Potenza, Italy. Tel.: +39 0971 205274; fax: +39 0835 1971441.
E-mail addresses: giuseppe.celano@unibas.it, celano.giuseppe@gmail.com (G. Celano).

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(GHG), mainly carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) in the atmosphere causing temperature to rise. Significant improvements are thus required to make food production and consumption more sustainable. As Gan et al. (2010) said, a comprehensive approach is needed to address issues such as technological innovation, consumer demand, and long-term environmental changes.

Efficient energy use in agriculture is one of the conditions for sustainable agricultural production, since it provides financial savings, preserves fossil resources and reduces air pollution (Pervanchon et al., 2002). According to Ozkan et al. (2004), considerable research has been conducted on energy use in agriculture and in conventional citrus production, however there is little scientific literature available on energy consumption in organic citrus production.

Namdari et al. (2011) carried out an input–output energy analysis of conventional citrus production in the Mazandaran province (Iran) to identify the major energy flows. Polychronaki et al. (2007) used an energy analysis to evaluate the energy efficiency of production processes, including conventional citrus production, in order to compare their energy consumption and to examine the sustainability of agro-ecosystems. Ozkan et al. (2004) carried out an energy and economic analysis of conventional citrus production in Turkey for an energy audit of citrus production. Only La Rosa et al. (2008) have used the energy analysis to compare conventional and organic productions of red oranges in Sicily, and to evaluate use of resources, productivity, environmental impact and overall sustainability. However this study is not directly comparable with our research since a different methodology was applied.

Although in the last decade the use of the life cycle assessment (LCA) methodology on food-processing has increased (Clasadonte et al., 2010), in the citrus sector only orange production is sufficiently weighed. As Knudsen et al. (2011) noted, LCA studies have focused mainly on orange juice (Coltro et al., 2009; Beccali et al., 2009; La Rosa et al., 2008; Schlich and Fleissner, 2005; Clasadonte et al., 2010; Munasinghe et al., 2009; PepsiCo UK & Ireland, 2008; Tesco, 2009; Tropicana, 2009). Regarding the carbon footprint (CF), data on greenhouse gas (GHG) emissions have been collected for orange production in Brazil, Italy and Spain, however, as Mordini et al. (2009) showed, only a few publications have reported data for agricultural production, while other data have been documented for the whole production chain of orange juice. Two studies reported GHG emissions for various production steps of the orange production in Spain (Ribal et al., 2009; Sanjuán et al., 2005). A complete literature review assessing the sustainability or environmental impacts of fruit production can be found in Cerutti et al. (2011).

The combined use of LCA and energy analysis could be useful to provide information for policy makers and producers in choosing sustainable management systems or products. In any case, increases in sustainable agricultural production with competitive costs, are vital to improve the economic conditions for farmers. In food production, the usual criteria to compare different management systems are the net return and the benefit–cost ratio (Ozkan et al., 2004, 2007), however as Mohammadi and Omid (2010) noted, the main objective in agricultural production is to increase yield and decrease costs.

Most studies, apart from Clasadonte et al. (2010), have analysed citrus production referring to only one crop year. Only a few research studies have compared organic and conventional farming (Knudsen et al., 2011; Ribal et al., 2009; La Rosa et al., 2008).

The aim of our study was to evaluate the sustainability of organic farming methods compared to conventional methods through an energy, environmental and production cost analysis of the whole production cycle of lemon and orange orchards (from orchard establishment to the end of the crop cycle).

2. Materials and methods

2.1. Orchard management systems

The study was performed in the provinces of Catania and Syracuse (Sicily, Italy). Data were collected from 80 face-to-face interviews with orange and lemon growers over the last four production years (2008–2011), using a survey questionnaire that was developed from results and information derived from previous focus groups. The questionnaire was administered to a stratified sample of producers, representative of study areas (farm size and homogeneous characteristic of cultivation and environment). Of these, four orchard systems, all of the same age, were chosen as case studies (conventional lemon – CL; organic lemon – OL; conventional orange – CO; organic orange – OO).

For a comprehensive analysis, field results, integrated with the literature data, were extended to the whole production cycle of citrus systems. Following suggestions from Milà i Canals et al. (2006) and Cerutti et al. (2010), the whole orchard life cycle was considered. The following farming operations were taken into account: orchard plantation (soil preparation, pre-plantation fertilization, tree plantation, irrigation system); soil tillage; fertilization; irrigation; weed and disease control; pruning; harvesting and orchard removal (Tables 1 and 2).

Lemon and orange orchards differed in terms of type and quantity of inputs used and also pruning operations: the lemon orchards were manually pruned every year, while the orange orchards were manually pruned soon after plantation and mechanically pruned a few years afterwards. Pruning residues were collected manually and removed from the lemon orchards for the subsequent burning, while they were cut and left on the ground as a mulch in the orange orchards. The two management systems (conventional and organic) differed mainly in terms of fertilization and weed and disease control techniques.

The reference period of the analysis was set at 50 years, equal to the average productive cycle for citrus orchards. The energy, economic and environmental evaluations performed refer to 1 ha and 1 kg of output (fruit crop yield).

2.2. Energy analysis (EA)

Following Namdari et al. (2011), the energy analysis technique was used to calculate the energy involved in the production of citrus. The data collected cover the duration of each operation and the quantities of each input (machinery, fuel, fertilizers, chemicals, irrigation water, labour, etc.). Energy values of unit inputs are given in mega joules (MJ) by multiplying each input by its own coefficient of equivalent energy factors taken from the literature (Pimentel and Pimentel, 1979; Volpi, 1992; Monarca et al., 2009; Page, 2009).

In order to calculate machinery energy, the following formula was used:

$$\mathrm{ME} = \left[\left(E_{\mathrm{eq}}{*}G/T\right)\right]{*}H \quad (1)$$

where E_{eq} was the machinery energy equivalent (MJ kg^{-1}), G the weight of machines (kg), T the economic life of machines (h), and H the number of hours the machine was used to carry out the various operations (h) (Ozkan et al., 2007).

Energy consumption for machinery maintenance was estimated as a percentage of energy in manufacturing and materials (23% for tractors; 30% for tillage machines) (Milà i Canals, 2003).