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ENERGY USE IN CITRUS PRODUCTION OF MAZANDARAN PROVINCE IN IRAN

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ABSTRACT

Energy is a fundamental ingredient in the process of economic development, as it provides essential services that maintain economic activity and the quality of human life. Modern agriculture has become very energy-intensive. The aim of this study was to evaluate energy use in citrus production in the Mazandaran Province in Iran. Data used in this study were obtained from 155 farmers using a face-to-face interview method. The total energy requirement under citrus farming was 17,112.2 MJ ha^{-1}, whereas 36.3 and 33.62% was consumed due to fertilisers and pesticides, respectively. Renewable energy was about 12% of total energy input. The energy ratio, productivities, specific and net energy gain were 1.71, 0.905, 1.104 and 12,251.4 MJ ha^{-1}, respectively. Citrus production needs to improve the efficiency of energy consumption and to employ renewable energy.

Key Words: Energy ratio, fertiliser, renewable energy, pesticide

RÉSUMÉ

L'énergie est un ingrédient fondamental dans le processus de développement économique, étant donné qu'ellefournit de services essentiels pour le maintien des activités économiques et la qualité de vie humaine. L'agriculture moderne est devenue trop exigente en énergie. L'objet de cette étude était d'évaluer l'usage de l'énergie dans laproduction de la pomme dans la Province d' Mazandaran en Iran. Les données utilisées dans cette étude étaientobtenues de 155 fermiers par la méthode d'interview face à face. Le total des besoins en énergie pour la production de la pomme était de 17,112.2 MJ ha^{-1}, alors que 36.3 et 33.62% étaient consommés par des pesticides, et poisons chimiques, respectivement. L'énergie renouvelable était de 12% du total d'énergie fournie. Le rapport de l'énergie fournie à celle consommée, la productivité, le gain net et spécifique en énergie étaient de 1.71, 0.905 kg MJ^{-1}, 1.104 MJ kg^{-1} et 12,251.4 MJ ha^{-1}, respectivement. La production de la pomme nécessite une amelioration efficiente de la consommation énergétique et l'emploi de l'énergie renouvelable.

Mots Clés: Le rapport de l'énergie, engrais, des énergies renouvelables, pesticide

INTRODUCTION

Citrus fruit (mandarins, Clementine and oranges) is among the most important tree fruit crops in the world. The term citrus includes four different types of fruits, namely, oranges, mandarin/ tangerine, lemon and grapefruit. Citrus fruits are produced in warm temperate to tropical areas of the world. According to FAO projections of World Production and Consumption of Citrus in 2010, Iran is one of the major citrus (Orenges, Lemons and Limes) producers (Sprean, 2010).

Energy is a fundamental ingredient in the process of economic development, as it provides

essential services that maintain economic activity and the quality of human life. Shortages of energy are a serious constraint to the development of low-income countries. However, considering the limited natural resources and the impact of using different energy sources on environment and human health, it is imperative to investigate energy use patterns in agriculture (Hatirli *et al.*, 2005). Energy input-output analysis is usually used to evaluate the efficiency and environmental impacts of production systems (Uhlin, 1998; Yilmaz *et al.*, 2005).Citrus are one of the most common fruits consumed on a regular basis by people globally. Citrus in Iran are often produced in mid-tropical and wet climate areas. Iran produces 4.216 million metric tonnes of citrus each year (Anon., 2008). Moreover, Mazandaran Province has produce 40% of that amount. The aim of this study was to assess energy use in citrus production, and the efficiency of energy consumption.

MATERIALS AND METHODS

Location. The study was carried out in 155 citrus producers in the Mazandaran Province in Iran. The province is located in the north of Iran, within 35° 47' and 36° 25' N latitude and 50° 34' and 54° 10' E longitude. Data were collected from the growers by using a face-to-face questionnaire in April to May 2012. In this study 5 zones were selected for sample, namely. Ramsar, Chalous, Amol, Sari and Behshahr.

Sampling. Random sampling of farms was done within whole population and the size of each sample was determined using Equation (1) (Stout, 1990).

$$n = 1 \quad \left(\sum N_h S_h\right)^2 \Big/ \left(N^2 D^2 + \sum N_h D_h^2\right) \quad (1)$$

Where:

n = required sample size;
N = number of holdings in target population;
N_h = number of the population in the h stratification;
S_h = standard deviation in the h stratification;
S_h^2 = variance of h stratification;
d = precision where $\left(\bar{x} - \overline{X}\right)$; and
z = reliability coefficient (1.96, which represents the 95% reliability); $D^2 = d^2 / z^2$

Energy indexes and equivalents of used input
The energy ratio (energy use efficiency), energy productivity, specific energy and net energy were calculated as per Equations 2 to 5 (Demircan *et al.*, 2006).

$$\text{Energy Ratio} = \frac{\text{Energy Output (MJ ha}^{-1})}{\text{Energy Input (MJ ha}^{-1})} \quad \ldots\ldots (2)$$

$$\text{Energy Productivity} = \frac{\text{Citrus Output (kg ha}^{-1})}{\text{Energy Input (MJ ha}^{-1})} \quad \ldots (3)$$

$$\text{Specific Energy} = \frac{\text{Energy Input (MJ ha}^{-1})}{\text{Citrus Output (kg ha}^{-1})} \quad \ldots\ldots (4)$$

$$\text{Net Energy} = \frac{\text{Energy Output (MJ ha-1)}}{\text{\% Energy Input (MJ ha}^{-1})} \quad \ldots\ldots (5)$$

Inputs in citrus production in Iran are human labour, machinery, diesel fuel, inorganic fertilisers, manure, pesticides and irrigation water (Rafiee *et al.*, 2010). Outputs are citrus fruits. Energy equivalents shown in Table 1 were used for estimation. Basic information on energy inputs and citrus yields were analysed using the Statistical Package for Social Scientists (SPSS) Version 17 and Excel 2010.

Based on the energy equivalents of the inputs and outputs, output-input energy ratio, energy productivity, specific energy and net energy gain were calculated (Singh, 2002; Sartori *et al.*, 2005; Demircan *et al.*, 2006). Input energy is also classified into direct, indirect, renewable and non-renewable forms. The indirect energy consists of pesticide, fertiliser, machine and equipment, manure fertiliser and labour; while the direct energy includes diesel and electricity used in the production process. On the other hand, non-renewable energy includes diesel, electricity, pesticide, fertilisers and machinery; while renewable energy consists of human and manure fertiliser (Demircan *et al.*, 2006).

RESULTS AND DISCUSSION

The farms investigated were mainly devoted to citrus production. In the non-mechanised form, tillage was done with human power, while in the mechanised form it was done with rotary tiller that gives power from power take off shaft of tractor. Scatter of manure was done before tillage operation. Both spread and cart of manure was done with human power. Operations of pest control mainly were mechanised and a few of them (e.g. fungicide) were non-mechanised. Pruning operations were done with labour power and handsaw or motor saw. Harvesting was done by labour. Chemical fertilisers were used at about 139 kg ha^{-1}; while manure consumed was about 4,682 kg ha^{-1}.

A lot of manure was used because of the availability in the region. Application of chemical fertilisers was manual; while manure application was done by fertilising equipment and manual. Of all chemical fertilisers, the share of nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) were 46, 29.1 and 24.9%, respectively.

Analysis of energy use. The energy inputs in citrus production are showed in Tables 2 and 3. Fertilisers were the most energy consuming, and were the premier of energy inputs required in citrus production farms. These results are similar to many studies in orchards (Gezer *et al.*, 2003; Esengun *et al.*, 2007; Canakci, 2010). After fertilisers and pesticides, manure, machinery, fuel, labour and electricity are the most energy consumer inputs, contributing 8.29, 8.18, 7.53, 3.65 and 2.4% total energy use, respectively.

Diesel fuel was mainly consumed for land preparation, pruning practices, orchard spraying with tractor and transportation; and gasoline was mainly consumed for gasoline engine for

TABLE 1. Energy equivalents for different inputs and outputs in citrus production in Iran

Input	Unit	Energy equivalent (MJ $unit^{-1}$)	Source
Labour	h	1.96	Kittani, 1999
Machinery	kg	138	Kittani, 1999
Diesel fuel	L	47.8	Kittani, 1999
Gasoline	L	46.3	Kittani, 1999
Manure	tonne	303.1	Esengun *et al.*, 2007
NH_3	kg	74.2	Lockeretz, 1980
P_2O_5	kg	13.7	Lockeretz, 1980
K_2O	kg	9.7	Lockeretz, 1980
Pesticide	kg	363	Fluck and Baird, 1982
Fungicide	kg	99	Fluck and Baird, 1982
Citrus	kg	1.96	Kittani, 1999

TABLE 2. Percentage of energy input in citrus production in Iran

Inputs	Percentage
Fuel	7.54
Electricity	2.42
Machinery	8.20
Fertilisers	36.30
Pesticides	33.62
Labour	3.65
Manure	8.29
Total	100

TABLE 3. Amount of inputs in citrus production in Iran

Inputs	Energy consumption (MJ ha^{-1})
Fuel	1289.01
Electricity	413.1
Machinery	1400.42
Fertilisers	6212.78
Pesticides	5753.43
Labour	624.05
Manure	1419.38
Total	17112.19

electricity production for irrigation and power operated sprayer. Electricity was the least demanding energy input in citrus production, with 413.1 MJ ha^{-1} (only 2.4% of the total input energy) (Table 3). This was followed by labour with 624.05 MJ ha^{-1} (3.65% of the total input energy). Chemical fertilisers were the highest demanding energy input in citrus production with 6212.78 MJ ha^{-1} (36.3% of the total input energy). Results of this study are similar to the result of other studies where chemical fertilisers consumption was high (Canals *et al*., 2006; Strapatsa *et al*., 2006; Page, 2009). As in this study, despite the fact that part of fertilisers were replaced by manure, fertilisers were equally high. Energy consumption of manure was 1419.38 MJ ha^{-1}. This is a strong point from energy and environment point of view (Table 3). The amount of 88.05% of total energy input resulted from non-renewable and 11.95% from renewable energy; also 9.95% from direct energy and 90.05% indirect energy (Table 4). Direct inputs were mainly fuel and electricity for field operations; and the indirect inputs were included chemical fertilisers, manure, machinery, labour and pesticides. In other words, citrus production was highly dependent on indirect inputs. Proper management of chemical fertilisers, pesticides and manure might reduce the indirect energy requirements for fertilisation, pest control.

Efforts to reduce the direct dependency on energy (fuel and electricity) will improve overall, energy efficiency of citrus production. Results indicate that the current energy use pattern among farms is mainly based on non-renewable (Table 4). Average yield of the citrus fruit in this study was 15,454 kg ha^{-1}. In energy balances, the output-input energy ratio is often used as a parameter to describe the energy efficiency in agricultural production. The average output-input energy ratio was 1.716. In studies that were done on other fruits production systems, energy ratio was mostly between 1 to 2 (Pimentel *et al*., 1983; Reganold *et al*., 2001; Page, 2009; Sami *et al*., 2011). Energy productivity, specific energy and net gain energy were, respectively, 0.905, 1.1 and 12,251.4 MJ ha^{-1}in the peresent study (Table 5).

TABLE 4. Total energy input in the form of direct, indirect, renewable and non-renewable energy for citrus production in Iran

Form of energy	Quantity (MJ ha^{-1})	Percentage [a]
Direct	2043.43	12
Indirect	15068.76	88
Renewable	1702.12	10
Non-renewable	15410.07	90

TABLE 5. Energetic parameters in citrus production in Iran

Parameter	Unit	Value
Energy input	MJ ha^{-1}	17112.19
Energy output	MJ ha^{-1}	29363.63
Yield	Kg ha^{-1}	15454.54
Energy ratio	…	1.716
Energy production	Kg MJ^{-1}	0.905
Specific energy	MJ kg^{-1}	1.10
Net energy gain	MJ ha^{-1}	12251.40

CONCLUSION

Total input energy in citrus production in Mazandaran Province in Iran is 17,112.19 MJ ha^{-1}. Fertilisers and pesticides for fertilisation and pest control are the major energy inputs with 36.3 and 33.62%, respectively. In addition, electricity and labour are lower energy inputs with 2.42 and 3.65%, respectively. About 88% of total energy input in citrus production is non-renewable, while about 12% is renewable. Also about 10% of total input energy is direct and while about 90% is indirect. Thus, use of renewable energy in the farms is low. There is need by citrus farmers to improve the efficiency of energy consumption in production and to employ renewable energy.

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