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## FULL LENGTH ARTICLE

# On-farm energy flow in grape orchards

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## KEYWORDS

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**Abstract** Efficient use of energy is an important step toward enhancing the sustainability of agricultural systems. In this study, we evaluated the energy balance of grape orchards in Shahriar, Iran. We collected information of energy input and energy output in 120 grape orchards through face to face questionnaires. This information was further used to evaluate net energy, energy use efficiency, energy intensity, and energy productivity in these orchards. The total energy used in grape orchards was 31777 MJ ha<sup>-1</sup>. Nitrogen fertilizer, manure, and irrigation water were the major energy-demanding inputs in grape production by a share of 36, 17, and 11% of the total energy inputs, respectively. The energy output was estimated as 202871 MJ ha<sup>-1</sup>. Net energy, specific energy, energy efficiency, and energy productivity in orchard grape were calculated as 171095 MJ ha<sup>-1</sup>, 1.85 MJ kg<sup>-1</sup>, 6.38, 0.54 kg MJ<sup>-1</sup>, respectively. This information can be very useful in evaluating the sustainability of grape production in this region and can also provide a useful guide in order to prioritize the steps toward enhancing energy efficiency in these orchards. © 2016 The Authors. Production and hosting by Elsevier B.V. on behalf of King Saud University. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

## 1. Introduction

Energy is the driving source in agroecosystem. In fact, agricultural systems are both, energy consuming and energy producers (Yilmaz et al., 2005; Cruse et al., 2010; Keshavarz Afshar et al., 2015). Therefore, the balance of energy between energy input and energy output in these systems plays an important role in their overall sustainability. Consumption of energy especially non-renewable energy in agriculture has been following an increasing trend in recent decades (Ozkan et al.,

2004; Mohammadi et al., 2010; Fore et al., 2011). Study of the flow of energy can provide useful information in order to enhance energy efficiency in these systems (Kaltsas et al., 2007; Mohammadi et al., 2014; Afshar et al., 2015).

The energy balance of various agricultural commodities such as kiwifruit (Mohammadi et al., 2010), olives (Kaltsas et al., 2007), apples (Strapatsa et al., 2006), and pistachio (Keshavarz Afshar et al., 2013) has been evaluated. There is little information about energy balance in grape (*Vitis vinifera* L.) orchards. Today, grapes are cultivated in a vast zone worldwide. Grapes are among the major horticultural commodities produced by Iran and this country is ranked 7th in the world for grape production. Therefore, efficient use of energy from this crop is highly important.

Ozkan et al. (2007) examined the energy use patterns in greenhouse and open-field grape production in Turkey. They found that that total input energy use in greenhouse and open-field production was 24,513 and 23,641 MJ/ha,

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respectively. They also reported that output energy of greenhouse and open field grapes were 73,396 and 120,596 MJ ha<sup>-1</sup>, respectively. [Hamedani et al. \(2011\)](#) also reported that average yield and energy input of grape in Hamedan province of Iran were 18,530 kg ha<sup>-1</sup> and 45,214 MJ ha<sup>-1</sup>, respectively. They found that fertilizers, electricity and farmyard manure had the biggest share in the energy input used in grape orchards.

The objective of this study was to evaluate energy input and output of grape orchards in Shahriar, Iran.

## 2. Materials and methods

In this experiment, in-farm flow of energy in grape orchards located in Shahriar, south west of Tehran Province, was evaluated in 2011 and 2012. The data of 120 grape orchards were collected through interviewing the farmers on specially designed and pre-tested questionnaire ([Keshavarz Afshar et al., 2013](#)). These farms were randomly selected based on the stratified random sampling method. The size of each sample was determined using following equation ([Yamane, 1967](#)):

$$n = \frac{(\sum N_h S_h)}{N^2 D^2 + \sum N_h S_h^2}$$

where  $n$  is the required sample size;  $N$  is the number of holdings in the target population;  $N_h$  is the number of the population in  $h$  the stratified;  $S_h^2$  is the variance of  $h$  the stratified;  $D^2 = d^2/z^2$ ;  $d$  is the precision where  $(x-X)$ ; and  $z$  is the reliability coefficient (1.96 which represents the 95% reliability). The permissible error in sample size was defined to be 5%, and the sample size was calculated to be 238 for 95% reliability.

Energy balance was evaluated using the process analysis methodology ([Fluck and Baird, 1980](#)). The study has accounted for energy used in crop production only ([Keshavarz-Afshar and Chen, 2015](#); [Keshavarz Afshar et al., 2015](#)). Data of all inputs including human labor, machinery, diesel fuel, electricity, chemical fertilizers, farmyard manure, pesticides, irrigation water and seed were accounted. The environmental sources of energy (radiation, wind, etc.) were not included in the analysis. System output was dry paddy and straw yield. Using standard energy coefficients ([Table 1](#)), inputs and outputs were converted into their energy equivalents.

Energy inputs were further categorized into direct (human labor, electricity, diesel fuel and irrigation water) and indirect (chemical fertilizers and pesticides, manure, machinery and seed) energies. The inputs were also classified into renewable (human labor, manure, irrigation water and seed) and non-renewable (diesel fuel, electricity, chemicals, and machinery) sources.

Energy balance was evaluated using the following indices ([Keshavarz Afshar et al., 2013](#)):

Energy efficiency = Energy output (MJ ha<sup>-1</sup>)/Energy input (MJ ha<sup>-1</sup>)

Energy Productivity = Paddy yield (kg ha<sup>-1</sup>)/Energy input (MJ ha<sup>-1</sup>)

Specific Energy = Energy input (MJ ha<sup>-1</sup>)/Paddy yield (kg ha<sup>-1</sup>)

Net Energy = Energy output (MJ ha<sup>-1</sup>) – Energy input (MJ ha<sup>-1</sup>)

**Table 1** Energy equivalents used in energy calculation.

Energy source	Unit	Energy equivalent (MJ unit <sup>-1</sup> )	References
<b>Inputs</b>			
Human labor	h	1.96	<a href="#">Keshavarz Afshar et al. (2013)</a>
Nitrogen (N)	kg	60.60	<a href="#">Keshavarz Afshar et al. (2013)</a>
Phosphorous (P <sub>2</sub> O <sub>5</sub> )	kg	11.10	<a href="#">Keshavarz Afshar et al. (2013)</a>
Potassium (K <sub>2</sub> O)	kg	6.70	<a href="#">Keshavarz Afshar et al. (2013)</a>
Manure	kg	0.30	<a href="#">Keshavarz Afshar et al. (2013)</a>
Insecticide	kg	199.00	<a href="#">Keshavarz Afshar et al. (2013)</a>
Fungicides	kg	92.00	<a href="#">Keshavarz Afshar et al. (2013)</a>
Herbicide	kg	238.00	<a href="#">Keshavarz Afshar et al. (2013)</a>
Diesel fuel	L	56.31	<a href="#">Keshavarz Afshar et al. (2013)</a>
Machinery	h	62.70	<a href="#">Keshavarz Afshar et al. (2013)</a>
Water for irrigation	m <sup>3</sup>	0.63	<a href="#">Keshavarz Afshar et al. (2013)</a>
Electricity	kW h	3.6	<a href="#">Kizilaslan (2009)</a>
<b>Outputs</b>			
Grape	kg	11.80	<a href="#">Hamedani et al. (2011)</a>

## 3. Results and discussion

### 3.1. Energy input

The total consumed energy in grape orchards was 31776.6 MJ ha<sup>-1</sup> ([Table 2](#)). The top three energy intensive inputs were nitrogen fertilizer, manure and water for irrigation, which had a share of 36%, 17% and 11%, of the total energy inputs, respectively. [Hamedani et al. \(2011\)](#) reported that total energy input used in grape orchards in Hamedan province of Iran was 45,213 MJ ha<sup>-1</sup> in which chemical nitrogen fertilizer, farmyard manure, electricity and irrigation water were responsible for almost 82% of the total energy inputs in grape orchards of Hamedan province of Iran. [Ozkan et al. \(2007\)](#) also found that chemical fertilizers, Machinery, and human labor were major sources of energy input in grape orchards in Turkey. In their evaluation, total energy input in grape orchards in Turkey was estimated as 24,513 MJ ha<sup>-1</sup>.

Our results showed that about 43% (13,538 MJ ha<sup>-1</sup>) of the total energy input in grape orchards was related to chemical fertilizers. Among the fertilizers, nitrogen possessed the biggest share by 36% proportion in the total energy input. Various rates of nitrogen have been reported for grape production in different regions. For example, [Hamedani et al. \(2011\)](#) and [Ozkan et al. \(2007\)](#) found that application rate of nitrogen in grape orchards in Hamedan province of Iran and Turkey was 202 and 62 kg ha<sup>-1</sup>, respectively. A part of that difference in application rate of nitrogen among the regions is related to variation in use of farmyard manure application in these

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