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Is saffron more energy and economic efficient than wheat in crop rotation systems in northeast Iran?

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A B S T R A C T

Saffron and wheat production systems were evaluated in view of the energy balance in Khorasan Razavi province, Iran. Data and information were collected from saffron and wheat growers in 2013 using the face-to-face questionnaire method. Results showed that the total energy used in various processes for producing saffron and wheat was 21580 MJ ha^{-1} and 32061.21 MJ ha^{-1}, respectively. Among the saffron production practices, corm used for cultivation (seed) had the highest energy consumption (59.66%), followed by nitrogen fertilizer (13.79%) and manure (13.35%). In wheat, nitrogen fertilizer (25.89 %) and electricity (18.64 %) were the most energy-consuming inputs. Renewable energy shares were 79.95% and 26.19% in saffron and wheat systems, respectively. Energy use efficiency was 0.0035 for saffron and 2.63 for wheat. The benefit-to-cost ratios for saffron and wheat production systems were 2.78 and 2.17, respectively. Saffron production was more efficient and sustainable than wheat, because it was more environmentally friendly in terms of ecological indices such as amount of energy used and renewable energy consumption.

Keywords: Crop production; Energy productivity; Renewable energy; Benefit–cost ratio

1. Introduction

Saffron (*Crocus sativus* L.), an autumn-flowering geophyte frequently grown in the Near East and the Mediterranean basin is a chief spice and medicinal plant and one of the most costly plant products (Zohary and Hopf, 1994; Negbi, 1999). It is by far the most expensive spice (Rees, 1988). Recent decades have seen a severe reduction in saffron-cultivated areas in traditional saffron-producing European countries because of the intensive manual labor required to pick the flowers daily and separate the stigmas (Renau-Morata et al., 2012).

In contrast, saffron in Iran is planted as a perennial crop, and its cultivated area has increased greatly from 4100 ha in 1981 to 61 775 ha in 2012 (Anonymous, 2012). In recent years, public interest in using natural additives instead of synthetic chemicals has increased the employ of saffron as a natural flavoring in the food industry (Kafi, 2006).

Iran has a long history of saffron production and has a lot of established saffron populations which are being cultivated since ancient times (Baghalian et al., 2010). Producing more than 90% of the universal production of saffron and having more than 90% of the global saffron cultivation area, Iran is certainly the most important saffron producing country in the world. Khorasan Razavi province, with 61 775 ha of saffron fields, is the greatest saffron cultivation area in Iran. In

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this province, saffron production creates a very key income for numerous rural families and is an important source of employment. One of the most important saffron production and cultivation regions in this province is Torbat Heydarieh covering about 45.5% (28 100 ha) of the cultivated area in Khorasan Razavi province in 2012 (Anonymous, 2012). In this region, some farmers cultivate wheat in crop rotation, but others prefer to cultivate saffron or barley in autumn rather than wheat. Mentioned below are some reasons for substituting saffron for wheat in a rotation: 1—Water shortage and low-level groundwater contribute in the region mean that farmer's prefer to cultivate saffron instead of wheat. 2—Saffron production is much more economically viable than wheat. 3—Saffron is produced by perennial plants so agronomic practice after the first year is less than that of wheat production, which requires annual cultivation. 4—Wheat and saffron are both autumn crops in this particular agricultural region. 5—Wheat and saffron are both tolerant to winter temperatures below freezing. Thus computing energy expenditures and economical indices in wheat and saffron production systems will assist farmers in selecting rotation crops.

The tendency of agricultural systems to rigorously use energy is chiefly because of mechanization and the use of chemical fertilizers, high-yield seeds, and synthetic pesticides. The dependence of conventional agricultural systems on intensive energy use is a major cause of environmental problems such as global warming in most developing and developed countries. Resource and energy use efficiency is one of the primary necessities of eco-efficient and sustainable agriculture (Risoud, 2000). Highly efficient energy use in agriculture will help reduce environmental problems, prevent damage to natural resources, and encourage sustainable agriculture as an economical production system. Energy use is one of the key indicators for developing more sustainable agricultural practices. Vaster use of renewable energy sources, a boost in energy supply, and more efficient use of energy can contribute to meeting sustainable energy development targets (Streimikiene et al., 2007). Therefore, agriculture and energy have complementary structures and are affected by each other.

Many studies have investigated the energy efficiency and economic analysis of different cropping systems, such as irrigated and rainfed wheat, potato, greenhouse strawberry, and greenhouse cucumber in Iran (Banaeian et al., 2011; Mohammadi et al., 2008, 2010; Ghorbani et al., 2011), sugarcane in Morocco (Mrini et al., 2001), rice in Malaysia (Bockari-Gevao et al., 2005), stake-tomato and greenhouse tomato in Turkey (Hatirli et al., 2006; Esengun et al., 2007) and maize and sorghum in the United States (Franzluebbers and Francis, 1995). However, no studies have been published on the energy and economical analysis of saffron production in Iran. In the present study, energy balance and efficiencies for saffron and irrigated wheat (high input) production systems were investigated based on input data from farm surveys conducted in Khorasan Razavi province, Iran.

2. Materials and methods

The survey was carried out in Torbat Heydarieh, Khorasan Razavi province located in northeastern Iran. Data was collected from saffron and wheat growers in 2013 using the face-to-face questionnaire method. Information obtained by surveys and previous studies of related organizations, e.g., Jihad-e-Keshavarzi of Khorasan Razavi province, was also used in this study. A random sampling method was used; the sample size was calculated using Eq. (1) (Newbold, 1994):

$$n = \frac{N \times S^2}{(N-1)S_X^2 + S^2} \tag{1}$$

where n is the required sample size, N is population size, S is standard deviation, S_X is standard deviation of sample mean ($S_X = d/z$), d is the permissible error in the sample size defined to be 5% of the mean for a 95% confidence interval, and z is the reliability coefficient (1.96 which represents 95% reliability). Based on this calculation, sampling sizes of 35 and 40 were considered for saffron and wheat fields, respectively. The most important consideration for selection of sample farms was that of similarity. Criteria for farm selection were; farm size, agricultural practice, irrigation type, sowing method, planting pattern, field age, farmer's knowledge and other technical and economic aspects. Farms with the highest similarity in terms of the specified criteria were selected as samples for the study.

The energy efficiency of the agricultural system was evaluated by the energy ratio between output and input. Human labor, machinery, diesel oil, fertilizer, pesticides, and seed amounts along with output yield values of saffron and wheat production systems were used to estimate the energy ratio. Energy equivalents used for evaluation are presented in Table 1.

Excel software was used to calculate equations relating to energy and economic data. Based upon the energy equivalents of the inputs and outputs (Table 1), the energy ratio or energy use efficiency, energy productivity, and the specific energy were calculated (Tsatsarelis, 1991).

The economic inputs of saffron and wheat production systems were included in fixed and variable expenditures. The fixed costs of production were comprised of land value, water value, and constructions; variable costs were comprised of current costs (e.g., chemicals, fuel, human labor, and electricity). The economic output of saffron and wheat production systems included stigma, leaf, corm, seed, and straw. Net and gross return, gross value of production, total cost of production, benefit to cost ratio, and productivity were calculated based on Erdal et al., 2007; Beheshti Tabar et al., 2010; and Ozkan et al., 2004.

The main agricultural practices applied to each of the crop systems are shown in Table 2.

3. Results and discussion

3.1. *Analysis of energy use in saffron and wheat production systems*

Results indicated that the total energy used in various production processes for producing saffron and wheat was 21 580 MJ ha^{-1} and 32 061.21 MJ ha^{-1}, respectively (Table 3). Among the saffron production practices, consumed corm for cultivation (seed) was the most energy-consuming input (59.66%), followed by nitrogen fertilizer (13.79%) and manure (13.35%) (Table 3). In wheat, nitrogen fertilizer (25.89%) and electricity (18.64%) were the most energy-consuming inputs (Table 4). Zahedi et al. (2015) reported most of the input energy for wheat production was related to diesel fuel, nitrogen and water for irrigation by 42.7%, 17.9% and 10.03%, respectively.