Saffron: An Efficient Crop Production System in Energy Use in Iran

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***Abstract*—Efficient use of energy helps to achieve increased production and productivity, and contributes to the economy, profitability and competitiveness of agricultural sustainability of rural communities. Evaluation of saffron production system in view of energy balance was conducted in Khorasan Razavi province, Iran. Data and information was collected by using a face to face questionnaire from saffron fields in 2013. Results revealed that the total energy used in various production processes for producing saffron was 21580 MJ ha^{-1}. Amongst the production practices in saffron production, consumed corm for cultivation (seed) was the most energy consuming input (59.66%), followed by nitrogen fertilizer (13.79%) and manure (13.35%). Outputs in saffron are consist stigma, leaf and corm. Stigma, leaf and corm yields were 3.86, 1230 and 1630 kg ha^{-1}, respectively for average of five years period. The total energy input consumed could be classified in saffron fields as direct (17.14%), indirect (82.86%), renewable (79.95%), and non-renewable (20.05%), energies. The share of renewable energy input used in total energy input was around 4 times more than non-renewable energy in saffron fields. Overall, in view of sustainability saffron production was a sustainable system.**

***Index Terms*—crop production, energy input, renewable energy**

I. Introduction

Saffron (*Crocus sativus* L.) is one of the major spicy and medicinal plants worldwide. It is one of the most costly of plant product, and the most expensive spice by far [1] an autumn-flowering geophyte broadly grown in the Near East and the Mediterranean basin [2].

In Iran, saffron is planted as a perennial crop and its cultivated area has extensively increased from 4100 ha in 1981 to 61775 ha in 2012 [3]. In recent years, public interest in the use of natural additives in place of synthetic chemicals has increased the use of saffron as a natural flavoring in the food industry [4].

By far Iran has been the most important saffron producing country, producing more than 90% of global production of saffron with around 80,000 ha under its cultivation. This comprises more than 90% of global saffron cultivation area. Khorasan Razavi province with 61775 ha saffron filed is the greatest saffron cultivation area in Iran [3]. In this province, saffron production creates a very key income for numerous rural families and it is an important source of employment.

Tendency towards intensive use of energy in agricultural systems is profoundly due to mechanization, using chemical fertilizers, high-yielding seeds and synthetic pesticides. On other hand, dependence of conventional agricultural systems to intensive using of energy is one of the main reasons creating environmental problems such as global warming in the most developing and developed countries. Resource and energy use efficiency is one of the principal requirements of eco-efficient and sustainable agriculture [5]. High energy use efficiency in agriculture will help to minimize the environmental problems, prevent destruction of natural resources, and promote sustainable agriculture as an economical production system. Energy use is one of the key indicators for developing more sustainable agricultural practices. Wider use of renewable energy sources, increase in energy supply and efficiency of use can make a valuable contribution to meeting sustainable energy development targets [6]. Therefore, agriculture and energy have a complementary structure and are affected each other [7].

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 production system was investigated based on input data from farm surveys in Khorasan Razavi province, Iran.

II. Materials and Methods

The survey was carried out in Torbat-e-Heydarieh in Khorasan Razavi province that locates in the Northeast of Iran. Data were collected from the saffron growers by using a face-to-face questionnaire in 2013. As well information obtained by surveys, previous studies of related organizations such as Ministry of Jihad-e-Agriculture of Khorasan Razavi province was also used in this study. A random sampling method was used; the sample size was calculated using Equation (1) [8]:

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

where n is the required sample size, N is population size, S is standard deviation, SX is standard deviation of sample mean (SX = d/z) , d is the permissible error in the sample size was defined to be 5% of the mean for a 95% confidence interval and z is the reliability coefficient (1.96 which represents the 95% reliability). Based on this calculation a size of 35 was considered as sampling size for saffron fields. The energetic efficiency of the agricultural system has been evaluated by the energy ratio between output and input. Human labor, machinery, diesel oil, fertilizer, pesticides and seed amounts and output yield values of saffron production system have been used to estimate the energy ratio. Energy equivalents revealed in Table I were used for estimation. The sources of mechanical energy used on the selected farms included tractors and diesel oil. The mechanical energy was computed on the basis of total fuel consumption (L ha^{-1}) in different operations. Therefore, the energy consumed was calculated, using conversion factors (1 L diesel = 56.31 MJ) and expressed in MJ ha^{-1} [9].

TABLE I. ENERGY EQUIVALENTS USED FOR ESTIMATION IN SAFFRON

Particulars	Unit	Energy equivalent (MJ $unit^{-1}$)
A. Inputs		Saffron
1. Human labor	h	1.95
2. Machinery	h	62.7
3. Diesel fuel	l	50.23
4. Chemical fertilizers		
(a) Nitrogen (N)	kg	75.46
(b) Phosphate (P2O5)	kg	13.07
(c) Potassium (K2O)	kg	11.15
5. Chemicals	kg or l	
(a) Herbicides		356.29
(c) Pesticides		280.44
(d) Fungicides		181.9
8. Electricity	kWh	3.6
9. Water for irrigation	m3	1.02
10. Manure	kg	0.3
10. Seeds	kg	14.97
B. Outputs		
1. Stigma	kg	19.8
2. Straw	kg	17.4
3. Corm	kg	14.97

Basic information on energy inputs and saffron yield were transferred into Excel spread sheets, and analyzed. Based on the energy equivalents of the inputs and outputs (Table 1), the energy ratio or energy use efficiency, energy productivity and the specific energy was calculated [10].

$$\text{Energy use efficiency} = \frac{\text{Energy output}(MJ\ ha^{-1})}{\text{Energy input}(MJ\ ha^{-1})} \quad (2)$$

$$\text{Specific Energy} = \frac{\text{Energy input }(MJ\ ha^{-1})}{\text{crops output}(t\ ha^{-1})} \quad (3)$$

$$\text{Energy productivity} = \frac{\text{crops output}(Kg\ ha^{-1})}{\text{Energy input}(MJ\ ha^{-1})} \quad (4)$$

$$\text{Energy intensiveness} = \frac{\text{Energy input }(MJ\ ha^{-1})}{\text{cost of cultivation }(\$\ ha^{-1})} \quad (5)$$

Net energy = Energy output (MJ ha^{-1})–Energy Input (MJ ha^{-1}) (6)

Indirect energy included energy embodied in seeds, chemical fertilizers (NPK), herbicide, pesticide, fungicide and machinery while direct energy covered human labor, diesel, electricity and irrigation water used in the saffron fields. Non-renewable energy includes diesel, electricity, chemical fertilizers, herbicides, pesticides, fungicides and machinery, and renewable energy consists of human labor, seeds and irrigation water.

III. RESULTS AND DISCUSSION

A. Analysis of Input–Output Energy Use in Saffron Production System

Results revealed that the total energy used in various production processes for producing saffron was 21580 MJ ha^{-1} (Table II). Amongst the production practices in saffron production, consumed corm for cultivation (seed) was the most energy consuming input (59.66%), followed by nitrogen fertilizer (13.79%) and manure (13.35%). (Table II).

Safa *et al*. [11] reported that total energy consumption for irrigated wheat, barley and maize were estimated at 51587, 53529 and 72743 MJ ha^{-1}, respectively. Also energy consumption for wheat and barley systems was estimated at 12543 and 11935 MJ ha-1, respectively. Ghorbani *et al*. [12] the total energy requirement under irrigated wheat was 45367 MJ ha^{-1}, that this result is more than two times further our finding on saffron (21580 MJ ha^{-1}). Therefore saffron production in comparison to wheat production is a low input system. Saffron has not real seed and it cultivates by corm. Required seed amount (corm) for cultivation was 4300 kg ha^{-1} which share of corm from total inputs was 59.66% in this study (Table II).

Our results revealed that 1831 h of human labor was used result in application of human labor in saffron fields is a key element for cultivation stage, flower harvest and stigma separation. Manure in saffron production plays a main role among the inputs. It could be use for soil fertilization, improve soil properties and reduce soil temperature in summer season. Average application of manure in saffron fields in Torbat-e-Heydarieh was 48000 kg ha^{-1} and consists 13.35% of total inputs.

Outputs in saffron are consist stigma, leaf and corm. Stigma, leaf and corm yields were 3.86, 1230 and 1630 kg ha^{-1}, respectively for average of five years period (Table II).

Energy efficiency in barley systems was nearly 1.08 times more than wheat systems; energy efficiency of barley was higher than wheat systems which could be due to using low energy input in barley fields. It seems that production of barley is more sustainable than wheat production. Also it severely recommended entering leguminous crop in crop rotations for increase energy efficiency.

There are two ways for calculation of energy use efficiency in saffron. First based on the total saffron outputs like stigma, leaf and corm and second based on just saffron stigma. Because of very low yield of stigma in saffron the value of energy use efficiency achieves very trace in the second way. In this way, we found energy use efficiency 0.0035 (Table II).

Beheshti Tabar *et al*. [13] stated that with higher yields and improved agricultural practices in the wheat high input systems, the unit of land used per unit of output, reduced by 32% in 2006 compared to 1990. It can be inferred that improvements in the crop irrigation efficiency together with the promotion of targeted application of fertilizers can be have a significant effect on the energy efficiency of Iranian agriculture. It seems that advances in irrigation systems will also lighten the effect of droughts on energetic parameters. Employment of more productive cultivars and more intense crop management will cause more efficient consumption of resources, and will consequently lead to higher energy use efficiency.

B. Energy Types of Producing Saffron

The total energy input consumed could be classified in saffron fields as direct (17.14%), indirect (82.86%), renewable (79.95%), and non-renewable (20.05%), energies (Table III). The share of indirect energy input in saffron was 4.3 times further than direct energy. The share of renewable energy input used in total energy input was around 4 times more than non-renewable energy in saffron fields (Table III). As a result production of saffron in view of relaying to synthetic materials and energy conservation is an efficient system.

The specific energy was 5590.72 MJ kg^{-1} (based on stigma) in saffron production system. Canakci *et al*. [14] achieved specific energy for different field crops and vegetable production in Turkey, such as 16.21 for Sesame, 11.24 for cotton, 5.24 for wheat, 3.88 for maize, 1.14 for tomato, 0.98 for melon and 0.97 for watermelon. Energy productivity was achieved 0.00018 kg MJ^{-1} saffron production system. Net energy was 24299.35 MJ ha^{-1} in saffron system (Table IV).

The application of renewable energy in saffron production system was slight, indicating the fact that this system is relying extremely on renewable energies such as human labor and manure. In other crop production systems, high consumption of fossil resources is considered to achieve higher yields. The utilization of fossil resources in agriculture threatens fertility of the soil and weakens the economic independence of farmers.

TABLE II. ENERGY CONSUMPTION AND ENERGY INPUT–OUTPUT RELATIONSHIP IN SAFFRON PRODUCTION

Item	Quantity per unit area (ha)	Energy equivalent (MJ $unit^{-1}$)	Total energy equivalent (MJ)	Percentage of total energy input (%)
Input				
Human labor (h)	1831.71	1.95	3571.83	7.47
Machinery (h)	21.46	62.70	1345.36	2.81
Diesel fuel (l)	99.88	50.23	5016.86	10.49
Nitrogen (kg)	87.4	75.46	6595.204	13.79
Phosphate (P_2O_5) (kg)	75.9	13.07	992.013	2.074
Potassium (K2O) (kg)	47.5	11.15	529.625	1.11
Herbicides (kg or l)	2	238.32	476	0.99
Manure	48000	0.3	14400	13.35
Fungicide (kg or l)	5	92.01	460	0.962
Electricity (kWh)	21513.4	3.60	5976	12.49
Water for irrigation (m^{-3})	3850	1.02	3927	8.21
Seed (kg)	4300	14.97	64371	59.66
Total energy input (MJ)			21580.18	
Outputs				
Stigma yield (kg)	3.86	19.8	76.43	0.17
Leaf yield (kg)	1230	17.4	21402	46.68
Corm yield (kg)	1630	14.97	24401.1	53.18
Total energy output (MJ)			45879.53	
Energy use efficiency (Based on stigma+leaf+corm)			2.13	
Energy use efficiency (Based on stigma)			0.0035	

IV. CONCLUSIONS

Based on the results of the investigation, it concluded that nitrogen fertilizer, found as the most energy consuming input was followed by diesel fuel and water for irrigation in saffron production system. The ratio of renewable energy was greater than that of non-renewable energy consumption while in some other crops it was adverse. Since the main non-renewable input was diesel, electricity and chemical fertilizers, management and improvement of application of machinery, consumption of irrigation water and plant nutrients by renewable resources would increase share of renewable energy. The energy use efficiency, energy productivity, specific energy and net energy of saffron production were 2.13, 0.00018 kg MJ^{-1}, 5590.72 MJ kg^{-1} and 24299.35 MJ ha^{-1}, respectively. Overall, in view of sustainability saffron was a sustainable production system and in term of economical indices it was an efficient production system. In this condition improving timing, quantity and consistency of water use, increasing the energy use efficiency of water pumping systems, employment a improved machinery management techniques, utilization of substitute sources of energy such as manure and organic fertilizers or integrating the legume crops into the rotation may be the options to increasing the energy use efficiency and to reduce the environmental contamination.

TABLE III. TOTAL ENERGY INPUT IN THE FORM OF DIRECT, INDIRECT, RENEWABLE AND NON-RENEWABLE ENERGIES FOR SAFFRON

Type of energy	Saffron	
	(MJ ha^{-1})	%[a]
Direct energy[b]	3698.34	17.14
Indirect energy[c]	17881.84	82.86
Renewable energy[d]	17253.97	79.95
Non-renewable energy[e]	4326.21	20.05
Total energy input	21580.18	100

a: Indicate percentage of total energy input.
b: Indicates human labor, diesel, electricity and water.
c: Indicates seeds, manure, chemical fertilizers, herbicides, fungicides and machinery.
d: Indicates human labor, manure, seed and water.
e: Indicates diesel, electricity, chemical fertilizers, herbicides, fungicides and machinery.

TABLE IV. ENERGY INPUT– OUTPUT RATIO IN SAFFRON PRODUCTION SYSTEM

Items	Unit	Saffron
Energy input	MJ ha^{-1}	21580.18
Energy output	MJ ha^{-1}	45879.53
Energy use efficiency (Based on stigma+leaf+corm)	-	2.13
Energy use efficiency (Based on stigma)	-	0.0035
Energy intensiveness	MJ $\$^{-1}$	7.19
Specific energy	MJ kg^{-1}	5590.72
Energy productivity	kg MJ^{-1}	0.00018
Net energy	MJ ha^{-1}	24299.35

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