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# Operational wise energy use pattern in saffron production of the Pulwama district in Kashmir region, India

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## Abstract
Efficient energy use helps to achieve increased production and productivity. It also contributes to the economy, profitability and competitiveness of agricultural sustainability of rural communities. Study of saffron production system in view of energy consumption was conducted in district Pulwama of Kashmir region. Ten villages from the district were selected on the basis of highest saffron grown area and their average mean data were used. Data and information was collected by using a face to face questionnaire from saffron fields. Results revealed that the total energy used in various production processes for producing saffron was 155880.7 MJha$^{-1}$. Amongst the production practices in saffron production, human labour was the most energy consuming input (48.79%), followed by seed (38.41%), nitrogen fertilizer (6.18%) and FYM manure (1.92%). Outputs in saffron are stigma, leaf, flower and corm. Stigma, leaf, flower and corm yields were 1.59, 507, 634.21 and 672.37 kg ha$^{-1}$. The total energy input consumed could be classified in saffron fields as direct (50.87%), indirect (49.13%), renewable (89.13%), and non-renewable energy (10.86%). The share of renewable energy input used in total energy input was around 8 times more than non-renewable energy in saffron fields. Energy use efficiency Specific energy, energy productivity and net energy were found to be 0.18, 40383.60 MJ Kg$^{-1}$, $2.4\times10^{-5}$ Kg MJha$^{-1}$and –127,254.51 MJha$^{-1}$ respectivelly.

**Keywords:** Saffron, saffron harvest Jammu and Kashmir, energy input, renewable energy, energetics

## 1. Introduction
Saffron is a nonperishable high value low volume commercial crop of Jammu & Kashmir State and is made from the dried stigmas of the Saffron flower (Crocus Sativus Linn, Fig. 1). Saffron grows in climatically diverse regions, varying in temperature, altitude and humidity conditions. Saffron is a high price spice because of much labour requirement for its cultivation, harvesting, packaging and handling (Alam, A. 2008) [3]. Jammu and Kashmir agriculture has an international identity. The world's best saffron is grown in the valley and its major intensity is in district Pulwama and Budgam. Nearly 90% of the total area in the state under this crop is cultivated in Kashmir province only (Table 1). Its cultivation in Jammu division is limited to district Kishtwar only. Saffron is a rain fed crop and Saffron is a kharif crop. The main output of the crop is a dark yellow substance obtained from the flowers called the saffron. Saffron the identity of Jammu and Kashmir and the pride of valley is rapidly vanishing although its cultivation had spread beyond the terraces of Pampore in South Kashmir, where it has been grown since ancient times. The recorded Saffron cultivation and production in Jammu &and Kashmir dating back to year 1980-89 used to be about 300-400 quintals per year while the cultivation has been now reduced to 130 quintals per year (Khanday *et al.* 2008) [2]. In Jammu and Kashmir the saffron has been growing at a rate 1.63 kg per hectare, while in other saffron producing countries of the world, it is relatively more (Anonymous, 2014) [4]. Saffron in Kashmir region is grown on an area of about 3,200 ha and average land holding of saffron farmers is 0.56 ha. Saffron cultivation is not highly mechanized in this day and age, although it requires high labour input during the most important growing phases (Anonymous, 2014) [5].
Energy is considered to be the basic driving force for development of human. The history of successful civilization of human also depended on man’s progress in harnessing energy, i.e. to use energy more efficiently and convert it into a more useful form. In agriculture, energy is important in terms of crop production and agro-processing for value adding (Ozkan *et al.* 2004) [6]. 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

(Streimikiene *et al.*, 2007) [8]. Resource and energy use efficiency is one of the principal requirements of ecoefficient and sustainable agriculture (Jonge 2004) [14]. It enables researchers to calculate output-input ratio, relevant indicators, and energy use patterns in an agricultural activity (Hatirli *et al*. 2006) [11]. Therefore, agriculture and energy have a complementary structure and are affected each other (Ozkan *et al*., 2004) [6]. However, no studies have been published on the energy analysis of saffron production in Kashmir. In the present study, operational wise energy for saffron production system was investigated based on input data from farm surveys in different villages of Pulwama district of Kashmir (J&K), India.

**Table 1:** District wise area, production and productivity of Saffron in J&K

| District | Major Villages growing saffron | Area under saffron, ha | Production, MT | Productivity, Kg/ha | No. Of families involved in saffron cultivation |
|---|---|---|---|---|---|
| Pulwama | Khrew, Ladoo, Dussu, Lathipora, Sambora, Awantipora, Koil, Pampore, Balhuma,Wayun, Munpur, Mueej, Konibal, Dus, Zundhur, Letpur, Sombar, Baras and Ladu | 3,200 (84.5) | 8,014 (84.7) | 2.50 | 9, 000 (55.46) |
| Budgam | Chadura, Nagam, Lasjan, Ompora and Kralpura | 300 (7.9) | 750 (7.9) | 2.50 | 1,227 (7.56) |
| Srinagar | Zewan and Zawreh | 165 (4.4) | 404 (4.3) | 2.45 | 732 (4.51) |
| Kishtwar | Poochal, Bemarnag, Matta, Hidyal, Berwar, begana, Hatta, Sangramabatta, Cherhar, Nagni, Layel and Doda (Namil, Gatha) | 120 (3.2) | 294 (3.1) | 2.45 | 5,310 (32.72) |
| Total | | 3,785 (100) | 9,462 (100) | 2.50 (Ave.) | 16,229 (100) |

(**Source;** Directorate of Agriculture, J&K, Nehvi *et al*., 2008) [1]

**Fig 1:** The Saffron flower

## 2. Material and methods

The survey was carried out in district Pulwama of Kashmir (J&K). Data were collected from the saffron growers by using a face-to-face questionnaire. As well information obtained by surveys, previous studies of related organizations such as department of agricultural production of Kashmir and valuable data from Skuast-Kashmir was also used in this study. The energetic efficiency of the agricultural system has been evaluated by the energy ratio between output and input. 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 $ha^{-1}$. Inputs in Saffron production are human labour, machinery, diesel fuel, inorganic fertilizers, manure, pesticides, fungicides, irrigation water etc. Based on the energy equivalents of the inputs and outputs (Table 2), the energy ratio or energy use efficiency, energy productivity the specific energy and net energy were calculated formula (a, b, c and d). Indirect energy included energy embodied in seeds, chemical fertilizers (NPK), herbicide, pesticide, fungicide and machinery while direct energy covered human labour, 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 labour, seeds and irrigation water.

(a) Energy use efficiency = Energy output (MJ $ha^{-1}$) / Energy input (MJ $ha^{-1}$)
(b) Specific Energy = Energy input (MJ $ha^{-1}$) / crops output (t $ha^{-1}$)
(c) Energy productivity = crops output (Kg $ha^{-1}$) / Energy input (MJ $ha^{-1}$)
(d) Net energy = Energy output (MJ $ha^{-1}$) –Energy Input (MJ $ha^{-1}$)

**Table 2:** Energy equivalents for different inputs and outputs in saffron production

| Input/Output | Unit | Energy Equivalent (MJ/unit) | Reference/source |
|---|---|---|---|
| A. Inputs | | | |
| 1. Human labour | h | 1.96 | Beheshti Tabar *et al.* 2010 [7], Mohammadi *et al.* 2008 |
| 2. Machinery (other prime mover including self propelled machine) | h | 64.80 | Mobtaker *et al.* (2010) [15], Nabavi-Pelesaraei *et al.* (2014) [17] |
| 3. Diesel fuel | L | 56.31 | Mobtaker *et al.* 2010 [15] |
| 4. Chemical fertilizers | kg | | |
| a. Nitrogen (N) | | 66.14 | Esengun *et al.* 2007 [9], Mousavi-Avval *et al.* 2011[16] |
| b. Phosphate ($P_2O_5$) | | 12.44 | Esengun *et al.* (2007) [9], Mousavi-Avval *et al.* 2011[15] |

| | | | |
|---|---|---|---|
| c. Potassium ($K_2O$) | | 11.15 | Esengun *et al.* 2007 [9], Mousavi-Avval *et al.* 2011 [16] |
| 5. Water for irrigation | m3 | 0.63 | Erdal *et al.* 2007 [9] |
| 6. FYM | kg | 0.3 | Demircan *et al*. 2006 |
| 7. Chemicals | kg | | |
| a) Pesticides | Kg | 363 | Fluck and Baird, 1982 [10] |
| b) Herbicides | kg | 288 | Kitani, 1999 [13] |
| c) Fungicides | kg | 55.7 | Agricultural engineering vol 4 by Patrick and Vincent |
| d) Insecticide | | 52.7 | Agricultural engineering vol 4 by Patrick and Vincent |
| e) Rodenticide | kg | 17.2 | Pimentel (1980), Strapatsa *et al*. (2006) |
| 8. Seed (Corm) | kg | 13.81 | Calculated |
| B. Output | | | |
| 1. Stigma | kg | 19.76 | Calculated |
| 2. Corm | kg | 14.97 | Calculated |
| 3. Flower | kg | 16.17 | Calculated |
| 4. Leaf | kg | 16.32 | Calculated |
| 5. Straw | kg | 17.4 | Calculated |

## 3. Results and discussions

The Study of distribution of energy consumption in agricultural operations is important because it guides us to know that which operation is more important for energy saving (Pellizzi *et al*., 1988) [18]. Inputs in saffron production are human labour, machinery, diesel fuel, chemical fertilizers, farmyard manure (FYM), chemicals, irrigation water, and seed (corm) used in the sowing operations. Stigmas are the exquisite economic outputs and corms, leaves, and flowers as by-products. By the way, amounts of by-products have been considered for computing produced energy amounts. Comprehensive outline of energy consumption (MJ $ha^{-1}$) for completely saffron production within the surveyed region and the percentage allocation of the energy related to the inputs is listed in Table 4. The total energy inputs and outputs were calculated about 155880.7 and 28626.19 MJ $ha^{-1}$, respectively.

Human labour is used for almost every task on farms, from driving, repairing agricultural machinery, crop irrigation, spraying against diseases and pests, and fertilizer distribution to farm management (Pimentel and Pimentel 2008) Most saffron management techniques, above all planting, weeding, flower picking, and separating, are performed by hand. However, ploughing and tillage operations are sometimes performed by machines. The sizable number of human labour was employed in stigma cleave, plant protection, and flower harvesting operations. Harvesting operation of incorporated with picking the saffron flowers and separating the thread-like stigma, which could be a fine task, both done with the hands. Picking flowers generally starts as soon as they emerge in the farm. In flowering period, picking should be performed workaday to prevent flower from risk of damage and reducing the quality of stigma accordingly (Kafi, and Showket 2007) [2]. The results revealed that 76048 h of human labour were needed per hectare of saffron production followed by followed by seed (59880 MJ $ha^{-1}$), nitrogen fertilizer (9638.44 MJ $ha^{-1}$) and FYM manure (3000 MJ $ha^{-1}$). Human labour represents a high share namely 48.79 % of the total input and the second important input was found to be energy enclosed in the seeds as 38.41 %. Among the chemical fertilizers, nitrogen with a share of 6.18 % played the most important role. The average irrigation water is 700 $m^3$ $ha^{-1}$ that represented an energy share namely 0.28 %

The distribution of energy inputs in production systems according to the renewable (RE), non-renewable (NRE), direct (DE), and indirect (IDE) energy forms was also verified in Table 3. It can be seen the total energy input consumed could be classified as DE (50.87 %), IDE (49.13%), RE (89.13%), and NRE (10.86%). Results revealed that the rate of direct energy was slightly greater than that of indirect energy consumption in saffron production. The high share of RE in saffron production showed a high dependency of this cultivation on human labour (Fig. 2). Energy use efficiency and specific energy are integrative indices indicating the potential environmental impacts associated with the production of crops. The specific energy and net energy of saffron production were 40362.87 MJ $kg^{-1}$ and -127254.51 MJ $ha^{-1}$ respectively. Energy productivity is also an important index for more efficient use of energy, although higher energy productivity does not mean more economic possibility. However, the energy analysis shows the strategies to reduce the energy inputs and consequently to reinforce the energy productivity (Fluck and Baird 1982) [10]. The average energy productivity of saffron was $2.4 \times 10^{-5}$ kg $MJ^{-1}$. It should be noted that energy indexes are based on the sequestered energy of diesel fuel, fertilizers, machinery, human labour, etc. Solar energy, as either radiation or heat, was not taken into account, as it is considered as a free grant in the energetic or economic analysis of agricultural systems (Slesser 1973) [20].

**Table 3:** Total energy input in the form of direct, indirect, renewable and non-renewable energies for saffron

| Type of energy | Saffron | |
|---|---|---|
| | **(MJ $ha^{-1}$)** | **(%)** |
| Direct energy | 79524.00 | 50.87 |
| Indirect energy | 75260.46 | 49.13 |
| Renewable energy | 139369.00 | 89.13 |
| Non-renewable energy | 16340.66 | 10.86 |
| Total energy input | 155880.70 | 100 |

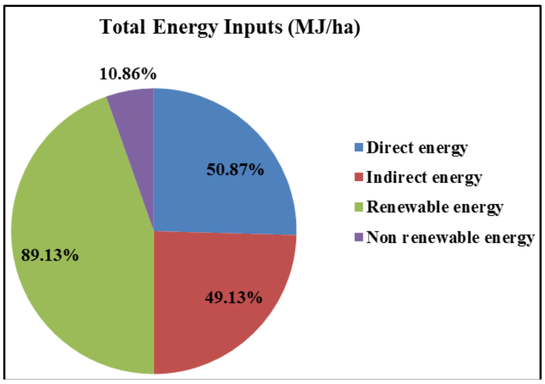


**Fig 2:** Total energy input in the form of direct, indirect, renewable and non-renewable energies for saffron

**Table 4:** 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 ha$^{-1}$) | Percentage of total energy input (%) |
|---|---|---|---|---|
| **A. Inputs** | | | | |
| 1. Human labour (Total) | 3880 | 1.96 | 76048 | 48.79 |
| 2. Machinery | - | 68.4 | 171 | 0.11 |
| 3. Diesel fuel | 54.22 | 56.31 | 3053 | 1.96 |
| 4. Chemical fertilizers | | | | |
| a. Nitrogen (N) | 145.728 | 66.14 | 9638.44 | 6.18 |
| b. Phosphate ($P_2O_5$) | 132 | 12.44 | 1642.08 | 1.05 |
| c. Potassium ($K_2O$) | 83 | 11.15 | 925.45 | 0.59 |
| 5. FYM | 10000 | 0.3 | 3000 | 1.92 |
| 6. Chemicals | | | | |
| a. Pesticides | 1 | 363 | 363 | 0.23 |
| b. Herbicides | 2 | 288 | 576 | 0.37 |
| c. Fungicides | 2.5 | 55.7 | 139.25 | 0.09 |
| d. Rodenticide | 0.2 | 17.2 | 3.44 | 0.01 |
| 7. Water for irrigation | 700 | 0.63 | 441 | 0.28 |
| 8. Seed (Corm) | 4000 | 13.81 | 59880 | 38.41 |
| **Total energy input (MJ)** | | | 155880.7 | |
| **B. Output** | | | | |
| a. Stigma | 1.59 | 19.76 | 31.42 | 0.10976 |
| b. Corm | 672.37 | 14.97 | 10065.38 | 35.16144 |
| c. Flower | 634.21 | 16.17 | 10,255.15 | 35.82436 |
| d. Leaf | 507 | 16.32 | 8274.24 | 28.90444 |
| Total energy output (MJ) | | | 28626.19 | |

## 4. Conclusions

Based on the results of the investigation, it concluded that human labour, found as the most energy consuming input due to lack was followed by mechanization. Results also revealed that the total energy used in various production processes for producing saffron was 155880.7 MJha$^{-1}$. Amongst the production practices in saffron production, human labour was the most energy consuming input (48.79%), followed by seed (38.41%), nitrogen fertilizer (6.18%) and FYM manure (1.92%). Outputs in saffron are stigma, leaf, flower and corm. Stigma, leaf, flower and corm yields were 1.59, 507, 634.21 and 672.37 kg ha$^{-1}$. The total energy input consumed could be classified in saffron fields as direct (50.87%), indirect (49.13%), renewable (89.13%), and non-renewable energy (10.86%). The share of renewable energy input used in total energy input was around 8 times more than non-renewable energy in saffron fields. Specific energy, energy productivity and net energy were found to be 40362.87 MJ Kg$^{-1}$, $2.4\times10^{-4}$ Kg MJha$^{-1}$and – 127254.51 MJha$^{-1}$. It was also found that the farmers growing saffron in the region face difficulties in timely completion of field operations due to lack of mechanization inputs like improved implements for planting, harvesting/ picking, separation and processing equipment. It is rather excessive demanding mechanization through appropriate tools, implements and machines which not only reduce excessive labour but remove drudgery so that new generation continues to practice saffron cultivation in Kashmir region. The application of mechanization technology would increase saffron productivity. Consequently, labour tied up with manual farm operations would be released to higher value activities.

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