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ENERGY USE EFFICIENCY AND ECONOMIC ANALYSIS OF CANOLA PRODUCTION IN THREE DIFFERENT AREAS IN IRAN

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ABSTRACT

Canola cultivation in Iran is relatively new and fairly unpracticed. The background of canola cultivation in Iran came back two decades ago and its planting area has been faced with ascending trend recently. Canola is one of important oil seed crop that is tilled in different areas of Iran. Energy in agriculture is important in terms of crop production and agro processing for value adding. The aim of this study was to evaluate the technical and economic aspects of canola production in Iran. Data were collected from 30 canola farms in three different areas by using a face to face questionnaire method. The results revealed that canola production consumed a total of 44889 MJ ha^{-1} of which diesel fuel and chemical fertilizer energy consumption were 37% and 36.3%, respectively. About 52.1% was direct (human labor, diesel) and 47.9% of the total energy inputs used in canola production was indirect (seeds, fertilizers, manure, chemicals, machinery). Nonrenewable energy was 98.8% of total input energy that concluded canola production needs to improve the efficiency of energy consumption in production and to employ renewable energy. Mean grain canola yield was about 2567 kg ha^{-1}, it obtained under normal conditions on irrigated farming, and taking into account the energy value of the seed, the total output energy, net energy was estimated to be 108489 and 63600 MJ ha^{-1} respectively. Also energy productivity value and energy use efficiency was determined 0.057 Kg MJ^{-1} and 2.42, respectively. Economic analysis of canola production showed that total expenditure, Gross income, net income and benefit–cost ratio (B: C ratio) were calculated as 1424.59 \$ ha^{-1}, 1765.44\$ ha^{-1}, 340.85\$ ha^{-1} and 1.24, respectively.

Keywords: canola production, energy use efficiency, economic analysis, Iran.

INTRODUCTION

Energy has a significant impact on development of key sectors of economic importance such as industry, transport and agriculture. This has motivated many researchers to focus their studies on energy management. Energy has been a key input of agriculture since the age of subsistence agriculture. It is an established fact worldwide that agricultural production is positively correlated with energy input (sing, 1999). In agricultural section, energy is an input which is used for various reasons such as increasing productivity, enhancing food security and contributing to rural economic development (FAO, 2000).

Energy use in agriculture has been increased in response to increasing population, limited supply of arable lands and a desire for higher standards of living. Tendency towards intensive use of energy in agricultural systems is profoundly due to mechanization, using chemical fertilizers, high-yielding seeds and synthetic pesticides. On the 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 (Jonge, 2004).

Many previous researchers have studied energy and economic analysis to estimate the energy efficiency of plant production, such as oilseed rape in Germany (Rathke and Diepenbrock, 2006), wheat, sugar beet, maize, sunflower, barley, oat, rye, grape, olive, lemon, orange, apple, peach in Italy (Triolo *et al*., 1987), sweet cherry, citrus, apricot, tomato, cotton, sugar beet, greenhouse vegetable, some field crops and vegetable in Turkey (Demircan *et al*., 2006), soybean, maize and wheat in Italy (Sartori *et al*., 2005), soybean based production system, potato in India (Mandal *et al*., 2002; Yadav *et al*., 1991), wheat, maize, sorghum in United States (Franzluebbers and Francis, 1995), cotton, sunflower in Greece (Tsatsarelis, 1991; Kallivroussis *et al*., 2002),sugarcane in Morocco (Mrini *et al*., 2001), rice in Malaysia (Bockari-Gevao *et al*., 2005). Furthermore Hatirli *et al*., (2005) in Turky and Alam *et al*., (2005) in Bangladesh have investigated about the energy use efficiency in agriculture sector.

It was reported by Singh (2002) that growth of crop production depends on the three sources: arable land expansion, increase in cropping intensity and yield growth. Okurut *et al*., (1999) stated that besides land, farm power is the second most important input to agricultural production. Borlaugh *et al*., (1993) reported that crop production environment including the generation and transfer of appropriate technology must be improved to increase the fertilizer use efficiency to meet the challenge of feeding increased population. Alam *et al*., (1999) illustrated a system dynamics model for analyzing different input energy use in rural farming system. Alam (2005) developed a simulation model of input energy structure of Bangladesh agriculture to evaluate the effectiveness of various agricultural energy inputs.

Canola is an important oilseed crop belonging to Cruciferae family and grown in subtropical to temperate climate. Recent discoveries have caused the scientific community to respond positively by directing a greater amount of research towards increasing production and improving the quality of canola oil. Today, the annual worldwide production is approximately 7.5 million tons on 4 million acres and ranks 5th in the production of world's oilseed crops following soybean, sunflower, groundnut and cottonseed. Canola Breeding fully explains the miraculous discoveries about the genetic materials which have contributed to the growth of this important crop with contributions from world-renowned researchers from North America, Europe, Asia, and Australia. Original varieties of canola had high levels of erucic acid and glucosinolates, making them unsuitable for human consumption. Breeding experiments led to the development of canola varieties that contained lower amounts of these undesirable compounds. The improved varieties, called canola, became commercially important in the 1960s (Edwards, 2005). Canola was bred (using conventional breeding techniques) to have by definition less than 2 percent erucic acid in the oil and less than 30 micromoles per gram of glucosinolates in the oil free meal and canola oil is recognized as a high quality and healthy edible oil or as a potential source for manufacturing a wide variety of environmentally friendly products such as biodiesel and bio plastics. The residual canola meal after oil extraction usually contains 35-40% protein content and is mostly utilized as an animal feed or a fertilizer. It has previously been reported that canola proteins contain excellent contents of essential amino acids (Ohlson and Anjou, 1979; Wu *et al*., 2008). These differences allow canola oil to be used for human consumption and the meal for a livestock feed protein supplement.

Canola cultivation in Iran is relatively new and fairly unpracticed. The background of canola in Iran came back two decades ago and its planting area has been faced with optimum ascending trend. It is a good crop in rotation with cereals specially wheat and barley. About 70% of Iran's agricultural area has been devoted to wheat and barley cultivation that doesn't have proper rotation. So canola cultivation can be considered as a good choice and will be resulted in decrement of weeds, pests and pathogens problems. Some of weeds in cereal crops displays resistance to herbicides and are out of control. Also some of soil pathogens in different parts of country are scattered and caused severe lost of cereal yield in main production areas. These kinds of problems can be relatively controlled via cereal- canola rotation. Being economic of rape seed cultivation is a necessity for applying this rotation. One of the most important indicators for determining of a crop production is related to its energy consumption and energy use efficiency. The relation between agriculture and energy is very close. Agriculture itself is an energy user and energy supplier in the form of bio-energy (Alam *et al*., 2005). Effective energy use in agriculture is one of the conditions for sustainable agricultural production, since it provides financial savings, fossil resources preservation and air pollution Reduction (Uhlin, 1998).

A significant objective in agricultural production is decreasing the costs and increasing the yield. In this respect, the energy budget is important. Energy budget is the numerical comparison of the relationship between input and output of a system or agricultural business in terms of energy units.

Therefore, the objective of the present study was to determine the input and output energy rates in canola fields at its main planted areas in Iran.

MATERIALS AND METHODS

The study was carried out in three different areas (Hamedan, Kermanshah and Fars provinces) as indices for cold and cold moderate climates in Iran. Data were collected from the 30 growers in each area by using a face-to-face questionnaire. The collected data belonged to the production period of 2008-2009. Usual rotations in studied areas were included wheat, canola, wheat- wheat, maize, canola-maize, sugar beet, canola-potato and canola. The observed pests in canola fields were included Cabbage Aphid (*Brevicoryne brassica*), rape pollen beetle (*Meligethes aeneus*) which has been managed via diazinon, Pirimor and metasystox application. The both narrow leaf and broad leaf Weeds were observed. Broad leaf weeds included charlock mustard (*Sinapis arvensis*), wild radish (*Raphanus raphanistrum*) and Iranian knapweed (Centaurea depressa) and also narrow leaf weeds included Wheat (*Triticum aestivum*), Barley (*Hordeum vulgare*), wild oat (*Avena fatua*), Johnsongrass (*Sorghum halepense*) and mouse barley (*Hordeum murinum*) and they were attacked via application of some herbicides such as Galant, Nabus and Focus. Furthermore Treflan was used before planting. Some of indices in canola cultivation have been recognized in Table-1. The average of land size of canola in studied areas is 2.3 hectares. The whole of canola farms are private.

Table-1. Some indices of canola production.

Practices/operations	Properties
Names of varieties	Okapi
Land preparation tractor used	285 MF 75 hp - Romany 75 hp
Land preparation period	September
Average tilling number	2.5
Planting period	Sep, Oct
Fertilization period	Sep, Apr
Average number of fertilization	3
Irrigation period	Oct, Nov, Mar, Apr, May, Jun
Average number of irrigation	6
Spraying period	Apr, May
Average number of spraying	4
Harvesting period	July
Average number of harvesting	1

All practices applied for canola production in the studied areas are listed in Table-2. Land preparation and soil tillage were mostly accomplished by a Massey Ferguson 75 hp along with using moldboard plow, disc harrows and land leveler.

Table-2. Amounts of inputs and outputs in rapeseed production.

A-Inputs	**Quantity per unit area** (ha**)**
1-Labor (h ha^{-1})	142.8
Land preparation	14.2
Seeding	5.6
Irrigation	50.3
Fertilizer application	15.2
Spraying	12.1
Harvesting	15.4
transporting	30
2-Machinery (h ha^{-1})	72.1
Land preparation	10.7
Seeding	5
Irrigation	28.7
Fertilizer application	3.1
Spraying	4.2
Harvesting	5.1
Transporting	15.3
3-Diesel (L ha^{-1})	295.4
Land preparation	64.2
Seeding	25
Irrigation	60
Fertilizer application	18.6
Spraying	25.2
Harvesting	30.6
Transporting	71.8
4-Fertilizers (kg ha^{-1})	
Nitrogen (N)	210
Phosphorus (P_2O_5)	120
Potassium (K_2O)	80
5-Chemicals (kg ha^{-1})	3.8
6-Water (m^3 ha^{-1})	6345
7-Seeds (kg ha^{-1})	10
B-Outputs	
1- grain (kg ha^{-1})	2567
2-Straw (kg ha^{-1})	3478

The ditcher that is operated by tractor and controlled by hydraulic system was used for penetrates in the soil due to its own weight and suction of the cutting point.

The ridger was used for making ridges and furrows and making field channels for irrigation. Also trailed centrifuge fertilizer spreader was used for spraying fertilizer. Furthermore pre-planting herbicides (narrow weed killer) was applied through trailed and hand herbicide spreader.

Phosphorous, potassium and one third of urea fertilizers were applied before planting during soil preparation meanwhile the rest of urea used at two separate stages.

The canola farm irrigated with well water supplied by motor pomp.

Energy equivalents of inputs and output are listed in Table-3 and also amounts of inputs and output are given in Table-4.

Based on the energy equivalents of the inputs and output, the energy use efficiency, energy productivity and the specific energy were calculated (Demircan *et al*., 2006; Sartori *et al*., 2005).

Energy use efficiency = Energy Output (MJ ha^{-1})/ Energy Input (MJ ha^{-1}) (1)

Energy productivity = Grain output (kg ha^{-1})/Energy Input (MJ ha^{-1}) (2)

Specific energy = Energy input (MJ ha^{-1})/ Grain output (kg ha^{-1}) (3)

Net energy = Energy Output (MJ ha^{-1})/ Energy Input (MJ ha^{-1}) (4)

For the growth and development, energy demand in agriculture can be divided into direct and indirect, renewable, and non-renewable energies (Alam *et al*., 2005). 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 are inputs and output included grain and straw yield. Indirect energy consists of seeds, fertilizers, manure, and pesticide and machinery energy while direct energy covered human labor and diesel fuel used in the canola production. Nonrenewable energy includes diesel, pesticide, fertilizers and machinery and renewable energy consists of human labor and seeds. Human Labor includes management, conducting the some agricultural operation via laborer and tractor and has been computed based on human labor working hours per hectare. Applied machinery (tractor) power computed based on spent hours of tractor power per hectare for any cultural practices.

Consumed fuel was computed according to spent hours of tractor and other machinery power and fuel consumption per hour. Consumed energy through amount of applied seed was calculated based on total energy of grain compounds. Used energy via applied pesticides, herbicides and fungicides computed according to consumed energy for their production, transportation and application. Consumed energy for canola irrigation was calculated based on water necessity, number of irrigation and required time for irrigation per hectare.

Table-3. Energy equivalent of inputs and outputs in agricultural production.

Inputs and outputs	Particulars unit	Equivalent (MJ unit^{-1})	References
A. Inputs			
1. Human labor	h	1.96	(Ozkan *et al*., 2004;Yilmaz *et al*., 2005; Singh *et al*., 2005)
2. Machinery	h	62.70	(Erdal *et al*., 2007; Singh *et al* ., 2002; Singh, 2002)
3. Diesel fuel	L	56.31	(Erdal *et al*., 2007; Singh *et al* ., 2002; Singh, 2002)
4. Chemical fertilizers	kg		
(a) Nitrogen (N)		66.14	(Esengun *et al* ., Yilmaz *et al*., 2005)
(b) Phosphate (P_2O_5)		12.44	(Esengun *et al* ., Yilmaz *et al*., 2005)
(c) Potassium (K_2O)		11.15	(Esengun *et al* ., Yilmaz *et al*., 2005)
5. Chemicals	kg	120	(Canakci *et al*., 2005, Mandal *et al* , 2005. Singh, 2002)
6. Water for irrigation	M^3	1.02	(Acaroglu, 1998.Acaroghu and Aksoy, 2005)
7. Seed	kg	30.60	(Koocheki and Hosseini, 1995)
B. Outputs			
1. Grain	kg	25.33	Computed based on energy produced from components
2. Straw	kg	12.50	Computed based on energy produced from components

RESULTS AND DISCUSSIONS

Results revealed that 142.8 and 72.1 h of human labor and machinery (tractor) power per hectare were used. The total energy equivalent of inputs was calculated 44889 MJ ha^{-1}. Diesel fuel had the highest share of 37% (295.4 L ha^{-1}), followed by chemical fertilizer 36.3% (410 kg ha^{-1}) energy consumption, respectively (Table-4). So it is suggested that specific policies (electrifying the motor pomp, using electricity power instead diesel fuel, using combine vehicle for doing different agricultural operation at the same time and consequences reducing the hours of tractor activity) is to be taken to reduce the fuel consumption and consequences decline the negative effect of energy inputs, such as pollution, global warning and nutrient loading. Within this framework energy flow analysis is an important task that will lead to develop more efficient, economic and environment friendly agricultural production system in Iran.

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 are inputs and output included grain and straw yield. The canola's grain and straw are main product and by product. By the way amounts of produced straw have been determined based on harvest index and it has been considered for computing produced energy amounts.

Table-4. Amounts of inputs and output in canola production.

Quantity (inputs and outputs)	**Quantity per unit area** (ha)	**Total energy Equivalent** (MJ ha^{-1})	**Percentage of the total energy input** (%)
A. Inputs			
1. Human labor (h)	142.8	279.9	0.6
2. Machinery (h)	72.1	4520.7	9.9
3. Diesel fuel (L)	295.4	16634	37
4. Chemical fertilizers (kg)	410	16274.2	36.3

(a) Nitrogen (N)	210	13889.4	31
(b) Phosphate (P_2O_5)	120	1492.8	3.3
(c) Potassium (K_2O)	80	892	2
5. Chemicals (kg)	3.8	456	1
6. Water for irrigation (m^3)	6345	6471.3	14.4
7. Seeds (canola) (kg)	10	253.3	0.56
Total energy input (MJ)		44889.4	100
B. Outputs			
1. Grain (kg)	2567	65022.7	60
2. Straw (kg)	3478	43466.8	40
Total energy output (MJ)		108489.5	100

Analysis of input-output energy use in canola production

The results showed that canola production consumed a total of 44889 MJ ha^{-1} of which diesel fuel and chemical fertilizer energy consumption was 37% and 36.3%, respectively (Table-5). The total output energy, net energy was estimated to be 108489 and 63600 MJ ha^{-1}, respectively. Shahan *et al*., (2008) by study of energy use and economical analysis of wheat production in Iran: A case study from Ardabil province reported that total energy inputs, total energy outputs and net energy were 47078.5, 92785.56 and 45707.1 MJ ha^{-1}, respectively. The specific energy and energy use efficiency of canola production were 17.49 MJ kg^{-1} and 2.42, respectively.

Canakci *et al*., (2005) reported specific energy for field crops and vegetable production in Turkey as 5.24 for wheat, 11.24 for cotton, 3.88 for maize, 16.21 for sesame, 1.14 for tomato, 0.98 for melon and 0.97 for water- melon. Energy productivity value in this study was determined 0.057 kg MJ^{-1}. Calculation of energy productivity rate is well documented in the literatures such as stake-tomato (1.0) (Esengun *et al*., 2007), cotton (0.06) (Yilmaz *et al*., 2005), sugar beet (1.53) (Erdal *et al*., 2007). Total energy input distributes as direct, indirect, renewable and non-renewable forms.

Table-5. Energy input-output ratio in canola production.

Items	**Unit**	**Value**
Energy input	MJ ha^{-1}	44889
Energy output (grain and straw)	MJ ha^{-1}	108489
Grain yield	kg ha^{-1}	2567
Energy use efficiency		2.42
Specific energy	MJ kg^{-1}	17.49
Energy productivity	kg MJ^{-1}	0.057
Net energy	MJ ha^{-1}	63600

About 52.1% (23385.2 MJ) was direct and 47.9% (21504.2) of the total energy inputs used in canola production was indirect (Table-6). Approximately 98.8% of total energy input from nonrenewable and 1.2% from renewable energy forms. It can be concluded that canola production needs to improve the efficiency of energy consumption in production and to employ renewable energy.

Table-6. Total energy input in the form of direct, indirect, renewable and nonrenewable for canola production (MJ ha^{-1}).

Form of energy	**Value** (MJ ha^{-1})	**a** (%)
Direct energy[b]	23385.2	52.10
Indirect energy[c]	21504.2	47.9
Renewable energy[d]	533.2	1.2
Non-renewable energy[e]	44356.2	98.8
Total energy input	44889.4	100

[a]Indicates percentage of total energy input.
[b]Includes human labor, diesel.
[c]Includes seeds, fertilizers, chemicals, machinery.
[d]Includes human labor, seeds
[e]Includes diesel, chemical, fertilizers, machinery.

Economic analysis of canola production

The total expenditure (variable and fixed costs) for the canola production was 1424.59 \$ ha^{-1}. The land rental cost is considered as one of fixed expenditures index that was exerted. Gross income, net income and benefit–cost ratio (B: C ratio) were calculated as 1765.44\$ ha^{-1}, 340.85\$ ha^{-1} and 1.24, respectively (Table-7). The results were compared and consistent with finding reported by other authors such as 1.43 for wheat (Shahan *et al*., 2008), 0.86 for cotton (Yilmaz *et al*., 2005), 1.17 for sugar beet (Erdal *et al*., 2007), 2.53 for sweet cherry (Demircan *et al*., 2006), 2.37 for orange, 1.89 for lemon and 1.88 for mandarin (Ozkan *et al*., 2004), 1.03 for stake-tomato (Esengun *et al*., 2007). The results display that one of the most important energy consuming part (36.3%) is related to chemical fertilizer application mainly nitrogen, within the total energy inputs after diesel fuel (37%). Therefore, reducing the inputs would provide more efficient fertilizer application and diesel. If chemical fertilizer application be reduced then non-renewable forms of energy consumption would declined. Measurements that is useful for decrease of nitrogen fertilizer included manure application and changing the current methods of fertilizer application. Also, proper plant rotation (wheat-canola) is one of the ways that can be very useful for reducing pests, diseases and weeds population. Furthermore integrated pest control techniques should be put in practice to improve pesticide use.

It can be expected that all these measurements would be useful not only for reducing negative effects to environment, human health, maintaining sustainability and decreasing production costs, but also for providing higher energy use efficiency.

Table-7. Economic analysis of canola.

Cost and return components	**Value**
Major product yield (kg ha^{-1})	2567
Byproduct yield (kg ha^{-1})	3478
Sale price of major product (\$ ha^{-1})	1591.54
Sale price of byproduct (\$ ha^{-1})	173.9
Total gross value of production (\$ ha^{-1})	1765.44
Total cost of production (\$ ha^{-1})	1424.593
Net return (\$ ha^{-1})	340.847
Benefit to cost ratio	1.24

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