Biological Forum – An International Journal **7**(1): 1452-1460(2015)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Energy Efficiency and Economic Analysis of Winter Caltivation (Lettuce, Bersim Clover, Broad bean) in Mazandaran Province of Iran

Bahram Razavinia, Hormoz Fallah and Yousef Niknejad
Agronomy Department,
Islamic Azad University, Ayatollah Amoli Branch, Amol, IRAN

(Corresponding author: Hormoz Fallah)
(Received 29 March, 2015, Accepted 07 May, 2015)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Energy consumption in the world and Iran has increased in recent years. Recently, farmers apply more energy to produce food. To achieve the best performance, review and analyze the energy and economic of food production is very important. In this study, the energy equivalences of input-output used in the winter cultivation (Lettuce, Bersim Clover, Broad bean) have been investigated in Mazandaran province of Iran. The required information has been achieved from the questionnaire with the help of 58 farmers from 6 villages in Amol city, Mazandaran province. The result illustrated that maximum value of energy consumed in the fall planting, are related to fertilizers and pesticides. Bean has higher energy efficiency compared to others, due to high yield per hectare and the energy content of the bean. Lettuce with a performance almost equal to the clover, due to lower energy content of it, has the lower ranking on this assessment. According to the results, lettuce as the best option from an economic perspective and then beans and clover as the next options are introduced.

Keywords: Lettuce, Bersim Clover, Broad bean, Energy analysis, Direct energy, Renewable energy.

INTRODUCTION

Nowadays, with the increasing world population on the one hand and extension of poverty and hunger in third world countries on the other hand, agriculture as a source of human nutrition is very important. In recent years, the trend towards increased consumption of energy in the world and also in Iran has caused to farmers use more energy to produce food. Thus, energy use in agriculture increases by increasing limited arable land, population, and increasing of life quality. On the other hand, due to limited resources and the adverse effects resulting from the appropriate use of various energy sources on human health and the environment, the need to examine the pattern of energy consumption in agriculture is unavoidable (Hatirli *et al.,* 2005). Considering the energy crisis, increasing fossil fuel consumption and consequently an increase in emissions of various greenhouse gases into the environment, reducing energy consumption as much as possible is necessary. Energy consumption in the world and also in Iran has increased in recent years and recently farmers apply more energy to produce food (Beheshti *et al.,* 2010). Energy analysis for stable management of resources is essential for agricultural production and thus effectual production and economic activity will be determined. Energy use in the agricultural sector depends on the size of the entertained population in agriculture, the amount of arable land and the level of mechanization. Analysis of input and output energy of agricultural systems enables producers and policy makers to investigate interactions between energy consumption and economic cost of producing a product (Yilmaz *et al.,* 2005). In agriculture, energy is consumed and also produced. It uses large quantities of locally available non-commercial energy, such as seed, manure and animate energy, as well as commercial energies, directly and indirectly, in the form of electricity, diesel, plant protection, fertilizer, chemical, irrigation water, machinery etc (Taheri-Garavand *et al.,* 2010). It is necessary to model the energy consumption of different ecological systems of agricultural production is carefully examined and analyzed. One of the most useful methods in the analysis of agricultural sustainability is energy applying as a calculating tool (Ghorbani *et al.,* 2011, Ceccon *et al.,* 2002). By analyzing the energy consumption and determining the share of renewable and non-renewable energies that directly and indirectly involved in the production, increasing the efficiency and productivity of the soil and water resources and chemical inputs and the possible establishment of an ecological production system can be carefully investigated.

Many studies are conducted in the field of energy efficiency and balance in agricultural production (Singh *et al.*, 2002, Ansari and Ghadimi 2015, Cecilio *et al.*, 2010, Karimi *et al.*, 2008, Nasrollahi-Sarvaghaji *et al.*, 2014, Mousavi-Avval *et al.*, 2011, Mohammadi *et al.*, 2008, Heidari and Omid 2011, Mohammadi and Omid 2010). In Diepenbrock's approach (Diepenbrock 2012) fossil energy input is divided to direct and indirect input components. Direct energy input includes the consumption of diesel fuel required for field operations taking into account the influences of management and location conditions. Thereto, energy consumption for manufacturing of agricultural machines is also considered as direct energy input. Indirect energy inputs consist of seed material, plant protection agents, fertilizers and operation of machines.

Lettuce (*Lactuca sativa*) is an annual plant of the daisy family Asteraceae. It is most often grown as a leaf vegetable, but sometimes for its stem and seeds. Lettuce was first cultivated by the ancient Egyptians who turned it from a weed, whose seeds were used to produce oil, into a food plant grown for its succulent leaves, in addition to its oil-rich seeds. Generally grown as a hardy annual, lettuce is easily cultivated, although it requires relatively low temperatures to prevent it from flowering quickly. A hardy annual, some varieties of lettuce can be overwintered even in relatively cold climates under a layer of straw, and older, heirloom varieties are often grown in cold frames. Lettuce flowers more quickly in hot temperatures, while freezing temperatures cause slower growth and sometimes damage to outer leaves (Smith *et al.*, 2015). Lettuce grows as a second crop after rice harvest each year in paddy cultivation of Amol city.

Berseem clover (*Trifolium alexandrinum* L.) belongs to leguminous family (Taylor, 1985). This plant is among the most valuable provender available for stock feeding. The protein percentage of berseem clover has been reported about 20.96% (Ansari and Ghadimi 2015). The production of 30 tons of fresh forage has been calculated per the basis hectare and only the resulting protein was estimated. The results show that 650 kg pure protein would be obtained from the cultivation of one hectare of bersim clover in each period (Cassida *et al.*, 2000). Bersim clover grows in all soils. The most suitable soil for the growth of clover is light and relatively heavy lime soil with humid weather.

A member of the legume family, broad beans are pretty tough and conformable. They grow in most soils and climates. They're a big source of protein and carbohydrates, as well as vitamins A, B1 and B2. In the US, they're known as fava beans (www.bbcgoodfood.com.). Broad beans have a long tradition of cultivation in Old World agriculture, being among the most ancient plants in cultivation and also among the easiest to grow. Along with lentils, peas, and chickpeas, they are believed to have become part of the eastern Mediterranean diet around 6000 BC or earlier. They are still often grown as a cover crop to prevent erosion, because they can overwinter and because as a legume, they fix nitrogen in the soil. Broad bean plants are highly susceptible to early summer infestations of the black bean aphid, which can cover large sections of growing plants with infestations, typically starting at the tip of the plant (http://en.wikipedia.org/wiki/Vicia_faba.). Broad beans are eaten while still young and tender, enabling harvesting to begin as early as the middle of spring for plants started under glass or overwintered in a protected location, but even the main crop sown in early spring will be ready from mid to late summer.

In this work, portion of direct and indirect energy, renewable and non-renewable energy in winter cultivation (Lettuce, Bersim Clover, Broad bean) in Mazandaran Province of Iranhave been investigated. This study can help to stability of hibernal implant.

MATERIALS AND METHOD

A. The statistical Community

In this study, data were collected from 58 winter cultivation farms in the Mazanderan province of Iran by using a face to face questionnaire in April 2014. The simple random sampling method was applied to determine survey volume from:

$$n = \frac{N \times S^2 \times T^2}{(N-1) \times D^2 + S^2 \times T^2} \qquad (1)$$

Where, *n* is the required sample size, *S* is the standard deviation, *T* is the T-value at 95% confidence limit, *N* is the number of holding in target population and D is the acceptable error (Kizilaslan, 2009).

B. Geographical Location

Amol city is located in the north of Iran, within 52° 21' east longitude and 36° 25' north latitude. Amol is located on the Haraz river bank. It is less than 20 kilometers (12 miles) south of the Caspian Sea and less than 10 kilometers (6.2 miles) north of the Alborz Mountains. It is 180 kilometers (110 miles) from Tehran, and 60 kilometers (37 miles) west of the provincial administrative center, Sari.

C. Energy Analysis Methodology

Energy analysis was performed to determine the Output- input ratio, Energy productivity, Net energy gain and Specific energy. In order to calculate these indexes, the data have been converted into output and input energy levels using equivalent energy values for each commodity and input. Energy equivalents shown in Table 1 were used for estimation.

Table 1: Energy equivalent of inputs and outputs in canola production.

Item		Unit	Energy equivalent (MJ/unit)	Reference
Inputs				
Labour		h	1.96	[3], [31], [32]
Diesel fuel		L	47.8	[32]
Tractor		kg	138	[32]
Plow		kg	180	[32]
Sprayer		kg	129	[32]
Equipment of fertilizing		kg	129	[32]
Trails		kg	138	[32]
Thresher		kg	148	[32]
Nitrogen fertilizer (N)		kg	74.2	[33]
Phosphorus (P_2O_5)		kg	17.4	[32]
Potash (K_2O)		kg	13.7	[32]
pesticide		kg	295	[32]
Seed	Bersim Clover	kg	13.5	[32]
	Lettuce	kg	0.05	[32]
	Broad bean	kg	18.02	[32]
Output				
Bersim Clover		kg	10.07	[32]
Lettuce		kg	0.7	[34]
Broad bean		kg	66.378	[34]

In this study, according to information obtained from the questionnaires, the amounts of inputs used in the production of Lettuce, Bersim Clover and Broad bean were specified in order to calculate the energy equivalences. Energy input consist of human labor, machinery, diesel fuel, chemical fertilizer, pesticides and seed amounts and output yield consist of grains of these products. The input energy is also divided into direct and indirect and renewable and non-renewable forms. Indirect energy consists of machinery, seeds, pesticide and fertilizers energy while direct energy covered diesel fuel and human labor used in the production of Lettuce, Bersim Clover and Broad bean. Non-renewable energy consists of machinery, diesel, fertilizers and pesticide, and renewable energy includes human labor and seeds.

Machinary and Equipments Energy. To calculate the energy content of Machinary and Equipments used in different operations, the following equation has been used:

$$ME = E\frac{G}{T} \times G_t \quad (2)$$

Where, *ME* is machinary and equipments energy (MJ/ha), E is machinery production energy equal to a constant value (62.7 MJ/kg), *G* is weight of machinery (kg), *T* is useful life of machinery (h) and G_t is total number of working hours per an agricultural season (h/ha).

Fuel Energy: To calculate the energy content of fuels used in different operations, the following equation has been used: $E_p = Q_i \times E_i$ (3)

Where, E_p is fuel energy (MJ/ha), Q_i is amount of consumed fuel (L/ha) and E_i is energy per unit of fuel (MJ/L).

Fertilizers and Chemical Pesticides Energy. To calculate the energy content of fertilizers and chemical pesticides, the following equation has been used:

$E_f = W_t \times E_i$ (4)

Where, E_f is energy content of fertilizers and chemical pesticides (MJ/ha), W_t is weight of fertilizers and pesticides (kg/ha), E_i is energy per one kg of fertilizers and pesticides (MJ/kg).

Labor Energy. The Labor energy can be calculated from the following equation:

$$E_l = W_l \times E_i \quad (5)$$

Where, E_l is labor energy (MJ/ha), W_l is number of labor (n/ha) and E_i is energy per one each labor (MJ/n).

Seed Energy. According to the farmer's responses in the questionnaires, the seed content has been determined. To calculate the energy content of seed, the following equation has been used:

$$E_s = W_i \times E_i \quad \ldots(6)$$

Where, E_s is seed energy (MJ/ha), W_i is weight of seed (kg/ha) and E_i is energy per one kg of seed (MJ/kg).

Output (Crops) Energy. The output (Crops) energy can be calculated from equation (7):

Crops Energy (MJ/ha) = Crops Yield (kg/ha) × Unit Energy (MJ/kg) …(7)

Where, unit energy is the energy of one kg of Crops.

Calculation of energy indexes. The energy indexes are defined according to following equations:

Output-Input ratio = (Output Energy (MJ/ha))/(Input Energy (MJ/ha)) …(8)

Energy Productivity = (Crops Yield (kg/ha))/(Input Energy (MJ/ha)) …(9)

Net Energy Gain = Energy Output (MJ/ha) - Energy Input (MJ/ha) …(10)

Specific Energy = (Input Energy (MJ/ha))/(Crops Yield (kg/ha)) (11)

RESULTS AND DISCUSSION

According to energy equivalences and result of questionnaires, energy analysis for Lettuce, Bersim Clover, and Broad bean was done. Basic information on energy inputs and Crops yields were entered into Excel and SPSS 20 spreadsheets.

A. Energy Analysis Results of Lettuce

The calculated values of input and output energy of Lettuce are illustrated in Table 2.

Table 2: Calculated values of input and output energy for Lettuce.

Item			Energy	
			MJ/ha	%
Inputs	Direct	Diesel fuel	6931	46.54
		Labor	431.2	2.89
	Indirect	Machinery	1567.5	10.52
		Phosphorus (P_2O_5)	348	2.34
		Potash (K_2O)	1096	7.36
		Nitrogen (N)	3339	22.42
		Pesticide	1180	7.93
		Seed	0.125	0.00
Total inputs			14892.825	100
Output		Lettuce	17500	100
Total output			17500	100

Table 2 show that total input energy was 14892.83 MJ/ha and total output energy was 17500 MJ/ha. From among all inputs, the diesel fuel has the biggest proportion in the total input energy with 46.54% (6931 MJ/ha). Diesel fuel was mainly used for operating tractor and combine harvester. Proportion of the fertilizer (consist of P_2O_5, Nitrogen, K_2O, pesticide) in the total energy was 40.05% (5963 MJ/ha) that show, Lettuce production intensively dependent on fertilizer. After fertilizer energy machinery energy was the highest with 10.52% (1567.5 MJ/ha).

Because of mechanized operation in Lettuce production, use of human labor was low (2.89% of total input energy), but it was very important input in increasing production yield. Ultimately, energy of seed was about 0.00% of total input energy. Fig. 1 shows the proportion of each item in total input energy for Lettuce.

Moreover, direct energy was 49.43% while indirect energy was 50.57% of total input energy (Fig. 2). Total output energy of Lettuce was 17500 MJ/ha.

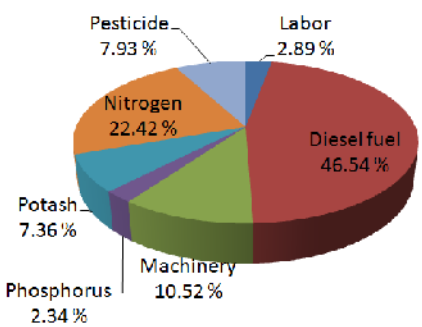

Fig. 1. Proportion of each item in input energy for Lettuce.

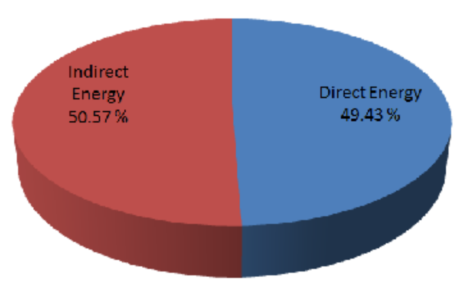

Fig. 2. Proportion of direct and indirect energies in input energy for Lettuce.

According to results, 97.11% of total energy input resulted from non-renewable and 2.89 % from renewable energy (Fig. 3).

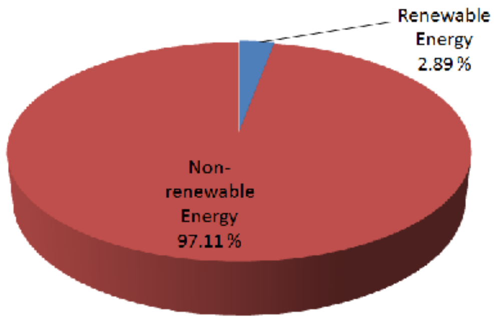

Fig. 3. Proportion of renewable and non- renewable energies in input energy for Lettuce.

The energy indexes were calculated by Eq(8)-Eq(11). The result of this calculation can be seen in Table 3).

Table 3: Energy indexes value in Lettuce production in Amol city.

Index	Calculated Value
Output-Input ratio	1.175
Energy Productivity (kg/MJ)	1.67
Net Energy Gain (MJ/ha)	2607.17
Specific Energy (MJ/kg)	0.595

The energy productivity and output-input energy ratio were calculated as 1.67 kg/MJand1.175, respectively. Net energy gain and specific energy were 2607.17 MJ/ha and 0.595 MJ/kg, respectively. The results show that the prevalent energy use pattern among the investigated farms in Amol city is based on non-renewable energy in the Lettuce production. Thus, this current method of production caused serious environmental problem.

B. Energy Analysis Results of Bersim Clover

The calculated values of input and output energy of Bersim Clover are illustrated in Table 4. Table 4 indicate that total input energy was 13935.5 MJ/ha and total output energy was 251750 MJ/ha.Similar to Lettuce, the diesel fuel has the biggest proportion in the total input energy with 49.74% (6931 MJ/ha). Proportion of the fertilizer (consist of P2O5, Nitrogen, K_2O, pesticide) in the total energy was35.05% (4885 MJ/ha) that show Bersim Clover production intensively dependent on fertilizer. After fertilizer energy machinery energy was the highest with 11.25% (1567.5 MJ/ha). In Bersim Clover production, use of human labor was low (1.05 % of total input energy), but it was very important input in increasing production yield.

Ultimately, energy of seed was about 0.00% of total input energy. Fig. 4 shows the proportion of each item in total input energy for Bersim Clover.

Table 4: Calculated values of input and output energy for Bersim Clover.

Item			Energy	
			MJ/ha	**%**
Inputs	Direct	Diesel fuel	6931	49.74
		Labor	147	1.05
	Indirect	Machinery	1567.5	11.25
		Phosphorus (P_2O_5)	870	6.24
		Potash (K_2O)	685	4.92
		Nitrogen (N)	1855	13.31
		Pesticide	1475	10.58
		Seed	405	2.91
Total inputs			13935.5	100
Output		Bersim Clover	251750	100
Total output			251750	100

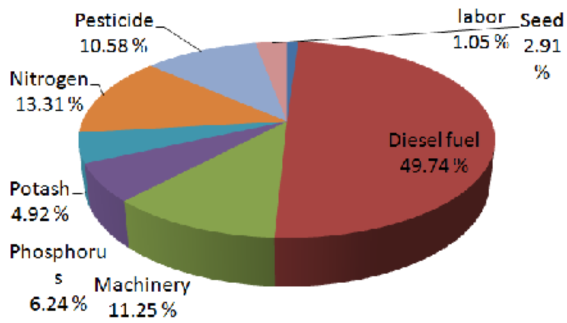

Fig. 4. Proportion of each item in input energy for Bersim Clover.

Moreover, direct energy was 50.79 % while indirect energy was 49.21 % of total input energy (Fig. 5). Total output energy of Bersim Clover was 251750 MJ/ha.

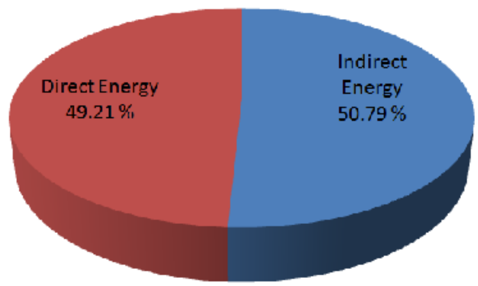

Fig. 5. Proportion of direct and indirect energies in input energy for Bersim Clover.

According to results, 96.04% of total energy input resulted from non-renewable and 3.96% from renewable energy (Fig. 6).

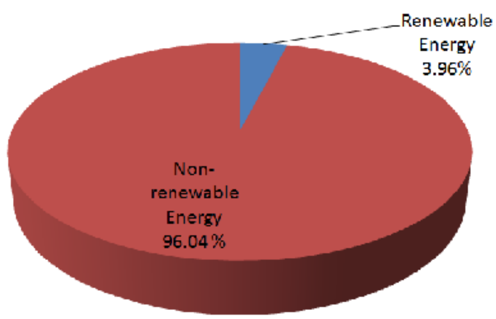

Fig. 6. Proportion of renewable and non- renewable energies in input energy for Bersim Clover.

The result of calculation of energy indexes for Bersim Clover can be seen in Table 5.

Table 5: Energy indexes value in Bersim Clover production in Amol city.

Index	Calculated Value
Output-Input ratio	18.065
Energy Productivity (kg/MJ)	1.79
Net Energy Gain (MJ/ha)	227814.5
Specific Energy (MJ/kg)	0.557

The energy productivity and output-input energy ratio for Bersim Clover were calculated as 18.065 kg/MJ and 1.79, respectively. Net energy gain and specific energy were 227814.5 MJ/ha and 0.557 MJ/kg, respectively. Similar to Lettuce, the results show that the prevalent energy use pattern among the investigated farms in Amol city is based on non-renewable energy in the Bersim Clover production. Thus, this current method of production caused serious environmental problem.

C. Energy Analysis Results of Broad bean

The calculated values of input and output energy of Broad bean are illustrated in Table 6.

Table 6: Calculated values of input and output energy for Broad bean.

Item			Energy	
			MJ/ha	%
Inputs	Direct	Diesel fuel	6931	41.61
		Labor	127.4	0.76
	Indirect	Machinery	1567.5	9.42
		Phosphorus (P_2O_5)	870	5.23
		Nitrogen (N)	2226	13.31
		Pesticide	1342.25	8.06
		Seed	3604	21.61
Total inputs			16636.79	100
Output		Broad bean	398268	100
Total output			398268	100

Table 6 indicate that total input energy was 16636.79 MJ/ha and total output energy was 398268 MJ/ha. Similar to Lettuce and Bersim Clover, the diesel fuel has the biggest proportion in the total input energy with 41.61% (6931 MJ/ha). Proportion of the fertilizer (consist of P_2O_5, Nitrogen, K_2O, pesticide) in the total energy was 26.6% (4438.25 MJ/ha) that show Broad bean production intensively dependent on fertilizer. After fertilizer energy seed energy was the highest with 21.61% (3604 MJ/ha). In Broad bean production, use of human labor was low (0.76% of total input energy), but it was very important input in increasing production yield.

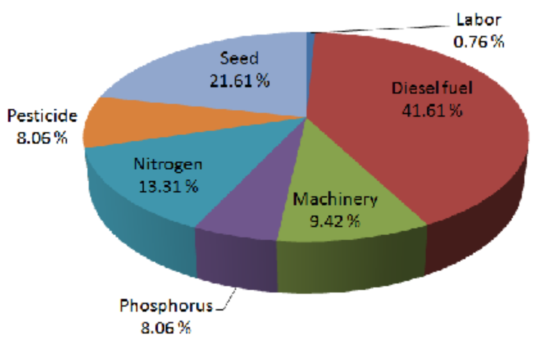

Fig. 7. Proportion of each item in input energy for Broad bean.

Ultimately, energy of seed was about 9.42 % of total input energy. Fig. 7 shows the proportion of each item in total input energy for Broad bean. Moreover, direct energy was 57.63% while indirect energy was 42.37% of total input energy (Fig. 8). Total output energy of Broad bean was 398268 MJ/ha.

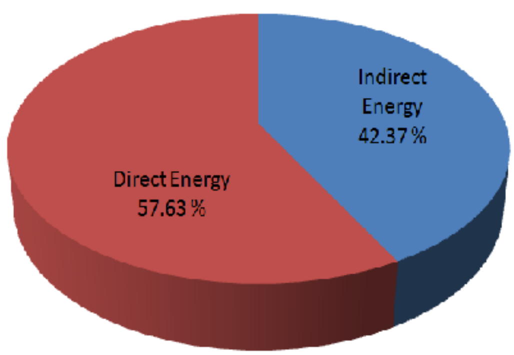

Fig. 8. Proportion of direct and indirect energies in input energy for Broad bean.

According to results, 77.63 % of total energy input resulted from non-renewable and 22.37% from renewable energy (Fig. 9).

The result of calculation of energy indexes for Broad bean can be seen in Table 7.

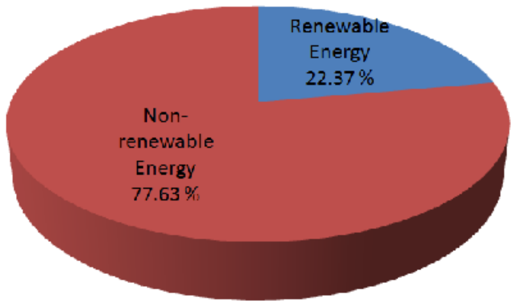

Fig. 9. Proportion of renewable and non- renewable energies in input energy for Broad bean.

Table 7: Energy indexes value in Broad bean production in Amol city.

Index	Calculated Value
Output-Input ratio	23.93
Energy Productivity (kg/MJ)	0.36
Net Energy Gain (MJ/ha)	681631.21
Specific Energy (MJ/kg)	2.77

The energy productivity and output-input energy ratio for Broad bean were calculated as 0.36 kg/MJ and 23.93, respectively. Net energy gain and specific energy were 681631.21 MJ/ha and 2.77 MJ/kg, respectively. Similar to Lettuce and Bersim Clover, the results show that the prevalent energy use pattern among the investigated farms in Amol city is based on non-renewable energy in the Broad bean production.

CONCLUSION

In this study, energy analysis of winter cultivation (Lettuce, Bersim Clover, and Broad Bean) production in Amol city of Iran was investigated. Data were collected from 58 farmers which were selected on random sampling method. The analysis results showed that the highest energy productivity was related to Bean Clover (1.79kg/MJ) and the lowest was related to Broad Bean (0.36 kg/MJ). The highest proficiency (Output-Input ratio) was related to Broad bean (681631.2 MJ/ha). Because of high efficiency per hectare and high energy content of Broad beam, this plant has higher proficiency in comparison with other plants (Lettuce and Bersim Clover). Despite of equal proficiency of Lettuce and Clover, Lettuce stands in end of this evaluation because of less energy content. From among all usable energy, the highest value is related to fertilizers and pesticides and where as input energy has straight respect with energy proficiency, it's suggest that operational standard is defined for enrich of dirt and decrease of fertilizer utilization to reach permanent agriculture.

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