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Full Length Research Paper

Effects of mechanization on energy requirements for apple production in Esfahan province, Iran

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The data used in this study to survey energy consumption in apple production were collected from 113 producers, using a face to face questionnaire method in the Esfahan province of Iran. The results showed that the average input energy increased in parallel to the mechanization scale of farms. Information revealed that 44938.57 MJ/ha energy were consumed by the first group (medium mechanized) and 33100.82 MJ/ha by the second group of farms. Fuel is mainly used for land preparation, pruning practices, transportation and chemicals for pest control were the major energy inputs in both types of farms. Output-Input energy ratio, energy productivity and net energy gain were higher on the second group as compared to the first group. The output–input energy ratio, energy productivity and specific energy were 1.02, 0.425 kg/MJ and 2.353 MJ/ha in the first strata and 1.35, 0.563 kg/MJ and 1.775 MJ/ha in the second strata, respectively. In first and second group of farms the nonrenewable form of energy input encompassed 88.45 and 77.93% of the total energy input. With correct adjustment and management of equipments and proper method of operation on the farms might help to increase efficiency of input energy.

Keyword: Iran, apple, energy, mechanization.

INTRODUCTION

Apple is one of the most common fruits which are consumed on a regular basis by many people in different cultures (Strapatsa et al., 2006). Apple fruits are known to be rich in flavonoid compounds such as anthocyanins, dihydrochalcones, quercetin 3-glycosides, catechin, epi-catechin and its polymers, which are mainly located in the skin (Awad et al., 2001; Awad et al., 2000). Apple has protective effects that attributed primarily to their anti-oxidant properties. Several phytochemical component of apple that ought to be protective in cancer are including carotenoids, flavonoids, isoflavonoids, phenolic acids and lignans (Liu, 2004; Lee et al., 2003).

Apple is one of the important fruits in Iran. The land area under apple production in Iran is about 1201349.6 hectare which produces 2661901 ton of apples annually. Esfahan is one of the major apple-producing province with 19816 hectare of apple farms lands that produce 236859.9 ton of apples yearly (Anonymous, 2005). Apple farms mostly are located in the south and mountainous areas of this province.

There is a close relationship between agriculture and energy. Agriculture uses energy, while supplies it in the form of bioenergy. At the present time, the productivity and profitability of agriculture depend upon energy consumption (Tabatabaeefar et al., 2009). Knowledge of rural energy resources and their consumption pattern is very important for making appropriate energy policies to develop efficient crop production systems particularly in populous and developing countries (Mani et al., 2007). Continually, rising prices, increasing proportion of commercial energy in the total energy input to agriculture and the growing scarcity of commercial energy sources, such as fossil fuels, have necessitated the more efficient use of these sources for deferent crops (Singh et al., 1999). Modern agriculture is heavily dependent on mechanization that includes the tools, implements, power sources

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and related management processes used in the production of food and non-food products. Mechanization is a major user of nonrenewable energy (Leiva and Morris, 2001). Apple is produced extensively around the world and in the most countries it becomes a crop with high energy inputs (due to inputs in machinery, chemicals and human labor) required for successful commercial production with high quality fruit (Strapatsa et al., 2006). However, considering limited natural resources and the impact of using different energy sources on environment and human health it is substantial to investigate energy use patterns in agriculture (Hatirli et al., 2005). The aim of this study was to investigate the efficiency of energy consumption in association with the effects of mechanization on energy usage in apple production in the south of Esfahan, province, Iran.

MATERIALS AND METHODS

n required sample size
N number of holdings in target population
N_h number of the population in the h stratification
S_h^2 variance of h stratification
d precision ($\bar{x}$ - $\bar{X}$)
z reliability coefficient (1.96 in the case of 95% reliability)
D^2 d2/z^2

The study was conducted on 113 apple farms in the south of Esfahan province, Iran. Esfahan is located in the center of Iran, within 30° 43' and 34° 27' north latitude and 49° 36' and 55° 31' east longitude. Data were collected from the farms using a face-to-face questionnaire technique on March to April 2009.

The present study deployed to investigate the demand of energy resources for apple production under some specific levels of mechanization. Farms under this investigation were divided into two groups. Thus, two different strata were formed, first group of farms was called medium mechanized and the second group was called low mechanized. Random sampling of farms was done within whole plant population. The size of each sample was determined using Equation (1) which is derived from Neyman method (Yamane, 1967).

$$n = (\sum N_h S_h)/(N^2 D^2 + \sum N_h S_h^2) \quad (1)$$

Where n is the required sample size, N is the number of holdings in target population, N_h is the number of the population in the h stratification, S_h is the standard deviation in the h stratification, S_h^2 is the variance of h stratification and D^2 is

$$D^2 = d^2 / z^2 \quad (2)$$

Where d is the precision where ($\bar{x}$ - $\bar{X}$) (5%) is the permissible error, z is the reliability coefficient (1.96 which represents the 95% reliability). 30 farms were selected for the first strata and 83 farms were selected for the second strata. Energy equivalents of the inputs used in the apple production are illustrated in (Table 1).

Basic information on energy inputs and apple fruits were entered into excel and SPSS 15 spreadsheets. Inputs in apple production include human labor, machinery, diesel fuel, chemical fertilizers, manure, insecticides, herbicide, irrigation water and fungicide. Based on the energy equivalents of the inputs and output, output–input energy ratio, energy productivity and specific energy were calculated according to the following equations, respectively, (Bayramoglu and Gundogmus, 2009; Hatirli et al., 2006; Mohammadi et al., 2008).

$$\text{Output} - \text{Input energy ratio} = \frac{\text{Output energy (MJ/ha)}}{\text{Iput energy (MJ/ha)}} \quad (3)$$

$$\text{Energy productivity} = \frac{\text{Apple output (kg/ha)}}{\text{Input energy (MJ/ha)}} \quad (4)$$

$$\text{Net energy gain} = \text{Output energy (MJ/ha)} - \text{Input energy (MJ/ha)} \quad (5)$$

$$\text{Specific energy} = \frac{\text{Input energy (Mj/ha)}}{\text{Apple output (kg/ha)}} \quad (6)$$

The input energy was divided into direct, indirect, renewable and non-renewable energies (Erdal et al., 2007; Mohammadi et al., 2008). The indirect energy consists of chemicals, fertilizer, machinery and equipment, while the direct energy includes human power and diesel used in the production process. Nonrenewable energy includes diesel, chemicals, chemical fertilizers, machinery and equipment. Renewable energy consists of human and manure fertilizer in apple production (Mandal et al., 2002; Hatirli et al., 2006).

RESULTS AND DISCUSSION

Socio- economic structure of apple farms

The average mechanization level on the surveyed farms was increase in parallel with the sizes of farms. The average size of the first and second strata of farms was 4.3 and 1.1 hectare, respectively. These farms were mainly devoted to apple. Two different irrigation systems were used to supply water on farms. The second group farms are irrigated by flow of water but the first groups mostly used pump for the supply of irrigation water. (Table 2) shows the agronomic practice period during the process of apple production with the parsonage of mechanization scale relevant to these preparations. Pest control and irrigation are performed during May to September.

Manure fertilization is done in November to December or April to June or both periods and harvesting is done in second mid of September till November. The Pruning and tillage period are March to April and April to May, respectively. In the first group, percentage of pruning mechanization practice was 93% (the highest percentages) that is followed by pest control and manure fertilizing operation with 82 and 71%, respectively, while in the second group chemical fertilization, tillage and manure fertilization operation are the highest mechanized

Table 1. Energy equivalents for different inputs and outputs in apple production.

Input/output	unit	Energy equivalent (MJ/unit)	reference
Labor	h	2.2	(Pimentel and Pimentel., 1979)
Machinery	kg	138	(Kitani, 1999)
Diesel fuel	L	56.31	(Singh, 2002)
Gasoline	L	46.3	(Kitani, 1999)
manure	ton	303.1	(Esengun et al., 2007)
Nitrogen fertilizer (N)	kg	74.2	(Lockeretz, 1980)
Phosphorus fertilizer (P_2O_5)	kg	13.7	(Lockeretz, 1980)
Potassium fertilizer (K_2O)	kg	9.7	(Lockeretz, 1980)
Ca and Mg fertilizer	kg	8.8	(Pimentel and Pimentel, 1979)
Pesticide	kg	363	(Fluck and Baird, 1982)
Fungicide	kg	99	(Fluck and Baird, 1982)
Herbicide	kg	288	(Kitani, 1999)
Apple fruit	kg	2.4	(Jarach, 1985)

Table 2. Management practices for apple.

0peration	period	Mechanization practice (%)	
		First group	Second group
Pruning	March to April	93	7
Tillage	April to May	68	32
Pest control	May to September	82	8
Chemical Fertilization	Mostly April to June	66	38
Manure fertilization	November to December or April to June or both	71	23
Irrigation	May to September	69	0
Harvesting	15 of September to November	0	0

Table 3. Chemical fertilizers for apple production (kg).

Chemical fertilizer	First group	Second group
Nitrogen (N)	11.09	6.25
phosphorus (P_2O_5)	2.74	1.54
potassium (K_2O)	11.63	6.77
Other	6.84	3.98

operations with 38, 32 and 23%, respectively.

Harvesting process is done by labor in the both groups. (Table 3) shows the chemical fertilizers that are used for apple production in the area of survey. Nitrogen (N), phosphorus (P_2O_5), potassium (K_2O) and others (such Mg and Ca fertilizer) in the first group farms were 11.09, 2.47, 11.63 and 6.48 kg, respectively, while in second group farms were 6.25, 1.54, 6.77 and 3.98 kg, respectively.

Esengun et al. (2007) reported that the consumption of potassium, Nitrogen and phosphorus were the biggest chemical fertilizer consumption in apricot production in Turkey, respectively.

Analysis of input–output energy use apple production

(Table 4) shows the energy inputs used in each operation in two types of farms in apple production in the area of survey. Pest control, application of manure and supply of water for irrigation operations were the most energy consuming operations with 60.54, 12.39 and 11.79% of total energy consumption in first group of farms, respectively. While in the second group of farms, pest control, application of manure and harvesting operations were the most energy consumption with 76.54, 12.66 and 2.74% of total input energy, respectively, (Table 4). Pest control includes control of insects, herbs (with chemical method) and fungi. Since in the first group of farms, mechanization scale was higher than second group of farms, energy consumption of tillage, weed control and fertilizing operations are higher than second group. Total input energy in first and second group of farms were

Table 4. Energy inputs in each operation.

operation	Type of farms			
	First groups		Second groups	
	MJ/ha	(%)	MJ/ha	(%)
Tillage	2540.83	5.66	730.84	2.21
Pruning	452.02	1.01	374	1.13
Practice of manure	5624.04	12.39	4191.08	12.66
Chemical fertilizing	1077.26	2.40	616.96	1.86
Pest control	27174.73	60.56	25334.7	76.54
Weed control	1489.41	3.32	564.96	1.71
Supply water for irrigation	5292	11.79	0	0
Irrigation (control and scatter)	380.16	0.85	380.16	1.15
Harvesting	908.12	2.02	908.12	2.74
Total	44938.57	100	33100.82	100

Table 5. Input energy in apple production.

Input	Energy			
	First group		Second group	
	MJ/ha	(%)	MJ/ha	(%)
Labor	1704.24	3.79	3487.4	10.54
Machinery	899.04	2.00	483	1.46
Fuel	12473.25	27.76	6622.06	20.00
Chemicals and chemical fertilizer	21084.26	46.92	18689.3	56.46
Manure	3485.78	7.76	3819.06	11.54
Water	5292	11.77	-	-
Total	44938.57	100	33100.82	100

44938.57 and 33100.82 MJ/ha, respectively. Total input energy in first group was higher than second group of farms Irrigation (control and scatter) operation in first group and pruning operation in second group of farms were the least energy consumers (Table 4). Total energy inputs in apple production in Greece were 50.7 GJ/ha that Pest control, harvesting, transport and fertilizer consume 39.8, 21.6 and 16.8% of total input energy, respectively, (Argiro et al., 2006).

The input values that are used in apple production are illustrated in (Table 5). The overall energy consumptions of the first and second group of farms are directly correlated with the scale of mechanization and the first of the farms is greater in the energy consumed. In the first group of farms, chemicals and chemical fertilizer were the most input energy with 46.92% (21084.26 MJ/ha) of total energy inputs that is fallowed by input energy for fuels and water with 27.76% (12473.25 MJ/ha) and 11.77% (5292 MJ/ha) of total input energy, respectively, while in the second group, chemicals and chemical fertilizer, fuel and manure were the most input energy with 56.46% (18689.3 MJ/ha), 20.01% (6622.06 MJ/ha) and 11.54% (3819.06 MJ/ha) of total input energy in apple production, respectively. Chemicals were used in pest control operation. Because of higher mechanization scale in the first group of farms, input energy of machinery, fuel and supply of water for irrigation were higher in this group but energy of labor was less in compare to second group. Input energy of labor in the first and second group of farms was 3.79% (1704.24 MJ/ha) and 10.54% (3478.40 MJ/ha) of total consumption energy, respectively. Kemal et al. (2007) reported that the average number of personnel on the farms of apricot in Turkey increased in parallel to the sizes of farms.

Output, forms and parameters of energy in apple production are shown in (Table 6). The yield of first group was more than second group of farms. Yield and total output energy in the first group of farms were 19100 kg/ha and 45840 MJ/ha, respectively. While in the second group were 18650 kg/ha and 44760 MJ/ha, respectively. In both types of farms the rate of indirect energy was greater than direct energy. The direct and indirect input energy in first group were 14177.49 MJ/ha (31.55%) and 30761.08 MJ/ha (68.45%), respectively.

Table 6. Output, forms and parameters of energy in apple production.

Item	unit	Type of farms	
		First group	Second group
Total output energy	MJ/ha	45840	44760
Direct energy	MJ/ha	14177.49	10109.46
Indirect energy	MJ/ha	30761.08	22991.36
Renewable energy	MJ/ha	5190.02	7306.46
Nonrenewable energy	MJ/ha	39748.55	25794.36
Output-input energy ratio	-	1.02	1.35
Energy productivity	Kg/MJ	0.425	0.563
Specific energy	MJ/kg	2.353	1.775
Net energy gain	MJ/ha	901.43	11659.18

While in the second group, direct and indirect input energy were 10109.46 MJ/ha (30.54%) and 22991.36 MJ/ha (69.46%), respectively. The results revealed that nonrenewable form of energy input in the first group of farms was 88.45% (39748.55 MJ/ha) compared to 77.93% (25794.36 MJ/ha) in the second group. Also the results indicated that output-input energy ratio, energy productivity and net energy gain were greater in the second group of farms but specific energy was less. This shows that in the second group, efficiency of using energy is higher. Output-input energy ratio, energy productivity and specific energy in first group were 1.02, 0.425 and 1.353 MJ/kg, respectively, while in the second group of farms were 1.35, 0.563 and 1.775 MJ/kg, respectively.

In Greece energy productivity, energy intensity and energy efficiency were calculated (average of the 2 years) as 0.42, 2.50 and 1.0 kg/MJ by Argiro et al. (2006).

Conclusion

Overall, the energy consumptions of the first and second group of apple farms in Esfahan province are directly correlated with scale of mechanization and in the first group of farms consumed a total of 44938.57 MJ/ha, while the second group consumed 33100.82 MJ/ha. Chemicals for pest control and fuel were the major energy inputs in both types of farms. Total output energy in the first and second group of farms were 45840 and 44760 MJ/ha, respectively. Output-input energy ratio, energy productivity and net energy gain were higher in the second group of farms. Efficiency of consuming energy in the first group was less than that of the second group. Output-input energy ratios in the first and second group were 1.02 and 1.35, respectively. Energy productivity and specific energy in the first group were 0.425 and 2.353 MJ/kg, respectively; while in the second group were 0.563 and 1.775 MJ/kg, respectively. The nonrenewable form of energy input in first and second group was 88.45 and 77.93% of the total energy input, respectively. This indicates that apple production mainly depends on nonrenewable energy in the research area. Correct adjustment and management of equipments and proper method of production can increase efficiency of input energy (Esengun et al., 2007).

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