American-Eurasian J. Agric. & Environ. Sci., 16 (1): 209-215, 2016
ISSN 1818-6769

DOI: 10.5829/idosi.aejaes.2016.16.1.12856

Energy Analysis of Summeryy Vetch Production in Turkey: A Case Study for Kırklareli Province

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Abstract: This study aims to determine an energy analysis of summeryy vetch plant production in dry conditions in Kırklareli province of Turkey during the production season of year 2013. In order to determine the energy input-output of vetch, surveys have been performed in 40 vetch farms, all selected through Neyman method and located in Kırklareli province. The data have been collected through face to face questionnaires. The energy input and output have been calculated as 8972.39 MJ ha^{-1} and 85333.05 MJ ha^{-1}, respectively, in vetch production. Energy inputs consist of 41.67% diesel fuel energy, 26.83% chemical fertilizer's energy, 22.44% seed energy, 8.31% machinery energy and 0.75% human labour energy. Energy usage efficiency, specific energy, energy productivity and net energy in vetch plant production have been calculated as 9.51, 0.39 MJ kg^{-1}, 2.51 kg MJ^{-1} and 76360.66 MJ ha^{-1}, respectively.

Key words: Energy · Kırklareli · Energy analysis · Turkey · Vetch

INTRODUCTION

Among the vetch species, the most commonly farmed specie is the ordinary vetch. It is being planted in all parts of Turkey and the size of the cultivation area is ever so growing. Ordinary vetch is most commonly used as rotational plant, green grass, dry, silo forage and green manure. Green and dry fodder is highly delicious and nutritious for the animals. There is 3-4% raw protein in the green part and over 20% raw protein in its grain. Being one of the annual forage legumes, ordinary vetch is one of the most suitable plants for croprotation alternation. It leaves a great amount of organic matter in the soil [1].

The total size of pasture area in the world is 3.4 billion hectare. Turkey's total pasture area size is 14.60 million ha, total size of forage plant cultivation area is 1, 874, 800 ha, while the amount of production is 38, 905, 000 tons. The total cultivation area of vetch in Turkey is 499, 043 ha, total production value is 4, 492, 466 tons and the share among the total forage crops is 27% [2]. Agriculture is an important part of the Turkish economy; despite the fact that the share of agriculture in the Turkish economy has tended to fall over a period of several decades, due to the increase in industrial and services sectors. Agriculture still accounts for a relatively larger share of total output and employment than in many other countries [3].

Azizi and Heidari [4] reported that, "Energy consumption per unit area in agriculture is directly related to the development of farming technology and the production level. Energy use is one of the key indicators for developing more sustainable agricultural practices [5]. The amount of energy used in agricultural production, processing and distribution is significantly high. A sufficient supply of the right amount of energy and its effective and efficient use are necessary for an improved agricultural production [6].

Several researches have been conducted on energy input-output analysis of agricultural products. Some of these researches may be listed as those on the energy usage activities of sugar beet [7], wheat [8], lentil [9], barley [10]), chick pea [11], tobacco [12], corn [13], pumpkin seed [14], canola [15], sunflower [16], apple [17], watermelon and melon [18], apricot [19], black carrot [20], rose [21] etc. No any research related to the energy balance of summeryy vetch plant production in Thrace region has been contained in this study. Summery vetch plant is the most important plant in macro and micro terms and defining the energy balance is the aim of this study.

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MATERIALS AND METHODS

The province of Kırklareli is located in the Thrace region of the Turkey. Kırklareli province is located between 41° 44' - 42° 00' north latitude and 26° 53' - 41° 44' east meridians. The land size of Kırklareli province is 6555 km^2. Kırklareli is neighboured by Bulgaria with a length of 159 km border with in the north; Black Sea coastline 58 km from the east; Edirne province in the west; Istanbul province in the southeast; and Tekirdag province in the south [2].

Main material of the research composed of the data gathered through face to face surveys with 40 summery vetch producers in Kırklareli province. The farms to be surveyed have been determined by using the Neyman method. The calculation of the surveys conducted at the farms was done through the Neyman method, proposed by Yamane [22, 23]. The formula has been given below.

$$n = \frac{(\sum N_h S_h)^2}{N^2 * D^2 + \sum N_h S_h^2} \quad (1)$$

In the formula, n, is the required sample size; N, the number of total business in population; N_h, the number of the population in h (small or large); Sh^2, the variance of h; $D^2 = d^2 / z^2$; d is the precision and z is the reliability coefficient (1.96, which corresponds to 95% confidence). The permissible error in sample population has been defined to be 5% and the sample size has been calculated to be 40 for 95% reliability. Total energy input in unit area (ha) constitutes each total of input energy. Human labour, machinery, chemical fertilizers, diesel fuel and vetch plant seed have been calculated inputs. Summery vetch plant yield has been the calculated output. Following the experiments and measures conducted at the vetch plant facilities in Kırklareli region, energy input and output values have been defined. As energy inputs, human labour energy, machinery energy, chemical fertilizers energy, diesel fuel energy and seed energy values have been taken into consideration. In the agricultural production given in Table 1, energy equivalents of input and output have been taken as energy values. Energy balance calculations have been made to determine the productivity levels of summery vetch plant production. The units shown in Table 1 have been used to find out the input values in summery vetch plant production. Input amounts have been calculated and then these input data have been multiplied by the energy equivalent coefficient. When determining the energy equivalent coefficients, previous energy analysis sources have been used. By adding energy equivalents of all inputs in MJ unit, the total energy equivalent has been found. For example, in order to determine the energy usage efficiency in wheat production, Mohammadi *et al*. [5] reported that, "The energy ratio (energy use efficiency), energy productivity, specific energy and net energy have been calculated by using the following formulates [24, 25].

$$\text{Energy use efficiency} = \frac{\text{Energy output}\left(\frac{\text{MJ}}{\text{ha}}\right)}{\text{Energy input}\left(\frac{\text{MJ}}{\text{ha}}\right)} \quad (2)$$

$$\text{Specific energy} = \frac{\text{Energy input}\left(\frac{\text{MJ}}{\text{ha}}\right)}{\text{Vetch plant output}\left(\frac{\text{kg}}{\text{ha}}\right)} \quad (3)$$

$$\text{Energy productivity} = \frac{\text{Vetch plant output}\left(\frac{\text{kg}}{\text{ha}}\right)}{\text{Energy input}\left(\frac{\text{MJ}}{\text{ha}}\right)} \quad (4)$$

$$\text{Net energy} = \text{Energy output (MJ ha}^{-1}) - \text{Energy input (MJ ha}^{-1}) \quad (5)$$

In the calculation of quantities of inputs used in vetch plant production, the energy equivalences given in Table 1 have been used. Quantities of inputs have been calculated in accordance with the area (hectare) and then they have been multiplied with the equivalence of these inputs. Resources of previous researches have been used when determining the coefficients of energy equivalence. In addition, data released by organizations related to summery vetch producers have also been used. Following the analysis of data by through Microsoft Excel program, by referring to the inputs, the results have been tabulated. Summery vetch plant input-output values have been assessed and the calculations have been given in Table 2. Kocturk and Engindeniz [26] reported that; "The input energy can also be classified into direct and indirect and renewable and non-renewable forms. The indirect energy consists of pesticide and fertilizer while the direct energy includes human and animal power, diesel and electricity energy used in the production process. On the other hand, non-renewable energy includes petrol, diesel, electricity, chemicals, fertilizers, machinery, while renewable energy consists of human and animal labour [24, 27]. Energy input-output and efficiency calculations in summery vetch plant production are given in Table 3.

Table 1: Energy equivalents of inputs and outputs in production of vetch plant

Inputs and outputs	Unit	Energy equivalent coefficient	Sources
Inputs	Unit	Values (MJ / unit)	Sources
Human labour	h	1.96	[28, 29]
Machinery	h	64.80	[30, 31]
Chemical fertilizers			
Nitrogen	kg	60.60	[31]
Phosphorous	kg	11.10	[31]
Potassium	kg	6.70	[31]
Chemicals	kg	101.20	[32]
Diesel fuel	l	56.31	[31, 33]
Seed	kg	10	[34]
Support plant seed *	kg	14	[35, 36]
Outputs	Unit	Values (MJ/unit)	Sources
Vetch plant	kg	17.239	Measured

Table 2: Energy input - output analysis in summery vetch plant production

Inputs	Unit	Energy equivalent (MJ / unit)	Input used per hectare (unit ha^{-1})	Energy value (MJ ha^{-1})	Rate (%)
Human labour	h	1.96	34.40	67.42	0.75
Land preparation	h	1.96	3.90	7.64	
Planting-fertilization	h	1.96	5.30	10.39	
Hoeing	h	1.96	0.90	1.76	
Harvesting	h	1.96	1.70	3.33	
Turning-drying	h	1.96	12.70	24.89	
Baling	h	1.96	1.50	2.94	
Transporting	h	1.96	8.40	16.46	
Machinery	h	64.80	11.50	745.20	8.31
Land prepartion	h	64.80	3.90	252.72	
Planting-fertilization	h	64.80	2.30	149.04	
Hoeing	h	64.80	0.90	58.32	
Harvesting	h	64.80	1.70	110.16	
Baling	h	64.80	1.50	97.20	
Transporting	h	64.80	1.20	77.76	
Chemical fertilizers			44.31	2406.99	26.83
Nitrogen	kg	60.60	38.69	2344.61	
Phosphorous	kg	11.10	5.62	62.38	
Diesel fuel	l	56.31	66.40	3738.98	41.67
Seed				2013.80	22.44
Vetch plant seed	kg	10	144.68	1446.80	
Support plant seed	kg	14	40.50	567	
Total inputs				8972.39	100
Outputs	Unit	Energy equivalent (MJ / unit)	Output per hectare (unit ha^{-1})	Energy value (MJ ha^{-1})	Rate (%)
Vetch plant yield	kg	17.239 (%22 dry matter)	22500	85333.05	100

*: Barley seed has been used as supporting plant seed.

Table 3: Energy input-output and efficiency calculations in vetch plant production

Calculations	Unit	Values
Vetch plant	kg ha^{-1}	22500
Energy input	MJ ha^{-1}	8972.39
Energy output	MJ ha^{-1}	85333.05
Energy use efficiency		9.51
Specific energy	MJ kg^{-1}	0.39
Energy productivity	kg MJ^{-1}	2.51
Net energy	MJ ha^{-1}	76360.66

For calorific values of vetch plant IKA brand C200 model bomb calorimeter device has been used. For measuring purposes, the amount of fuel (~0.1 g) has been combusted inside the calorimeter bomb, which was filled with oxygen for full combustion with adequate pressure (~30 bars), the filled bomb calorimeter was put in the device and surrounded by an adequate amount of ordinary water (~2000 mL at 18-25 °C ± 1°C). The heat of combustion was transferred to the water and measured through the rising temperature in the calorimeter. The device was given a calorific value in MJ kg^{-1} unit. The device can perform calorific value measurement in accordance with EN 61010, EN 50082, EN 55014 and EN 60555 standards. For samples, reading of the calorific value was measured repetitively for 3 times and then the average value has been reported in this study. The method employed by Gokdogan *et al*. [37] for the energy balance calculation of *Nigella sativa* (L.) oil has been used in this study to determine the energy values of vetch plant.

RESULTS AND DISCUSSION

During the studies in the farms, the amount of summery vetch plant produced per hectare during the 2013 production seasons has been calculated as an average of 22500 kg. The 2013 summery vetch plant production and the energy output - input analysis of vetch plant production related to this study have been provided in Table 2. It can be seen from these tables that the first, second and third highest energy inputs in summery vetch plant production are diesel fuel energy by 41.67%, chemical fertilizers energy by 26.83% and seed energy by 22.44%. If the average values are examined by referring to Table 2, it can be seen that the highest energy inputs in vetch plant production are diesel fuel energy by 3738.98 MJ ha^{-1} (41.67%), chemical fertilizers energy by 2406.99 MJ ha^{-1} (26.83%), seed energy by 2013.80 MJ ha^{-1} (22.44%), machinery energy by 745.20 (8.31%) and human energy by 67.42 MJ ha^{-1} (0.75%).

In previous studies, [16] concluded in his sunflower study that the fertilizer application energy had the biggest share by 9707.20 MJ ha^{-1} (51.28%), [38] concluded in his sugar beet study that the fertilizer application energy had the biggest share by 16879.59 MJ ha^{-1} (42.53%) and [10], conclude in their barley study the fertilizer application energy had the biggest share by 10055.92 MJ ha^{-1} (59.33%). In this study, fertilizer application energy had the second biggest share by 26.83%. The reason for chemical fertilizers energy being so high is due to the fact that chemical fertilizers have been used, instead of the farm or organic fertilizers.

As can be seen from Table 2, human labour energy input has been calculated 67.42 MJ ha^{-1}. Human labour energy has been used for tractor and farm operations such as land preparation, planting-fertilization, hoeing, harvesting, turning-drying, baling and transportation. Diesel energy input has been calculated as 3738.98 MJ ha^{-1}. The amount of chemical fertilizers used for summery vetch plant growing was 44.31 kg ha^{-1}. Nitrogen was the most common chemical fertilizer used in summery vetch plant production, by 38.69 kg ha^{-1}, followed by phosphorus, 5.62 kg ha^{-1}. Vetch plant yield, energy input, energy output, energy use efficiency, specific energy, energy productivity and net energy in vetch plant production have been calculated as 22500 kg ha^{-1}, 8972.39 MJ ha^{-1}, 85333.05 MJ ha^{-1}, 9.51, 0.39 MJ kg^{-1}, 2.51 kg MJ^{-1} and 76360.66 MJ ha^{-1}, respectively.

Table 4: Energy input in the form of direct and direct renewable and non-renewable energy for summery vetch plant production

Type of energy	Energy input (MJ ha^{-1})	Ratio (%)
Direct energy [a]	3806.40	42.42
Indirect energy [b]	5165.99	57.58
Total	8972.39	100
Renewable energy [c]	2081.22	23.19
Non-renewable energy [d]	6891.17	76.81
Total	8972.39	100

[a]Includes human labour, diesel; [b] Includes seed, chemical fertilizers and machinery;
[c]Includes human labour and seed; [d] Includes diesel, chemical fertilizers and machinery

The distribution of inputs, used in the production of summery vetch plant, in accordance with the direct, indirect, renewable and non-renewable energy groups is given in Table 4. As can be seen from Table 4, the total energy input consumed in summery vetch production could be classified as 42.42% direct and 57.58% indirect. Similarly, in previous studies it has been concluded that the ratio of indirect energy is higher than the ratio of direct energy in canola [15], wheat [39], lentil [9], barley [10] and in dry land wheat [4]. As can be seen from Table 4, the total energy input consumed in summery vetch plant production could be classified as 23.19% renewable and 76.81% non-renewable. Similarly, it has been concluded that the ratio of non-renewable energy is higher than the ratio of renewable energy in maize [40], wheat [41], lentil [9] and barley [4].

CONCLUSIONS

Energy use in agriculture has been increasing in response to increasing population, limited supply of arable land and a desire for higher standards of living. Continuous demand in increasing food production resulted in intensive use of chemical fertilizers, pesticides, agricultural machinery and other natural resources. However, intensive usage of energy causes problems, which threaten public health and environment. Efficient use of energy in agriculture may minimize environmental problems, may prevent destruction of natural resources and promote sustainable agriculture as an economical production system [38]. The importance of energy increases each day, as fossil fuels have a limited period of usage and renewable energy resources are eco-friendly and sustainable energy systems [42].

The research results indicate that the ratio of non-renewable energy is higher than the ratio of renewable energy and the ratio of indirect energy is higher than ratio of the direct energy. Farm fertilizers can also be used in vetch plant production, instead of chemical fertilizers, which make up an important part of the inputs. For example, Tipi *et al*. [3], reported that; "The use of renewable energy is very low, indicating wheat production depends mainly on fossil fuels. Continually rising fossil fuel prices have necessitated more efficient use of diesel, chemicals and fertilizers for wheat production. Efficient use of energy helps to achieve increased production and productivity levels and contributes to economy, profitability and competitiveness of agricultural sustainability in rural life.". Similarly, these conclusions should also be taken into account in vetch plant production.

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