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Energy Productivity and Efficiency in Poppy (*Papaver somniferum* L.) Production

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ABSTRACT

The purpose of this work was to analyse the energy productivity and efficiency of agricultural enterprises growing poppy. The number of enterprises investigated in the study was determined from a stratified random sample of 87, the data is from 2019, and the study was conducted in Turkey. All inputs and outputs used in poppy production were obtained by multiplying energy equations with conversion coefficients in determining the energy use of the enterprises. Data Envelopment Analysis (DEA) method was employed to calculate the technical, pure-technical, and scale efficiency of poppy-producing enterprises. Poppy energy inputs consisted of the use of human labour, machinery, fertilizer, pesticides, seeds, water, and fuel. The poppy capsule yield per unit area was regarded as the energy output. In the end, 40.23% of the total energy input in poppy production consisted of direct and 59.77% indirect energy. Non-renewable energy consumption (88.70%) was found to be rather high in the research area. Therefore, the use of chemical fertilizers and fuels, which are non-renewable energy sources, must be lessened for poppy plant production. The energy efficiency was found to be 0.08 in poppy production. According to this result, the production systems of the enterprises producing poppy are sufficient and energy is used efficiently. The specific energy value in the enterprises was calculated as 11.95 MJ kg^{-1} and the Technical Efficiency (TE) was calculated as 0.683. Producers produce at the same level with 68.3% of their capital, and 31.7 % saving.

Keywords: Energy Efficiency, Energy Productivity, Poppy Production, Konya.

INTRODUCTION

Poppy (*Papaver somniferum* L.) is one of the few medicinal plants that have been cultivated and used since prehistoric times (Shukla *et al*., 2006). It was reported that the Sumerians, who lived in Mesopotamia around 5,000 BC, used poppy as food and medicine (Beyer *et al*., 2009). In some Assyrian reliefs and paintings around 3,000 BC, poppy was used medicinally, and the ancient Egyptians also used it for medicinal and narcotic effects (Lack, 2016). Turkey ranks first among all poppy-producer countries (FAO, 2021). Two important products are obtained from poppy, namely, the seed and the capsule shell, which have economic value (Mahdavi-Damghani *et al*., 2010). Poppy seeds can be grey–blue, yellow, white, raw coffee and pink. The most important characteristic of poppy seed is that it has 45-54% oil and 20-30% protein content (Baser and Arslan, 2014). Its use in both food and pharmaceutical industries has made poppy a noteworthy agricultural product. Poppy cultivation plays a key role in the development and sustainability of rural areas (Gillies *et al*., 2019). In recent years, the trio of economy, energy, and environment has been analyzed together in line with the principles of sustainable agriculture. Improving energy use reduces energy use in the agricultural sector (Oğuz

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and Yener, 2019). The energy use of sunflower and soybean in co-sowing systems has been compared. (Hamzei and Seyyedi, 2016). Another sunflower study analyzed the energy flow and indices of sunflower farming systems, calculated the carbon footprint and determined the water footprint of sunflower farming systems. (Yousefi *et al*., 2017). In another study, the energy consumption of wheat and sunflower plants was compared (Unakıtan and Aydın, 2018). In the study conducted in Konya, the energy consumption and energy efficiency of milk production were calculated (Oğuz and Yener, 2019). As a result, when you look at energy consumption studies in the literature, you can see that they are not only studied in the economic, but also in the environmental and social dimensions (Hulsbergen *et al*., 2001; Pervanchon *et al*., 2002; Singh *et al*., 2002; Esengün *et al*., 2007; Imran *et al*., 2022). Oğuz (2022) reported the gross production value, gross profitability and cost of the enterprises producing poppy from the context of the economic analysis. However, there are no articles on the energy use efficiency of poppy farming. Konya is one of the provinces with the largest poppy production in Turkey. For the first time in Konya Region, energy use efficiency has been calculated for poppy production enterprises. The fact that Turkey's energy is mostly provided by fossil fuels leads to high CO_2 emission levels. For this purpose, it is tried to use and expand environmentally friendly energy sources that do not pollute the environment and that we can use as a resource as long as the sun exists. For a cleaner world, it would be justified to evaluate all the opportunities in the field of energy in this energy resources investment. For this reason, the transition to new and renewable environmentally friendly energy sources has now become a necessity (Hocaoğlu *et al*., 2007; Imran and Ozçatalbaş, 2020). The energies obtained from the current energy flow in natural processes are called renewable energy (Sarıkaya, 2010). Renewable energy sources include wind, solar, geothermal, water, hydrogen and bioenergy. Renewable energy sources are not limited to energy sources such as coal-based fossil fuels. As a developing economy, Turkey's energy demand has grown dramatically over the past three decades. Strong economic growth and improved macroeconomic balances in the last decade have been the main drivers of growth in energy demand.

Adequate and balanced nutrition of the world population needs to be increased, and this is only possible with the use of inputs that increase productivity per unit area and per unit animal. Since the total input use per unit area has increased significantly, there is a greater need for fossil fuel energy (Oğuz and Yener, 2018; Demeneix, 2020). It is important to calculate the energy efficiency of poppy production, because it is widely used both in the oil industry and in the health sector. The purpose of this research was to study the energy efficiency and effectiveness in agricultural enterprises producing poppy.

MATERIALS AND METHODS

Method Used to Determine Sample Size

The study consisted of the original data obtained according to the survey technique from the enterprises producing poppy in the Ilgın District and villages of Konya Province, in 2019. The surveys were conducted in July, August, and September. At the time of the survey, exchange rate was 1US ($= 5.62 TL). In the study, stratified sampling method was used to ensure adequate representation of different segments of the population and to increase the accuracy of data and findings to be collected from the enterprises (Güneş and Arıkan, 1985). The Neyman method was used to select the sample volume. In the study, considering the land widths of the enterprises, the number of enterprises to be surveyed was determined as 87 with a 10% margin of error at the 90% confidence limit.

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$$n=\frac{\sum(Nh.Sh)^2}{N^2.D^2+\sum Nh.(Sh)^2} \qquad D^2=(\frac{d}{t})^2$$

Where, n: Number of samples, N: Number of enterprises in the population, Nh: The Number of enterprises in the h^{th} layer, Sh: Variance of the h^{th} layer, d: Allowable margin of error from the population mean, t: t table value corresponding to the 99% confidence limit predicted in the research (Yamane, 1967).

A survey was conducted with 15 enterprises that cultivated poppy in 4-10 decares, 42 enterprises in 11-30 decares, and 30 enterprises producing in 31 and more decares. In calculating workforce in the enterprises as Man Power Unit (MPU), the workforce in the 7-14 age group with a coefficient of 0.50, the workforce in the 15-49 age group with a coefficient of 1.00 for men, 0.75 for women, and the workforce in the 50 and older group with a coefficient of 0.75 for men and 0.50 for women were multiplied and calculated. The coefficients were multiplied by the number of days worked by the workforce in the enterprise and the Man Work Power Day (MWPD) was calculated. In the calculation of the economic activity, results of the examined enterprises Gross Production Value (GPV) was calculated by adding the value of the products yielded in the enterprise to the value of the farmyard prices, by adding the increase in the value of the field fixtures in the plant production. Calculated by subtracting Gross Profit (GP)= GPV-Variable Costs (VC) (Açıl and Demirci, 1984). The simple cost calculation method was used in the calculation of poppy production costs as follows:

General administrative expense= Total Variable expenses×0.03

Building Capital Depreciation= (Building Value×0.02)

Building or Tool-Machine Capital Interest= (Total Value/2)×0.05)

Tool-Machine Depreciation= (Machine's New Value-Scrap Value)/Economic Life (Years)

Total Production Costs= Total Changing Costs+Total Fixed Costs

Production cost of 1 kg of poppy= Total Production Costs ($/Decar)/Production Amount (kg/da) (Oğuz and Bayramoğlu, 2018).

Calculating the Energy Efficiency of Poppy-Producing Enterprises

To calculate the energy efficiency of enterprises producing poppy, firstly, energy inputs and outputs must be calculated. The energy equivalent coefficients are given in Table 1.

Calculation of Energy Inputs

The energy inputs and outputs used in poppy production were calculated. Inputs were divided into direct (fuel-oil, labor and water) and indirect energy (machinery, seed, fertilizer and medicine). The output is the poppy capsule efficiency. The energy equivalents of all inputs were calculated by multiplying the energy input amount by the energy equivalent.

Human Labor Energy (HE)

HE= (Working Hours)/(ha)×EE (1)

EE= The Energy Equivalent of the human workforce MJ ha^{-1}).

Human labor includes labor forces employed in hoeing, irrigation, harvesting, etc.

Machine Labor Energy (ME)

ME= (GxEExt)/T (2)

Where, G is the machine weight (kg), while EE is the Energy Equivalent of machine labor (MJ kg^{-1}), t is the time (h) of machine labor used per hectare, and T is the economic life of the machine (h). Also, ME

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Table 1. Input and output energy equivalents used in poppy production.

Inputs and Outputs	Unit	MJ unit^{-1}	References
Inputs			
Human Labor	ha	2.30	Özkan *et al*., 2004
Machine			
Soil preparation	ha	62.70	De *et al*., 2001; Singh *et al*., 2002
Pulverizator (Spray)	ha	48.25	Zentner *et al*., 2004
Fertilization	ha	10.90	Alluvione *et al*., 2011
Marketing	ha	29.80	Fluck ,1992
Fertilization			
N	kg	75.40	Spugnoli *et al*., 1993
P	kg	10.90	Spugnoli *et al*., 1993
K2O	kg	9.20	Preininger, 1987
S	kg	1.12	Zentner *et al*., 2004
Agricultural Spraying			
Herbicides	kg	288	Green, 1987; Hülsbergen *et al*., 2001; Unakitan *et al*., 2010
Fungicides	kg	196	Green, 1987; Hülsbergen *et al*., 2001
Insecticides	kg	237	Green, 1987; Dalgaard *et al*.,2001; Hülsbergen *et al*., 2001
Fuel	L	56.31	De Haan *et al*., 2001; Singh *et al*., 2002; Özkan *et al*., 2007
Water	m^3	0.63	Yaldiz *et al*., 1993
Seed	kg	2.50	Ozkan *et al*., 2004
Output			
Poppy Capsule	kg	15.48	Voltr *et al*., 2021

is Machine labor Energy (MJ/ha), which is the machine labor energy equivalent. It includes the utilization of tractors and other machinery used in plant production (Pishgar-Komleh *et al*., 2012).

Fuel and Oil Energy (FE)

FE= Qf×EE (3)

Where, FE is Fuel Energy per hectare (MJ ha^{-1}), Qf is fuel consumption (L ha^{-1}), and EE is fuel Energy Equivalent (MJ L^{-1}). It includes the use of fuel-oil used in plant production.

Lubricant Energy (LE)

LE= (FE×0.045)×LE (4)

Where, LE is Lubricant Energy input per hectare (MJ ha^{-1}), FE is fuel consumption (L ha^{-1}), and LE is energy value of lubricant (MJ L^{-1}). It is obtained as a result of multiplying the energy input of seeds, pesticides, fertilizers, water and human labor by the number of inputs used or spent per unit area and the energy equivalent of these input types.

Calculation of Total Energy Output (TEO)

TEO= AV×EU (5)

Where, TEO is Total Energy Output (MJ ha^{-1}), AV is poppy yield (kg ha^{-1}), and EU is Energy equivalent (MJ kg^{-1}). In our study, energy use efficiencies (6-11) were calculated according to the following formulas (Mobtaker *et al*., 2010).

Energy Use Efficiency (EUE)= Energy output (MJ ha^{-1})/Energy input (MJ ha^{-1}) (6)

Energy Productivity= Poppy yield (Output) (kg ha^{-1})/ Energy input (MJ ha^{-1}) (7)

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Specific Energy= Energy input (MJ ha^{-1})/Poppy yield (Output) (Kg ha^{-1}) (8)

Energy Intensity= Poppy input (MJ ha^{-1})/Energy output (MJ ha^{-1}) (9)

Energy Intensiveness=Energy input (MJ ha^{-1})/Cost of production ($ ha^{-1}) (10)

Net Energy Gain (NEG)= Energy output (MJ ha^{-1})-Energy input (MJ ha^{-1}) (11)

In addition, technical, pure technical, and scale efficiency of poppy production enterprises was calculated using the non-parametric DEA method. Poppy pod yield per space is included as the only output variable in the model. Input variables included energy consumption, which consists of seven inputs, including labor, seeds, pesticides, fertilizers, fuel, water, and machinery. In DEA, inefficient decision units can be made efficient by symmetrically applying the same level of output (input-oriented) with minimal input as well as maximizing output levels (output-oriented), provided their inputs are held constant. The key performance criterion for data envelopment analysis is the weighted total of outputs divided by the weighted total of inputs. For multiple inputs and outputs, the TE points (ø) are found as follows (Coelli *et al*., 2002; Cooper *et al*., 2004; Esengün *et al*., 2007):

$$TE\ (\text{ø}) = \frac{U_1 Y_{j1} + U_2 Y_{2j} + \cdots \ldots\ldots + U_n Y_{nj}}{V_1 X_{j1ji} + V_2 X_{2j} + \cdots \ldots\ldots + V_n X_{nj}} = \frac{\sum_{r-1}^{n} + U_r Y_{rj}}{\sum_{s-1}^{m} + V_s X_{sj}}$$

Since agricultural enterprises typically tend to control inputs, Farrell's (1957) input-oriented efficiency measures were employed in the study. In the efficiency measurements, enterprises producing poppy use fertilizer (kg ha^{-1}), fuel oil (L ha^{-1}), water (m^3/ha), seeds (kg ha^{-1}), pesticides (g ha^{-1}), machine labor (h ha^{-1}) and human labor (h ha^{-1}) as inputs. There are CCR and BBC models in data envelopment analysis. The models were used to calculate the resource use efficiency of poppy producers. The former is based on the assumption of constant returns to scale while the latter model limit is given below.

$$min\ \lambda xi\ Wi * Xi *$$
$$-\text{yi} + \text{Y}\lambda \geq 0$$
$$xi * - X\lambda \geq 0$$
$$\lambda \geq 0$$

In the equation, the technical efficiency score for each agricultural enterprise, the vector of constants consisting of 1s, X represents the input matrix and Y represents the output matrix. A value of Xi * 1 indicates that the enterprise is on the frontier or that the enterprise has Technical Efficiency (TE) according to Farrell (1957). Inefficient companies have a Xi* value less than 1. In addition, according to the technical efficiency coefficient in the efficiency analysis, the farmers were classified as efficient, less efficient, and inefficient. Classification was done. 0.95< TE≤ 1 effective, 0.90< TE≤ 0.95 less efficient and 0.90≤ TE inefficient (Charnes *et al*., 1978). In terms of scale type, enterprises can offer diminishing, increasing and constant returns to scale (Cooper *et al*., 2000). Using the constant returns to scale definition confuses technical efficiency with scale efficiency if not all production units are at optimal scale according to the BBC model. Therefore, using a definition of variable returns to scale gives a calculation of technical efficiency without economies of scale (Coelli, 1998). Farrell's value of technical efficiency is divided into pure technical efficiency and scale efficiency. If the fixed-volume return and the Variable-Scale Return Technical Efficiency (TE_{VRS}) of a given production unit differ from each other, the production unit is considered to be inefficient. Thus, the following is the Scale Efficiency (SE) using the difference between the technical efficiency values obtained by these two assumptions (Farrell *et al*., 1985). Totaltechnical efficiency= Pure technical efficiency×Scale Efficiency (TECRS= TEVRS×SE).

It is the formula for total technical efficiency. In DEA, we want the number of decision units to be examined for efficiency to be many times larger than the number of inputs and outputs. Otherwise, as a result of

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the analysis, most of the decision units are evaluated as efficient**.** In practice, it is recommended that the number of decision units be at least equal to the product of the number of inputs and outputs, or three times the sum of inputs and outputs (Cooper *et al*., 2007). According to Sherman (1984), if n is the number of observations, m is the number of inputs, and s is the number of outputs, the number of decision units should be n> m+s. However, the generally accepted equality is the minimum number of decisions, Making units= 2×m×n (Kocakalay and Alim, 2003). Our study carried out an efficiency analysis of the resource use of poppy-producing companies in the DEAP program.

RESULTS AND DISCUSSION

Energy Use Efficiency in Poppy Producing Agribusinesses

Poppy is sown by machine. The second hoe and earthing-up procedures are done 15-20 days after the thinning and the first hoe. Before planting, the recommended herbicides should be applied to the soil and mixed with the help of a disc harrow and raked to a depth of 5-6 cm. Fungicide is also applied in the research area. Hoeing operations in poppy are done by hand. When the poppy plants have 7-10 leaves, thinning and first hoeing are accomplished. The energy equivalents used in poppy production are given in Table 2.

In poppy production, the total energy input is 20,663.06 (MJ ha^{-1}) and the total energy output is 267,697.24 (MJ ha^{-1}) and the net energy value is 247.034.18 (MJ ha^{-1}). EUE in the research area was found to be 12.96. According to the result, energy is used efficiently and enterprises are in good condition. Energy efficiency shows how much energy input to spend on poppy cultivation per hectare. The energy efficiency of poppy cultivation in the study area was calculated to be 0.08 (MJ kg^{-1}), if only the amount of poppy production per hectare is considered. In other words, under the conditions of Konya, 1 kg of the poppy is produced in exchange for energy consumption of 0.08 (MJ kg^{-1}). A low specific energy value means a high energy efficiency in production (Baran *et al*., 2014). The specific energy in the research area was calculated as 11.95. In other words, 11.95 (MJ kg^{-1}) energy is used effectively in production of a unit poppy (kg). Net energy gain was calculated as 247.034.18 (MJ ha $^{-1}$).

With regards to the total amount of energy, the direct energy value was determined as 40.23% while the indirect energy value was 59.77%. The renewable energy value was 11.30% and the non-renewable energy was 88.70% (Table 3). Depending on the intensity of energy consumption, the use of non-renewable energy sources increases as the use of machinery in agricultural production increases. To prevent damage from non-renewable energy sources, efficient use of agricultural machinery should be ensured, and attention should be paid to the use of fertilizers and pesticides. When the studies in the literature are examined, the energy values of the inputs-outputs used in seed corn production were calculated in a study conducted in Iran and their economic analysis was reported (Pishgar Komleh *et al*., 2012). In another study, the relationship between the inputs and outputs used in poppy production was determined by making a cost analysis of the poppy plant (Oğuz, 2022). In the study related to milk production, energy consumption and energy efficiency analysis were made in milk production (Oğuz and Yener, 2019). What is important here is the sustainable management of agricultural enterprises and the farmer's choice of products suitable for the enterprise, taking into account the energy use of different products. In addition, the energy values of the poppy plant were calculated for the first time in Turkey in this paper. To reveal the current situation of the enterprises producing poppy in the research area and to report the data on energy consumption by calculating the unit costs and profitability for 1 kg of poppy

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Table 2. Energy equivalents of inputs and outputs in poppy production.

Inputs and Outputs	(MJ ha^{-1})	Total Energy (MJ ha^{-1})	%
Inputs			
Human labor	88.06	202.53	0.98
Machine			
Soil preparation	39.66	2,486.38	12.03
Pulvazitor (Spray)	18.54	899.03	4.35
Fertilization	1.52	16.59	0.08
Marketing	6.50	193.61	0.94
Fertilizer			
N	104.17	7,854.17	38.01
P	53.58	583.99	2.83
K2O	12.67	116.59	0.56
S	8.45	9.46	0.05
Chemicals			
Herbicides	0.33	93.61	0.45
Fungicides	0.35	68.26	0.33
Insecticides	0.02	4.55	0.02
Diesel	106.60	6,002.82	29.05
Water	3,344.48	2,107.02	10.20
Seed	9.78	24.44	0.12
Total Input (MJ)	3,794.69	20,663.06	100.00
Poppy Capsule Yield	1,729.31		
Total Output (MJ)		267,697.24	
Output/Input (EUE)		12.96	
Energy productivity (MJ kg^{-1})		0.08	
Specific energy (MJ kg^{-1})		11.95	
Energy intensity		0.08	
Energy intensiveness (MJ \$$^{-1}$)		0.19	
Net energy gain (MJ ha^{-1})		247,034.18	

Table 3. Total energy inputs of poppy production enterprises (MJ ha^{-1}).

	Poppy energy value	%
Total energy input	20,663.06	
Direct energy[a]	8,312.38	40.23
Indirect energy[b]	12,350.68	59.77
Renewable energy[c]	2,334.00	11.30
Non-Renewable energy[d]	18,329.06	88.70

[a] Fuel-oil, human labor, water; [b] Machinery labor, seeds, chemical fertilizers, pharmaceuticals; [c] Human labor, seeds, water; [d] Machinery labor, chemical fertilizer, medicine, fuel-oil.

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production, the economic analysis of the enterprises has been assembled and given in Table 4.

The production value per ha in enterprises producing poppy is 1,729.31 kg. Total variable costs were determined as $110,428.81, total fixed costs as $1,118.35 and total costs as $111,547.16. The selling price of poppy is $1.69 and GPV is $111,660.05. The gross profit for poppy production is $1,231.24. Gross profit measures the success of businesses (Oğuz and Bayramoğlu, 2018).

Energy Efficiency Scores in Poppy Production

Limited resources in production require effective use of production factors to ensure the sustainability of enterprises. The performances of production units can be compared with their efficiency and effectiveness. In Table 5, total energy inputs per enterprise and energy efficiency according to the total output of the enterprises producing poppy in the research area are given.

According to table 5, average Technical Efficiency (TE) was calculated as 0.683. This means that if the production of farmers is carried out efficiently, the same level of production can be achieved with 68.3% of the resources and 31.7% of the resources can be saved. According to the results of the analysis, 2.29% of the enterprises are less efficient enterprises. It was determined that these enterprises were in the 1st and 2nd layer (10th enterprise and 56th enterprise). The average scale efficiency of inefficient enterprises was 0.756. The efficiency of scale shows the extent to which management practices need to be enhanced to raise the energy use

Table 4. Economic analysis of poppy production enterprises.[a]

Hectare	Value
Yield (kg ha^{-1})	1,729.31
Sale price ($ ha^{-1})	1.69
GDP ($/ha)	111,660.05
Fixed costs ($ ha^{-1})	1,118.35
Variable costs ($ ha^{-1})	110,428.81
Total costs ($ ha^{-1})	111,547.16
Gross profit ($ ha^{-1})	1,231.24

[a] In this study, conversion rate of 1 US$ is taken as 5.62 TL (July 2019). Gross production value= Poppy yield (kg ha^{-1})×Poppy price ($ kg^{-1}). Gross profit= Total gross production value ($ kg^{-1})-Total Variable costs ($ kg^{-1}).

Table 5. Technical, pure and scale efficiency of poppy-producing enterprises.

Farm Size (Decare)	Number of Businesses	Technical Efficiency	Total Technical Effi.	Pure Technical Effi.	Scale Effi.	Efficient	Less Efficient	Inefficient
4-10	15	0.547	0.547	0.856	0.676	3	0	12
11-30	42	0.685	0.685	0.928	0.733	10	0	32
31-+	30	0.736	0.736	0.949	0.774	6	0	24
Avg	87	0.683	0.683	0.898	0.756	18	2	66
Ratio (%)						20.69	2.29	75.86

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efficiency of the businesses and the productivity of inefficient farms. As a result, businesses need to reduce the amount of input by 31.70% to produce the same amount of the product from the unit area. As a matter of fact, 75.86% of the enterprises (66 enterprises) are not efficient in using inputs.

CONCLUSIONS

In the research area, 99% of the total costs in poppy production are variable costs. When the energy consumption of the poppy plant is discussed, the highest share is the fertilizer with 41.45% and fuel with 29.05%, and non-renewable energy consumption (88.70%) is found to be quite high. Therefore, it is rather essential to diminish the use of chemical fertilizers and fuel, which are non-renewable energy sources for poppy plant production. The use of animal manure can be recommended as an alternative to chemical fertilizers. In a similar study, it was determined that the greatest energy-saving potential would be realized by optimizing the use of nitrogen fertilizers (Imran *et al*., 2022). Reducing non-renewable energy sources will lessen adverse effects on both human health and the environment and improve energy use efficiency. The energy use efficiency in the research area was found to be 0.19, meaning that energy is not used efficiently according to the literature, as the energy input in poppy production is high. It can be adopted by reducing the use of fertilizers, pesticides, and machinery in poppy production in the region. In addition, 75.86% of the enterprises are far from using effective resources in the use of inputs. The energy efficiency results have indicated that, if the production of farmers is carried out efficiently, the same level of production can be achieved with 68.3% of the resources and 31.7% of the resources can be saved in the region. It shows that the energy efficiency improves the efficiency of poppy farms in economic perspective. Providing training within the scope of agricultural publication in cooperation with the public, university, and private sector will surely enhance awareness among farmers producing poppy. Therefore, agricultural energy is important in growing crops and creating added value in agricultural processing. Human, animal and mechanical energy is widely used in the cultivation of crops in agriculture. It is inevitable for Turkey to take part in the production pattern of energy crops such as poppy in terms of sustainability. The use of environmentally harmful inputs in agricultural production should be approached more sensitively and energy consumption should be reduced through proper methods.

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بهره وری و راندمان (بازده) انرژی در تولید خشخاش (*Papaver somniferum* L.)

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چکیده

هدف این پژوهش تجزیه و تحلیل بهره‌وری انرژی و راندمان شرکت‌های کشاورزی کشت خشخاش بود. تعداد شرکت‌های مورد بررسی در این پژوهش از یک نمونه تصادفی طبقه‌بندی شده (Stratified random sample) ۸۷نفر تعیین شد، داده‌ها مربوط به سال ۲۰۱۹ است و پژوهش در ترکیه انجام شد. در تعیین میزان مصرف انرژی شرکت ها، کلیه ورودی ها و خروجی های مورد استفاده در تولید خشخاش با ضرب معادلات انرژی با ضرایب تبدیل به دست آمد. از روش تحلیل پوششی داده ها (DEA) برای محاسبه بازده یا راندمان فنی، راندمان فنی خالص و راندمان مقیاس (Scale efficiency) شرکت های تولید کننده خشخاش استفاده شد. نهاده های انرژی خشخاش شامل استفاده از نیروی انسانی، ماشین آلات، کود، آفت کش ها، بذر ها، آب و سوخت بود. عملکرد کپسول خشخاش در واحد سطح به عنوان خروجی انرژی در نظر گرفته شد. در نهایت، ۴۰/۲۳ درصد از کل انرژی ورودی در تولید خشخاش را انرژی مستقیم و ۵۹/۷۷ درصد انرژی غیرمستقیم تشکیل می‌داد. مصرف انرژی غیرقابل تجدید (۸۸.۷۰٪) در محل این پژوهش نسبتاً بالا بود. بنابراین استفاده از کودهای شیمیایی و سوخت ها، که از منابع انرژی تجدید ناپذیر هستند، باید برای تولید گیاه خشخاش کاهش یابد. بازده انرژی در تولید خشخاش ۰.۰۸ بود. با توجه به این نتیجه، سیستم های تولید بنگاه های تولید کننده خشخاش کافی بوده و انرژی به گونه کارآمد مصرف می شود. مقدار انرژی ویژه در شرکت ها ۱۱/۹۵ مگاژول بر کیلوگرم و بازده فنی (TE)۰/۶۸۳ محاسبه شد. تولیدکنندگان با ۶۸.۳٪ از سرمایه خود و ۳۱.۷٪ صرفه جویی در همین سطح تولید می کنند.

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