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Determining the Energy Efficiency in Cotton Production: A Case of Adana Province

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Abstract
This study has been conducted to calculate the energy efficiency of cotton production held under the conditions of Adana/Turkey in 2020 and 2021. Basic data such as the economic life, work success, fuel and oil consumption and weights of the tools-machines used in the study as well as the fertilizer and seed amounts were obtained from the current measurements, other studies, various sources and catalogues. The study has concluded that the highest rate among the energy equivalents of the inputs used in cotton production belonged to the fertilizer energy input with 44.43%. This rate was followed by fuel-oil energy input with 23.68%. In cotton production, the energy output/input ratio years has been calculated as 2.33 and 2.26, the specific energy value as 5.06 MJ kg^{-1} and 5.21 MJ kg^{-1}, the energy productivity value as 0.20 kg MJ^{-1} and 0.19 kg MJ^{-1}, and the net energy efficiency as 36082.21 MJ $ha^{-1}$and 34194.21 MJ ha^{-1}.

Research Article

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1.Introduction

Cotton is a strategically significant product for world agriculture and it is the raw material of many sectors such as feed, textile and energy (Candemir et al., 2017). Cotton contributes greatly to the national economy through the employment and added value it creates and is the raw material of the gin industry in terms of processing, the textile industry with its fibre, the oil and feed industry with its core, and the paper industry with its linter. The oil obtained from the cotton core is also used as a raw material in the production of biodiesel in increasing amounts as an alternative to petroleum. In addition to these, population growth and rising living standards also increase the demand for cotton (Anonymous, 2022, Uğurlu, 2020). For these reasons, cotton is a strategic plant that has an important place in both national and world agriculture, industry and trade. The rapid increase of world population has proportionally increased the need and consumption levels of cotton. An increase in the cotton yield or cotton production areas is needed to meet this growing need and consumption. Despite being a plant with great agricultural incentives, producers tend to prefer other alternative products over cotton due to the increased input costs, lower profitability and the fact that it is a labour-intense production activity.

For enterprises to maintain their activities at the desired profitability level, it is imperative that mechanization practices, which have an impact on total production efficiency, must be evaluated based on scientific principles, with accurate recording, correct calculation method, at the end of each production season. One of the main purposes of the present study is to compare the mechanization application intensities and efficiencies of the enterprises that produce in similar production lines both in the same region and in different countries (Erdoğan, 2009; Şehri, 2012). An energy analysis to be made requires many economic and technical comprehensive studies. However, on the other hand, it is basically done in order to examine whether the production of the product or service to be offered to the market is possible in terms of energy use efficiency. Energy analysis mainly focuses on the engineering aspect of the production system. In order to evaluate production efficiency more realistically, the total energy value of the inputs used in agricultural production processes should be compared with the energy value of the obtained product (Öztürk and Ören, 2005, Öztürk, 2011; Bayhan, 2016). Energy analysis related to agricultural production play an important role in defining and grouping agricultural systems in terms of energy consumption. A careful analysis of the inputs and outputs used in production is beneficial to increase efficiency and reduce inputs (Sabah, 2010). Increasing the energy efficiency value is possible by increasing the efficiency or reducing the inputs. Increasing efficiency can be achieved within certain limits. However, reducing the total energy input can be possible by cautiously reducing the inputs of fuel, chemical fertilizers, agricultural pesticides, machinery and tractors, which have a large place in energy input (Çelen, 2016). A study conducted by Yılmaz et al. (2005) on cotton production reported that diesel fuel energy consumption has a share of 31.1% among the whole energy consumption and diesel fuel is followed by fertiliser and machinery energy. Energy rate and energy efficiency values were reported as 0.74 and 0.06 kg MJ^{-1}, respectively (Şehri, 2012). Erdoğan (2009) found the energy rate as 11.58, the specific energy value as 3.07 MJ kg^{-1}, the energy productivity value as 0.33 kg MJ^{-1}, and the net energy value as 292115.5 MJ ha^{-1} in the first crop corn production in the Çukurova Region/Turkey. After conducting a study in Adana on cotton production, Şehri (2012) reported the highest energy rate value to be 1.63, the lowest value in terms of specific energy to be 6.78 MJ kg^{-1}, energy productivity to be 0.15 kg MJ^{-1} and net energy yield to be 24155.4 MJ, all acquired for 10.1+ ha enterprises. In a study conducted by Bayhan (2016) in the production of second crop sunflower, the energy use efficiency was compared and the highest energy rate was 11.82, the lowest specific energy value was

2.23 MJ kg^{-1} and the highest energy productivity was 0.45 kg MJ^{-1} in direct sowing method. In addition, the highest net energy efficiency was obtained from the rotary method with a value of 63047.59 MJ kg^{-1}. In cotton production, according to Topdemir and Coşkun (2019), the highest energy input is seen in the traditional tillage method, the lowest energy input is in the direct sowing method, the highest energy output is in the traditional tillage with the highest yield, and the lowest energy output is in the direct sowing method with the lowest yield. They have further reported that the highest energy ratio is obtained from traditional soil processing by 4.38. Within the scope of the current study, the energy efficiency calculation of cotton production grown in Adana conditions in 2020 and 2021 was made. In line with the findings of the study, input branches where efficiency and productivity were negatively affected were determined and suggestions were made to eliminate this negativity.

2. Materials and Methods

The research data was made based on information received from agricultural enterprises operating in Adana/Türkiye. The number of inputs and outputs used in cotton production and the technical data of agricultural tools and machinery, which constitute the study material, were obtained from the previously made studies and catalogues and also from the Turkish Statistical Institute. The findings obtained in this study were calculated according to the agricultural tools and machinery commonly used in cotton production and specified in Table 1.

Table 1. Technical specifications of machines used in cotton production

Items	Agricultural machine	Witdth (cm)	Weight (kg)
Power suppley	Tractor	140	2250
Tillage	Plow	93	295
Tillage	Disc plow	210	1100
Tillage	Listeria	300	500
Tillage	Worshiper	300	700
Planting	Sowing machine	300	950
Hoeing	Hoeing	225	350
Fertilizer	Fertilizer machine	225	480
Chemicals	Sprayer	1600	400
Irrigation	Moldboard plow.	225	350
Irrigation	Arc plow	150	350
Irrigation	Arc closing	180	270
Harvest	Cotton harvester or cotton picking machine	300	12500

After the soil on which cotton will be produced is processed once with a plow and twice with a goblet disc in the autumn season, the ridges to be planted with a ridge lister are formed. After these ridges are formed, they are renewed again in the winter and spring seasons and cotton planting is carried out after the application of the ridge cap in the spring. In this study, the seed sowing norm was determined as 2.5 kg da^{-1}, the amount of fertilizer used was 10 kg da^{-1} pure phosphorus and 18 kg da^{-1} pure nitrogen. In the agricultural operations carried out during cotton growing in Adana, tractor hoeing is done 3 times, hand hoeing is done once, and weeding is done once. In addition, one herbicide application is made before tillage in the spring. In addition, a total of 9 chemical treatments are applied for pest control (aphids, leafhoppers, thrips, green worms, cotton leaf worms, red spiders, whiteflies, pink worms) and plant growth conditioners. Again, depending on the climatic conditions, flood irrigation is carried out 3 times and approximately 670 mm da^{-1} irrigation is made per unit area (Şehri, 2012).

2.1 Energy analysis calculations

In order to calculate the energy efficiency in cotton production in Adana province, first of all, energy inputs and energy outputs should be calculated. In these calculations, the energy equivalents of the input and output types must be known. The findings given in Table 2 have been usedto determine the energy equivalent.

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

Inputs	**Energy equivalent (MJ unit^{-1})**	**References**
Human power (hr)	2.3	Barut et al., 2011; Baran and Karaağaç, (2014)
Machinery Production Energy (kg)		
Tractor	158.3	Barut et al., 2011; Gözübüyük et al., 2012
Tillage Tools	121.3	Barut et al., 2011; Baran and Karaağaç, 2014
Fuels (L)		
Diesel	35.69	Eren, 2011; Sabah, 2010; Arıkan, 2011
Oil	6.51	Eren, 2011; Sabah, 2010; Arıkan, 2011
Fertilizers (kg)		
Nitrogen (N)	60.6	Öztürk, 2011; Barut et al., 2011; Bayhan, 2016
Phosphorus (P2O5)	11.1	Öztürk, 2011; Barut et al., 2011; Bayhan, 2016
Chemicals (kg)		
Herbicide	269	Ferrago, 2003; Sabah, 2010; Arıkan, 2011; Eren, 2011
Insecticide	214	Sabah, 2010; Arıkan, 2011; Eren, 2011
Plant Growth Regulator	101.2	Yaldız et al., 1993; Şehri, 2012
Seed (kg)	11.8	Singh, 2002, Şehri, 2012, Topdemir and Coşkun, 2019
Water for irrigation (m^3)	0.63	Barut et al., 2011; Öztürk, 2011; Öztürk and Ören, 2005
Output		
Cotton	11.8	Singh, 2002; Şehri, 2012; Topdemir et al.,; Coşkun, 2019

2.1.1 Energy input calculations

Energy inputs consisted of human power energy, machine energy, fuel-oil energy, fertilizer energy, pesticide energy, seed energy and irrigation energy. In the related energy calculations, the amount of input used/spent per unit area and the energy equivalents of these input types have been multiplied.

The energy input of chemical drug use was calculated. To make this calculation, a value of 101.2 MJ kg^{-1} was used as the energy equivalent coefficient of plant growth regulators (leaf defoliant, leaf dryer, boll opener, growth regulator) used in cotton production (Yaldız et al., 1993; Şehri, 2012).

Machine Energy Input (MJ ha^{-1}): Machine energy input was calculated with the formula given in Equation 1 (Yaldız et al., 1990).

$$ME = \frac{W * E}{T * EFC} \quad (1)$$

Where;

ME : Machine energy input ($MJ\ ha^{-1}$),

W : Weight of the tool (kg),

E : Production energy of unit weight of agricultural machine or tool ($MJ\ kg^{-1}$),

T : Economic life of tractor or tool (h),

EFC : Effective field capacity ($ha\ h^{-1}$).

Fuel-Oil Energy Input (MJ ha^{-1}): Fuel energy input has been calculated by using the formulae given in Equation 2 and oil energy input has been calculated by using the formula given in Equation 3 (Gözübüyük et al., 2012).

$$FEI = FC * FEV \quad (2)$$

$$OEI = (FC x 0.045) * OEV \quad (3)$$

Where;

FEI: Fuel energy input (*MJ ha^{-1}*)

FC : Fuel Consumption (l ha^{-1})

FEV: Fuel energy value (*MJ l^{-1}*)

OEI: Oil energy input (*MJ ha^{-1}*)

OEV: Oil energy value (*MJ l^{-1}*)

2.1.2. Energy output calculations

While calculating the energy outputs, the energy output per unit area was obtained with the formula given in Equation 4 (Öztürk, 2011).

*TEO: (MPY*Emp)+ (SPY*Esp)* (4)

Where;

TEO: Total energy output (*MJ ha^{-1}*),

MPY: Main product yield (*kg ha^{-1}*),

SPY: Side product yield (*kg ha^{-1}*),

Emp:Main product energy equivalent(*MJ kg^{-1}*)

Esp: Side product energyvalue (*MJ kg^{-1}*).

2.1.3. Energy efficiency calculations

In energy efficiency calculations, energy ratio, specific energy value, energy productivity value, net energy value calculations have been calculated by using the following formulas (Equations 5;6;7;8) (Eren, 2011; Imran et al., 2020).

Energy ratio= Energy Output / Energy Input (5)

Specific Energy (MJ kg^{-1}) = Total Energy Input / Total Harvested Product Amount (6)

Energy Productivity (kg MJ^{-1})=Total Harvested Product Amount / Total Energy Input (7)

Net Energy Production (MJ ha^{-1})= Total Energy output – Total Energy Input (8)

3. Results

3.1. Energy analysis calculations

The Energy input values in cotton cultivation in Adana province is given in Table 3. As Table 3 indicates, 295.83 MJ ha^{-1} of human energy was consumed per unit area, and the ratio of this value to total energy input constituted the lowest input with 1.09%. Among all inputs, fertilizer energy input had the highest value with 12018.00 MJ ha^{-1} and 44.43%. Oil-fuel energy was consumed at the rate of 6406.04 MJ ha^{-1} and took the second place with a rate of 23.68%.

Energy input was calculated as 27047.79 MJ ha^{-1} for both years in cotton production. This value was found to be 39537.7 MJ ha^{-1} in Southeastern Anatolia Region (Öztürk and Ören, 2005), 35882.22 MJ ha^{-1} in Adana (Şehri, 2012), and 15545.81 MJ ha^{-1} in Menemen (Topdemir and Coşkun, 2019).

Table 3. Energy input values in cotton cultivation in Adana province

Inputs	Quantities	Energy input (MJ ha^{-1})	Ratio (%)
Human energy (h)	**128.62**	**295.83**	**1.09**
Land preparation	9.29	21.37	
Planting	117.33	269.86	
Harvest	2.00	4.60	
Machinery (h)	**33.25**	**768.29**	**2.84**
Tractor	16.62	268.01	
Toprak Hazırlama İşlemleri	9.29	145.28	
Ekim ve Diğer İşlemler	6.33	223.09	
Hasat	1.00	131.92	
Diesel + Oil (l)	**186.04**	**6406.04**	**23.68**
Toprak Hazırlama İşlemleri	87.76	3021.85	
Ekim ve Diğer İşlemler	51.26	1764.96	
Hasat	47.03	1619.23	
Fetilizers (kg)	**280.00**	**12018.00**	**44.43**
Phosphorus (P)	100.00	1110.00	
Nitrogen (N)	180.00	10908.00	
Pesticides (kg l^{-1})	**16.40**	**3043.62**	**11.25**
Herbicide	2.50	672.50	
Insecticide	8.55	1829.70	
Plant growth regulator	5.35	541.42	
Seed (kg)	**25.00**	**295.00**	**1.09**
Irrigation (m^3)	**6700.00**	**4221.00**	**15.61**

Table 4. Energy output calculations

Outputs	Years	
	2020	**2021**
Cotton yields (kg ha^{-1})	5350	5190
Total Energy Output (MJ ha^{-1})	63130.00	61242.00
Total Energy Input (MJ ha-1)	27047.79	27047.79
Energy ratio	2.33	2.26
Specific Energy (MJ kg-^{1})	5.06	5.21
Energy Productivity (kg MJ^{-1})	0.20	0.19
Net Energy Production (MJ)	36082.21	34194.21

Energy output was determined as 63130.00 MJ ha^{-1} and 61242.00 MJ ha^{-1} for the years 2020 and 2021, respectively (Table 4).

As indicated in Table 4, energy ratio in cotton production in Adana has been calculated as 2.33 and 2.26 for the years 2020 and 2021. In other similar studies on cotton production, this rate was 4.8 in a study conducted in Antalya (Çanakçı et al., 2004), 3.79 in a study conducted in Adıyaman (Baran, 2016), 2.38 in a study conducted for the Southeastern Anatolia Region (Öztürk and Ören, 2005; Çanakçı et al., 2005), and 1.56, 1.49 and 1.63 respectively, in a study conducted in Adana Province on enterprise groups of 0.1-5 ha, 5.1-10 ha and >10 ha (Şehri, 2012), In another study conducted in İzmir/Menemen, the energy ratio value was found to be 4.38, 3.99, 3.93 and 3.72 in 4 different tillage methods (Topdemir and Coşkun, 2019). The specific energy values were found to be 5.06 MJ kg^{-1} and 5.21 MJ kg^{-1} for the years 2020 and 2021, respectively. In other similar studies, it has been calculated as 3.11 MJ kg^{-1} in Adıyaman (Baran, 2016), 10.52 MJ kg^{-1} in the Southeastern Anatolia Region (Öztürk and Ören, 2005), 6.78 MJ kg^{-1} in Adana (Şehri, 2012) and 2.70 MJ kg^{-1} in İzmir/Menemen (Topdemir and Coşkun, 2019).

In terms of energy productivity, the same Table indicates that 0.20 kg ve 0.19 kg cotton has been produced in 2020 and 2021 against an energy consumption of 1 MJ. This value has been reported as 0.095 kg MJ^{-1} in Southeastern Anatolia Region (Öztürk and Ören, 2005), 0.15 kg MJ^{-1} in Adana (Şehri, 2012) and 0.37 kg MJ^{-1} in Izmir/Menemen (Topdemir and Coşkun, 2019). In terms of net energy efficiency, it was calculated as 36082.21 MJ ha^{-1} and 34194.21 MJ ha^{-1} for the years 2020 and 2021, respectively. This value was found to be 54407.3 MJ ha^{-1} in the Southeastern Anatolia Region (Öztürk and Ören, 2005), 49512.94 MJ ha^{-1} in Adıyaman (Baran, 2016), 24155.4 MJ ha^{-1} in Adana (Şehri, 2012), and 52472.34 MJ ha^{-1} in Izmir/Menemen (Topdemir and Coşkun, 2019)

4- Conclusion

In the cotton production season of 2020 and 2021 in Adana, the energy rate was 2.33 and 2.26, the specific energy value was 5.06 and 5.21, the energy productivity values were 0.20 kg MJ^{-1} and 0.19 kg MJ^{-1}. The energy output/input ratio has a low value, and this low value indicates that an effective production technique is not applied in cotton cultivation. Fertilizer energy has the highest share in energy inputs in production, while fuel-oil energy takes the second place. Since most of the current inputs are imported from abroad, it causes significant foreign exchange loss. For this reason, the producers must have a soil analysis done and use the fertilizer on time and in accordance with the technique. In this way, it is thought that lower fertilizer use will occur. When this happens, the cost can be reduced and an advantage in terms of environmental protection can be achieved. Based on the findings of this study, it has been revealed that new studies that will reduce both fertilizer consumption and fuel-oil consumption should be given importance in R&D studies on cotton production.

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