Erdemir Gündoğmuş[1]

ENERGY USE PATTERNS AND ECONOMETRIC MODELS OF QUINCE PRODUCTION

This study was conducted to determine the balance between the inputs of energy and the energetic yield for quince production in Turkey. The data for the study were collected from 34 quince plantations. The total energy input of 49,698.33 MJ ha^{-1} was required for quince production. Chemical fertilizers, the single highest source of energy input, accounted for 52.86% of the total energy input. The two next highest energy sources were diesel fuel (16.27%) and electricity (12.85%). The values of energy efficiency, energy productivity, specific energy, and net energy were 1.07, 0.45 kg MJ^{-1}, 2.24 MJ kg^{-1} and 3,510.50 MJ ha^{-1}, respectively. Estimates made using econometric models showed that machinery, pesticides, diesel fuel, electricity and water used for irrigation energy inputs have significantly positive effects on energy yield. The results of the sensitivity analysis of the energy inputs show that the marginal physical productivity (MPP) value of water for irrigation is the highest, followed by electricity and diesel fuel.

Keywords: *energy efficiency, econometric model, benefit/cost ratio, quince plantations, Turkey.*

Ердемір Гюндогмуш

ГРАФІКИ ЕНЕРГОСПОЖИВАННЯ І ЕКОНОМЕТРИЧНІ МОДЕЛІ ДЛЯ ПРОМИСЛОВОГО ВИРОЩУВАННЯ АЙВИ

У статті надано результати дослідження, яке проведено для визначення балансу між витратами енергії і врожаями айви в Туреччині. Дані для дослідження були зібрані по 34 плантаціях айви. Загальна споживана потужність для виробництва айви склала 49,698.33 МДж/га. На хімічні добрива витрачено 52,86% від загального енергоспоживання, на дизельне паливо — 16,27% і електрику — 12,85%. Значення енергоефективності, продуктивності, питомої енергії, чистої енергії, — 1,07, 0,45 кг/МДж, 2,24 МДж/кг і 3510,5 МДж/га, відповідно. Виміри з використанням економетричних моделей показали, що енерговитрати на сільськогосподарське устаткування, пестициди, дизельне паливо, електрику і воду, використовувану для зрошування, значно позитивно впливають на урожай. Результати аналізу чутливості енерговитрат показали, що значущість граничної продуктивності води для зрошування — найвища, далі йдуть електрика і дизельне паливо.

Ключові слова: *енергоефективність, економетрична модель, співвідношення вигод/витрат, плантації айви, Туреччина.*

Таб. 7. Фор. 11. Літ. 19.

Эрдемир Гюндогмуш

ГРАФИКИ ЭНЕРГОПОТРЕБЛЕНИЯ И ЭКОНОМЕТРИЧЕСКИЕ МОДЕЛИ ДЛЯ ПРОМЫШЛЕННОГО ВЫРАЩИВАНИЯ АЙВЫ

В статье представлены результаты исследования, проведенного для определения баланса между затратами энергии и урожаями айвы в Турции. Данные для исследования были собраны по 34 плантациям айвы. Общая потребляемая мощность для производства айвы составила 49,698.33 МДж/га. На химические удобрения потрачено 52,86% от общего энергопотребления, на дизельное топливо — 16,27% и электричество — 12,85%. Значения энергоэффективности, производительности, удельной энергии, чистой энергии — 1,07, 0,45 кг/МДж, 2,24 МДж/кг и 3510,5 МДж/га, соответственно. Измерения с использованием эконометрических моделей показали, что энергозатраты на

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сельскохозяйственное оборудование, пестициды, дизельное топливо, электричество и воду, используемую для орошения, значительно положительно влияют на урожай. Результаты анализа чувствительности энергозатрат показали, что значимость предельной производительности воды для орошения — самая высокая, затем следуют электричество и дизельное топливо.

Ключевые слова: *энергоэффективность, эконометрическая модель, соотношение выгод/затрат, плантации айвы, Турция.*

Introduction. The main objective in agricultural production is to increase yield and decrease production costs. In this respect, the energy budget is important. Energy budget is the numerical comparison of the relationship between input and output of a system in terms of energy units. In general, increases in agricultural production on a sustainable basis and at a competitive cost are vital to improve farmers' economic condition.

47 countries in the world grow quinces economically. Turkey is ranked first in the world in quince production. The production of quince was about 121,000 tons per year in Turkey and the harvested land area was 10,233 ha in 2009. Turkey regularly exports quince. Each year, approximately $7.5 mln. is earned as a result of export of the annual quince volume of 10,000 tons (FAO, 2011a).

Although many previous experimental studies have investigated the use of energy in fruit production (Gezer et al., 2003; Ozkan et al., 2004; Gundogmus, 2006; Goktolga et al., 2006; Demircan et al., 2006; Akcaoz et al., 2009; Rafiee et al., 2010; Mohammadi et al., 2010; Banaeian and Zangeneh, 2011), no previous studies have analyzed the energetics of quince production. The main aims of this study are to analyze the energy used in quince production, to evaluate the associated relationship between inputs and output, and to compare input energy use with input costs, using the data from quince plantations in Bilecik and Sakarya provinces, Turkey.

Nomenclature

n	required sample size	e_i	error term
N	number of holdings in target population	α_i	coefficients of the variables
s	standard deviation	β_i	coefficients of the variables
D	acceptable error (permissible error was chosen as 5%)	γ_i	coefficients of the variables
T	confidence limit (1.96 in the case of 95% reliability)	DE	direct energy
Y_i	yield level of the i^{th} farmer	IDE	indirect energy
X_1	energy input from human labor	RE	renewable energy
X_2	energy input from machinery	NRE	non-renewable energy
X_3	energy input from chemical fertilizer	MPP_{xj}	marginal physical productivity of j^{th} input
X_4	energy input from pesticide use	α_j	regression coefficient of j^{th} input
X_5	energy input from diesel fuel	$GM(Y)$	geometric mean of yield
X_6	energy input associated with use of irrigation water	$GM(Xj)$	geometric mean of j^{th} input energy
X_7	energy input from electricity		

2. Materials and methods.

2.1. Selection of case study farms and data collection. The data for this study were obtained from 34 quince plantations in Bilecik and Sakarya. These provinces are the most intensive in quince production in Turkey at the rate of 30.4%. A face-to-face questionnaire was administered in the production year 2008/2009. A stratified random sampling method was used. The sample size was calculated using the Neyman method (Yamane, 1967):

$$n=\frac{N.\sum N_h.S^2{}_h}{N^2D^2+\sum N_h.S^2{}_h}, \tag{1}$$

where N_h is the number of producers in the h^{th} stratum, $S^2{}_h$ is the variance of the h^{th} stratum, D^2 is the value of $(d/t)^2$, d is the amount of permissible error around the population mean, and t = 1.96 for the 95% confidence limits. A sample size of 34 was obtained with this method. Accordingly, 34 quince producers were randomly selected from the population.

In the survey area, the input energy sources for quince production were human labor, machinery, diesel fuel, electricity, chemicals, electricity and irrigation water. The output energy from the area was taken to be the quince fruit. The energy equivalents of inputs and outputs shown in Table 1 were used to estimate the energy values.

The input energy in agricultural systems can be divided into direct and indirect or renewable and non-renewable. The sources of direct energy include human labor, diesel fuel, electricity and water for irrigation, whereas the indirect energy sources include chemical fertilizers, pesticides, electricity and machinery.

Renewable energy includes human labor. The sources of non-renewable energy are machinery, diesel fuel, pesticides, electricity, water for irrigation and chemical fertilizers. The energy input-output ratio (energy use efficiency), energy productivity, specific energy and net energy were calculated by using the total energy equivalent of inputs and outputs per unit area (MJ ha^{-1}) and fruit yield (kg ha^{-1}) according to the following equations (Rafiee et al., 2010):

$$Energy\ use\ efficiency=\frac{Energy\ output(MJ\ ha^{-1})}{Energy\ input(MJ\ ha^{-1})}, \tag{2}$$

$$Energy\ productivity=\frac{Quince\ output(kg\ ha^{-1})}{Energy\ input(MJ\ ha^{-1})}, \tag{3}$$

$$Specific\ energy=\frac{Energy\ input(MJ\ ha^{-1})}{Quince\ output(MJ\ ha^{-1})}, \tag{4}$$

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

A mathematical function is needed to specify the exact relationship between input energies and yield. The Cobb-Douglas production function was considered to be the best function for this purpose. It represents an attractive choice in terms of the statistical significance and expected signs of the parameters.

The Cobb-Douglas function has been used by several authors to investigate the relationship between input energies and production yield (Banaeian and Zangeneh, 2011; Heidari and Omid, 2011). The Cobb-Douglas production function is expressed as follows:

$$Y=f(x)\exp(u). \tag{6}$$

This function can be expressed as a linear relationship by taking the natural logarithms of both sides of the Cobb-Douglas equation and substituting as follows:

$$\ln Y_i = a + \sum_{j=1}^{n} \alpha_j \ln(X_{ij}) + e_i \quad i = 1,2,\ldots\ldots,n, \tag{7}$$

where Y_i denotes the yield by the i^{th} farmer, X_{ij} is the vector of inputs used in the production process, a is the constant term, the α_j represents the coefficients of inputs estimated from the model, and e_i is the error term. This model assumes that yield is a function of the input energies and allows the impact of each source of input energy on quince yield to be investigated. For each farmer i, Eq. (7) can be expanded in the following form;

Table 1. **Energy equivalents of inputs and outputs on quince production**

Equipment/input	Unit	Energy coefficients (MJ/unit)	Reference
A.INPUTS			
1.Human labor	h	1.96	(Singh and Singh, 1992)
2.Machinery (h)	h	62.70	(Singh and Singh, 1992)
3.Chemical fertilizers	kg		(Singh and Singh, 1992)
a-Nitrogen		60.60	(Singh and Singh, 1992)
b-Phosphorus		11.10	(Singh and Singh, 1992)
c-Potassium		6.70	(Singh and Singh, 1992)
4.Pesticides	kg		
a-Insecticides		199.00	(Hessel, 1992)
b-Fungicides		92.00	(Hessel, 1992)
5.Diesel fuel	L	56.31	(Singh and Singh, 1992)
6.Water for irrigation	m³	0.63	(Yaldiz et al., 1993)
7.Electricity	kWh	11.93	(Singh and Singh, 1992)
B.OUTPUT			
1.Quince (fruit)	kg	2.40	(Anonymous, 2011b)

$$\begin{aligned}\ln Y_i = \alpha_0 + \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 \\ + \alpha_5 \ln X_5 + \alpha_6 \ln X_6 + \alpha_7 \ln X_7 + e_i,\end{aligned} \tag{8}$$

where X_i (i = 1,2,...,7) represents the input energies from human labor (X_1), machinery (X_2), chemical fertilizer (X_3), pesticides (X_4), diesel fuel (X_5), water for irrigation (X_6) and electricity (X_7). In addition, the impacts of DE and IDE sources and RE and NRE sources on the yield were investigated. For this purpose, the Cobb-Douglas function was again selected and used in the following forms:

$$\ln Y_i = \beta_0 + \beta_1 \ln DE + \beta_2 \ln IDE + e_i, \tag{9}$$

$$\ln Y_i = \gamma_0 + \gamma_1 \ln RE + \gamma_2 \ln NRE + e_i, \tag{10}$$

where Y_i is the i^{th} farmer's yield and β_i and γ_i are the coefficients of the exogenous variables. DE and IDE are direct and indirect energies, respectively. RE is renewable energy and NRE is non-renewable energy.

In this study, the return-to-scale index was determined in order to analyze the proportional changes in output due to a proportional change in all the inputs (supposing that all inputs increase by a constant factor). The values of the return to scale for Eqs. (8)-(10) were determined by computing the elasticities. These quantities correspond to the regression coefficients in the Cobb-Douglas production function. A sum greater than, equal to, or less than unity implies increasing, constant, or decreasing returns to scale, respectively (Rafiee et al., 2010).

A finding of increasing, constant or decreasing returns to scale indicates that when the energy inputs are increased by a factor X, then the yield of quince production increases by more than, exactly or less than X, respectively.

In the final portion of the research, the marginal physical productivity (MPP) method based on the response coefficients of the inputs was used to analyze the sensitivity of quince yield to the energy inputs. The MPP of a factor indicates the change in the total output with a unit change in the factor input, assuming that all other factors are fixed at their geometric mean value. A positive value of MPP for any input variable shows that the total output is increasing with an increase in input. This property implies that one should not stop increasing the use of variable inputs so long as the fixed resource is not fully utilized. A negative value of MPP of any variable input indicates that every additional unit of input starts to diminish the total output of previous units. It is therefore preferable to keep the variable resource in surplus rather than utilizing it as a fixed resource.

The MPP of the various inputs was calculated using the α_j of the various energy inputs as follows (Rafiee et al., 2010):

$$MPP_{xj} = \frac{GM(Y)}{GM(X_j)} \times \alpha_j, \tag{11}$$

where MPP_{xj} is the marginal physical productivity of j^{th} input, α_j is the regression coefficient of the j^{th} input, $GM(Y)$ is the geometric mean of the yield, and $GM(X_j)$ is the geometric mean of j^{th} input on a per-hectare basis. Eqs. (8)-(11) were estimated using the ordinary least squares (OLS) technique.

3. Results and discussion.

3.1. Management practices for quince production. Quince has been grown in many countries all over the world since old times. It has been well-known for 4000 years. It originated in the Caucasus; then spread to the East, then to the South to Minor Asia, and to Ancient Greece. Latin name for quince is "cydonia", after Cydon, Crete where it has been grown from time immemorial.

Quince biological properties influence its distribution. Its growing is related to the regions where autumn is long and mild. The situation is similar with altitude — quince should be grown at altitude higher than 700 meters. However, quince is widespread in many countries all over the world, even at altitudes of 2500 meters in Tajikistan.

The management practices of quince plantations on the surveyed area are shown in Table 2. The distance between rows and in the line depends on many factors: applied surface, vigorous cultivar, training system, types of plants, environmental conditions and levels of systems. In practice, fortunately the distance between rows is 5 m, a fine of 4.5 to 5.50 m. The number of seedlings per hectare is 400 trees on average.

Quinn gives birth to a short, vitim and long branches. Short fruiting branches are not abbreviated, as their gender (mixed) buds are at the top. In quince production, the pruning is done in March.

The most suitable soil for quince is the one with moderate moist, porous and rich in nutrients. Heavy and moist soil, and extremely dry and sandy and carbonate are not suitable for growing quince. On the highly calcareous soil quince is threatened chlorosis. Between February and March, rows in quince plantations are cultivated by plough and disc-harrow. The number of cultivations applied changes varies from 3 to 5 times, 4 times on average.

Hand hoeing is done twice in the period between March and May. The pesticide applications are made between April and June, it is done 3.9 times on average (Table 2).

The amount of water in samples of quince is up to 85%, so without enough water in the soil and air it cannot be successfully grown. However, quince relatively well tolerates drought periods. In extreme cases, folded sheets are used to reduce transpiration. For normal growth and successful cultivation of quince, the literature states that it takes to fall 750 to 990 mm of water a year with good layout in the growing season. The irrigation on quince production is done 4.2 times between June-August.

Harvest time is determined by the color of the rind, whether fruits can be separated from the branches easily, the color of seeds etc. Harvest season is in September and generally done by hand.

Table 2. **Management practices of quince plantations**

Production processes	Quince Plantations
Common variety	Cydonia vulgaris piriformis
Number of seedlings (ha)	380-450
Soil cultivations	First tilling is applied between February and March, the second is applied between March-April using garden hoeing machine
Average tilling number	4.0
Pruning period	March
Fertilization period	April-May
Average number of fertilization	2.2
Spraying period	April-June
Average number of spraying	3.7
Hoeing period	March-May
Average number of hoeing	2.0
Irrigation period	June-August
Average number of irrigation	4.2
Harvesting period	September

3.2. Analysis of the input-output energy used in quince production. Table 3 presents the amounts of inputs and output associated with quince production and their energy equivalents. The study found that the quantities of labor and machine power required for quince production were 1,007.87 and 55.86 h/ha^{-1}, respectively. Most human labor was used during cultural practices (77%). Likewise, most of the use of machinery occurred during cultivation (79%). The study also found that 143.62 l of diesel fuel, 408.24 kg of nitrogen, 88.72 kg of phosphate, 81.49 kg of potassium, 10.66 kg of insecticides, 5.12 kg of fungicides, 1,404.85 m^3 of water and 535.18 kW/h of electricity per ha were used for quince production. The average quince yield in the study area was approximately 22,170.35 kg/ha^{-1}. The total energy equivalents of the inputs and output were calculated by multiplying the quantity per unit area by the equivalent energy value. The total energy input and energy output were calculated as 49,698.33 and 53,208.83 MJ ha^{-1}, respectively.

The relative percentages of energy consumption for quince production were 52.86% for chemical fertilizer, 16.27% for diesel fuel, 12.85% for electricity, 7.05% for machinery, 5.22% for pesticides, 3.97% for human labor and 1.78% for water for irrigation (Table 2). Chemical fertilizers accounted for the largest share of the energy input. This result is consistent with the published findings of Gundogmus (2006), Goktolga et al. (2006), Demircan et al. (2006), Mohammadi et al. (2010), Banaeian and Zangeneh (2011) for apricot, peach, cherry, kiwi fruit and walnut production, respectively. The results showed that in terms of energy input, the consumption of chemical fertilizers and diesel fuel was high for quince production in the region studied.

The energy efficiency, energy productivity, specific energy and net energy found for quince production are listed in Table 4. The value of 1.07 was found for the energy use efficiency (energy ratio). This value indicates that the energy consumption of quince production in the region was efficient, i.e., that energy production was greater than energy utilization.

Table 3. **Amount of inputs, outputs and their energy equivalences in quince production**

Input	Quantity per unit area (ha)	Total energy equivalent (MJ ha $^{-1}$)	Percentage of total energy input (%)
A.Inputs 1.Human labor (h)	1,007.87	**1,975.43**	3.97
2.Machinery (h)	55.86	**3,502.48**	7.05
3.Chemical fertilizers (kg)		**26,269.86**	52.86
a.Nitrogen	408.24	24,739.04	
b.Phosphorus	88.72	984.81	
c.Potassium	81.49	546.01	
4.Pesticides (kg)		**2,593.46**	5.22
a.Insecticides	10.66	2,122.28	
b.Fungicides	5.12	471.18	
5.Diesel fuel (l)	143.62	**8,087.33**	16.27
6.Water for irrigation (m^3)	1,404.85	**885.05**	1.78
7.Electricity (kWh)	535.18	**6,384.70**	12.85
Total energy input (MJ)		**49,698.33**	**100.00**
B.Output 1.Quince (fruit)	22,170.35	53,208.83	

Several authors have reported the energy ratio for different fruits. These values include 0.96 for cherry production (Demircan et al., 2006) and 0.93 for peach production (Goktolga et al., 2006) in Turkey, 1.54 for kiwi fruit (Mohammadi et al., 2010) and 2.90 for walnuts in Iran (Banaeian and Zangeneh, 2011), 1.25 for oranges, 1.06 for lemons and 1.17 for mandarins in Turkey (Ozkan et al., 2004).

The energy productivity, specific energy and net energy for quince production were found to be 0.45 kg MJ^{-1}, 2.24 MJ kg^{-1}, and 3,510.50 MJ ha^{-1}, respectively.

The distribution of input energy in quince production in terms of direct, indirect, renewable and non-renewable energy forms is shown in Table 4. Direct and indirect energy account for 34.88% and 65.12% of the total energy input, respectively.

Chemical fertilizers exhibit the highest share (81.16%) of indirect energy, followed by machinery (10.82%). Renewable and non-renewable energy account for 3.97% and 96.93% of the total energy input, respectively. Several studies have shown that the contribution of indirect energy is higher than that of direct energy and that the share of non-renewable energy is more than that of renewable energy in the production of different agricultural products (Gundogmus, 2006; Goktolga et al., 2006; Banaeian and Zangeneh, 2011; Akcaoz et al., 2009).

Table 4. **Energy input-output ratio in quince production**

Items	Unit	Quantity [e]
Energy use efficiency	-	1.07
Energy productivity	Kg MJ $^{-1}$	0.45
Specific energy	MJ kg $^{-1}$	2.24
Net energy	MJ ha $^{-1}$	3,510.50
Direct energy [a]	MJ ha $^{-1}$	17,332.51 (34.88%)
Indirect energy [b]	MJ ha $^{-1}$	32,365.82 (65.12%)
Renewable energy [c]	MJ ha $^{-1}$	1,975.43 (3.97%)
Non-renewable energy [d]	MJ ha $^{-1}$	47,722.90 (96.03%)
Total energy input	MJ ha $^{-1}$	49,698.33

[a] Includes human, diesel fuel, electricity and water for irrigation.
[b] Includes fertilizers, pesticides and machinery energy sources.
[c] Includes human labour.
[d] Includes diesel fuel, electricity, pesticides, fertilizers, machinery and water for irrigation.
[e] Figures in parentheses indicate percentage of total energy input.

3.3. Econometric model estimation of energy inputs for quince production. To investigate the relationship between energy inputs and yield associated with quince production, the Cobb-Douglas production function was chosen and its parameters estimated using the ordinary least squares (OLS) technique. This model assumed that the quince yield (endogenous variable) was a function of human labor, machinery, pesticides, chemical fertilizers, diesel fuel, electricity and water for irrigation (exogenous variables). The Durbin-Watson test was used to test for autocorrelation in the residuals from the regression analysis of the data used in this analysis (Hatirli et al., 2005). The value of the Durbin-Watson test statistics was 1.98 for Eq. (8). This result indicated (at the 1% significance level) that no autocorrelation was present in the estimated model. The R^2 (coefficient of determination) was 0.99 for this linear regression model. The regression results of Eq. (8) (Table 5) revealed that the contribution of human labor, pesticides, electricity and water for irrigation were statistically significant at the 1% level. The impacts of machinery, chemical fertilizer and diesel fuel inputs were significant at the 5% level. The values of the estimated coefficients indicated that all energy inputs except those associated with human labor and chemical fertilizer had positive impacts on quince yield. These results show that excessive amounts of human labor and chemical fertilizer were used in quince production.

Electricity labor had the highest impact (0.61) of all the inputs analyzed for quince production. This result indicates that under the conditions of the study, an increase in the input energy associated with electricity tended to increase the yield. The results showed that a 100% increase in the energy value of electricity corresponded to a 61% increase in quince output. The second important input, water for irrigation, was found to have an elasticity of 0.49. Mohammadi et al. (2010) analyzed an econometric model for kiwi fruit production in Iran. They reported that human labor, machinery, total fertilizers and water for irrigation produced significant improvements in the yield of kiwi fruit. In the study on walnut production Banaeian and Zangeneh (2011) found that human labor, transportation, farmyard manure, chemical fertilizers, electricity and water for irrigation had significant impacts on fruit yield.

The MPP values of the variables in the model are shown in the last column of Table 5. The MPP of and water for irrigation, electricity and diesel fuel were found to be 0.76, 0.74 and 0.26, respectively. These findings indicate that an increase of 1 MJ in each input of water for irrigation, electricity and diesel fuel would lead to an additional increase in yield of 0.76, 0.74 and 0.26 kg ha^{-1}, respectively. The value of return to scale for the model (1), calculated from the regression coefficients, was 0.94.

The regression coefficients of direct, indirect, renewable and non-renewable forms of energy input in relationship to the yield of quince production in models (2) and (3) were estimated using Eqs. (9) and (10), respectively. The results of this analysis are shown in Table 6. The regression coefficients of the direct and renewable energy forms were positive and significant at the 1% level. The coefficients of indirect and non-renewable energy forms were negative and significant at the 1% level.

Table 5. **Econometric estimation results of inputs**

Exogenous variables	Coefficient	t-ratio	MPP
Model 1 : $lnY_i = \alpha_0 + \alpha_1 lnX_1 + \alpha_2 lnX_2 + \alpha_3 lnX_3 + \alpha_4 lnX_4 + \alpha_5 lnX_5 + \alpha_6 lnX_6 + \alpha_7 lnX_7 + e_i$			
Constant	1.30	4.58 [a]	
Human labour	-0.56	-4.73 [a]	-0.79
Machinery	0.06	2.05 [b]	0.08
Chemical fertilizers	-0.02	-1.95 [b]	-0.02
Pesticides	0.14	3.82 [a]	0.19
Diesel fuel	0.22	2.46 [b]	0.26
Water for irrigation	0.49	3.08 [a]	0.76
Electricity	0.61	5.37 [a]	0.74
Durbin-Watson	1.98		
R^2	0.99		
Return to scale	0.94		

[a] Indicates significance at the 1% level.
[b] Indicates significance at the 5% level.

The impact of direct energy was higher than that of indirect energy (1.22 vs. -0.08). This result implies that a 100% increase in direct energy inputs produced a 122% increase in yield, whereas a 100% increase in indirect energy produced an 8% decrease in yield. The results also show that the impact of renewable energy (1.28) was more than that of non-renewable energy (-0.33) in quince production.

Several authors have reported that the impact of direct energy is higher than that of indirect energy (Banaeian and Zangeneh, 2001) and that the impact of renewable energy is higher than that of non-renewable energy (Mohammadi et al., 2010).

The statistical results for models (2) and (3) are shown in Table 6. The values of the Durbin-Watson were 1.77 and 1.81 for Eqs. (9) and (10), respectively. These results indicate that no autocorrelation occurred (1% significance level) in the estimated models. The R^2 values were 0.96 and 0.89, respectively.

Table 6. **Econometric estimation results of direct, indirect, renewable and non-renewable energies**

Exogenous variables	Coefficient	t-ratio	MPP
Model 2 : $lnY_i = \beta_0 + \beta_1 lnDE + \beta_2 lnIDE + e_i$			
Constant	-0.32	2.51 [a]	
Direct energy	1.22	27.19 [a]	1.33
Indirect energy	-0.08	-3.03 [a]	-0.08
Durbin-Watson	1.77		
R^2	0.96		
Return to scale	1.14		
Model 3 : $lnY_i = \gamma_0 + \gamma_1 lnRE + \gamma_2 lnNRE + e_i$			
Constant	0.64	2.20[b]	
Renewable energy	1.28	14.19 [a]	1.81
Non-renewable energy	-0.33	-5.00 [a]	-0.33
Durbin-Watson	1.81		
R^2	0.89		
Return to scale	0.95		

[a] Indicates significance at the 1% level.
[b] Indicates significance at the 5% level.

The values of return to scale for models (2) and (3) were 1.14 and 0.95, respectively. Table 6 shows that the MPP values of direct, indirect, renewable and non-renewable energies were 1.33, -0.08, 1.81 and -0.33, respectively. These results indicate that an additional use of 1 MJ in the direct and renewable energies would lead to additional increases in yield of 1.33 and 1.81 kg/ha^{-1}, respectively. The MPP values of indirect and non-renewable energies were found negative.

The economic results of quince production were given in Table 7. The results revealed that the cost of production per hectare was 5,993.31 \$/ha^{-1}. The net profit of quince was calculated by subtracting the production cost from the gross product value. The net profit value for quince production was found to be 7,308.89 \$/ha^{-1}. In the research, the benefit-cost ratio (B/C) of quince was calculated by dividing the gross value of the product by the total cost to determine economic efficiency. The results indicate that quince production has higher (2.22) B/C ratio.

Several investigations have done an economic analysis for crops production and benefit-cost ratio and concluded: (2.37 for oranges, 1.89 for lemons and 1.88 for mandarins (Ozkan et al. 2004), 1.11 and 1.19 for small and large farms of apricots, respectively (Gezer et al. 2003) and 1.83 and 2.21 for greenhouse and open-field grapes, respectively (Ozkan et al. 2007), 2.13 and 2.14 for organic and conventional dried apricots production (Gundogmus, 2006), 1.94 for kiwi-fruit in Iran (Mohammadi et al. 2010), 2.1 for walnut production (Banaeian and Zangeneh, 2011).

Table 7. **Economic results of quince production**

Cost of production (US \$/ha^{-1})	Gross product value (US \$/ha^{-1})	Net profit (US \$/ha^{-1})	Benefit/cost ratio
5,993.31	13,302.21	7,308.89	2.22

4. Conclusion. According to the econometric results of this study, quince producers should reduce their uses of human labor and chemical fertilizers to attain optimal values for their plantations. This optimization scheme can be expressed in mathematical form as a linear programming problem. The current study can be extended to distinguish efficient growers from inefficient ones, identify wasteful uses of energy inputs by inefficient growers and suggest the quantities of input from each energy source that should be used by each inefficient grower. Further studies of these questions are currently underway.

Optimum energy use in agricultural systems is reflected in 2 ways. Productivity can increase at the existing energy input levels. Alternatively, energy can be conserved without affecting productivity. Energy management acquires increasing importance if the energy used must be economical, sustainable and productive.

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