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An analysis of energy use, CO_2 emissions and relation between energy inputs and yield of hazelnut production in Guilan province of Iran

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ABSTRACT

The objectives of this research were to investigate influences of energy inputs and energy forms on output levels and evaluation of CO_2 emissions for hazelnut production in Guilan province of Iran. Moreover, the sensitivity analysis was done by marginal physical productivity (MPP) method for energy inputs and energy using linear regression. Initial data were collected from 120 orchardists in September and October 2012. The total energy of 2862.62 MJ ha^{-1} was calculated for gardening in one year. The results of energy forms analysis revealed the share of non-renewable and indirect energy was more than renewable and direct energy, significantly. The ratio of energy output to energy input was approximately 3.93. Total CO_2 emissions of hazelnut production was calculated as 77.66 $kgCO_{2eq.}$ ha^{-1}. Also, the diesel fuel had the highest share of emissions among all inputs with 33.84%. Econometric model estimation indicated that the impact of human labor, machinery, diesel fuel and pesticides energy inputs were significantly positive on hazelnut yield. The sensitivity analysis was presented that the marginal physical productivity (MPP) value of pesticides, farmyard manure and diesel fuel energy were the highest with 9.43 and -4.86 and 0.97, respectively. In energy forms econometric models, impact of direct, indirect and renewable energies were significantly. Furthermore, direct and renewable energies was the most sensitive groups in energy forms with MPP value of 0.98 and 1.19, respectively.

Key words: Energy consumption; Hazelnut production; CO_2 emissions; Cobb-Douglass function; Sensitivity analysis.

INTRODUCTION

A hazelnut is the nut of the hazel and is also known as cobnut or filbert nut according to species. A cob is roughly spherical to oval, about 15–25 mm long and 10–15 mm in diameter, with an outer fibrous husk surrounding a smooth shell. A filbert is more elongated, being about twice as long as it is round. (USDA,

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2004). Iran country with 23535 hectares orchard is eighth largest producer of hazelnut in the world (FAO, 2011). Moreover, one of the major poles of hazelnut production belongs to Guilan province in Iran (Anon, 2013) The development of energy efficient agricultural systems with a low input of energy compared to the output of products should therefore help to reduce the emissions of greenhouse gasses (GHGs) in agricultural production (Dalgaard et al., 2001). During agricultural activities, carbon is released through land use changes and agricultural production, the burning of fossil fuels, the production of synthetic fertilizers and pesticides, microbial decay or the burning of plant litter and soil organic matter (Hillier et al., 2011). The Cobb–Douglas production function is a particular functional form of the production function, widely used to represent the technological relationship between the amounts of two or more inputs and energy consumption or CO_2 emissions the amount of output that can be produced by those inputs. In recent years, several researchers have focused on determining modeling of energy use and GHG emissions in agricultural units and various products ranging from cultivation and horticulture to aquaculture. Ozkan et al. (2007) studied on the energy use patterns in greenhouse and open-field grape production. Their results indicated that total input energy use in greenhouse and open-field production was found to be 24513.0 and 23640.9 MJ ha^{-1}, respectively. Mohammadshirazi et al., (2012) studied the energy balance between inputs and output for tangerine production in Mazandaran province, one of the most important citrus production centers in Iran. Pishgar-Komleh et al., (2012) determined energy use and CO_2 emissions for potato production. Khoshnevisan et al., (2013) examined the modeling of energy consumption and GHG emissions for wheat production Esfahan production of Iran. In another study, Ghahderijani et al. (2013) investigated the energy consumption and CO_2 emissions for wheat production. Their results illustrated the total energy consumption and total CO_2 emissions was calculated about 31482 MJ ha^{-1} and 756 $kgCO_{2eq.}$ ha^{-1}, respectively. Nabavi-Pelesaraei et al. (2013a) studied the energy inputs-yield relationship for peanut production in Guilan, Iran. The regression results revealed that the contribution of energy inputs on yield (except for diesel fuel, chemical fertilizers and pesticides energies) was significant.

The aim of the present study is to determine the input to output energy use and CO_2 emissions in hazelnut production in Guilan province of Iran to find the energy efficiency and GHG emissions of this production. Also, the Cobb-Douglas production function is applied to study the relationship and the sensitivity analysis between energy inputs and hazelnut yield.

MATERIALS AND METHODS

Guilan province is one of the most important hazelnut producers in Iran, with 16975 hectares of total area under cultivation and 67.27% of total production in the country. Data were collected from 120 orchardists growing hazelnut in Roudsar city, Guilan province of Iran. This province is located in the north of Iran, within 36° 34′and 38° 27′ north latitude and 48° 53′ and 50° 34′ east longitude (Anon, 2013). Orchardists' responses were obtained through face-to-face interviews, conducted in production year of 2012. The data format is cross-section data in this study. Also, The questionnaire form covered information on inputs and yield for production of crop hazelnut. The stratified random sampling technique was used to select orchards randomly in the study region. Accordingly, The simple random sampling method was applied to determination of size of each sample. Consequently calculated sample size in this study was 107, but it was considered to be 120 to ensure the accuracy.

Based on the energy equivalents of inputs and the output (Table 1), the energy ratio (energy use efficiency) (Eq. (1)), energy productivity (Eq. (2)), specific energy (Eq. (3)), net energy (Eq. (4)) and energy intensiveness (Eq. (5)) were calculated using the following equations (Mandel, 2002; Pishgar-Komleh et al., 2011; Mohammadshirazi et al., 2012; Taki et al., 2013):

$$E_r = E_o / E_I \quad (1)$$

$$E_p = O_p / E_I \quad (2)$$

$$S_e = E_I / H_o \quad (3)$$

$$N_e = E_o - E_I \quad (4)$$

$$E_i = E_I / T_{pc} \quad (5)$$

where, E_r is energy ratio (energy use efficiency); E_O is energy output (MJ ha^{-1}); E_I is energy input (MJ ha^{-1}); E_p is energy productivity (kg MJ^{-1}); O_p is output production (kg ha^{-1}); S_e is specific energy (MJ kg^{-1}); H_o is hazelnut output (kg ha^{-1}); N_e is ne t energy (MJ ha^{-1}); E_i is energy intensiveness (MJ $\$^{-1}$) and T_{pc} is total production cost (\$ ha^{-1}).

In this study, we applied the CO_2 emissions coefficient of agricultural inputs to calculation of GHG emissions (Table 2). The amount of produced CO_2 was calculated by multiplying the input application rate (machinery, diesel fuel, chemical fertilizers and pesticides) by its corresponding emissions coefficient that is given in Table 2.

In the literature, Cobb-Douglas function was used by several authors to examine the relationship between energy inputs and production or yield (Singh et al. 2002; Fadavi et al., 2011), Cobb-Douglas function yielded better estimates in terms of statistical significance and expected signs of parameters among linear, linear logarithmic and second degree polynomial functions (Jalali et al., 2013).

Douglas production function is expressed as Eq. (6):

$$Y = f(x)\exp(u) \quad (6)$$

This can be further written as:

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

Eq. (7) can be expressed in the following form:

$$\ln Y_i = a_0 + \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + \alpha_6 \ln X_6 + e_i \quad (8)$$

Where Xi stands for corresponding energies as X_1, human labor; X_2, machinery; X_3, diesel fuel; X_4, chemical fertilizers; X_5, farmyard manure; and X_6, pesticides.

In the last part of this research, the marginal physical productivity (MPP) method, based on the response coefficients of the inputs was utilized. The MPP of a factor implies the change in the total output with a unit change in the factor input, assuming all other factors are fixed at their geometric mean level. A positive value of MPP of any input variable identifies that the total output is increasing with an increase in input; so, one should not stop increasing the use of variable inputs so long as the fixed resource is not fully utilized (Mousavi-Avval et al., 2011b).

The MPP of the various inputs was computed using the j of the various energy inputs as follow (Singh et al., 2004; Royan et al., 2012):

$$MPP_{xj} = \frac{GM(Y)}{GM(X_j)} \times \alpha_j = \frac{GM(P)}{GM(E_j)} \times \alpha_j \qquad (9)$$

where MPP_{xj} is the marginal physical productivity of jth input, α_j denote the regression coefficient of jth input, *GM(Y*) is geometric mean of yield and $GM(X_j)$ denote the geometric mean of jth input energy on per hectare basis, *GM(P)* geometric mean of production $GM(E_j)$ geometric mean of jth input on orchard ($E_{ji} = X_{ij}A_i$).

Basic information on energy inputs of hazelnut production were entered into Excel 2010 spreadsheets and SPSS 20.0 software program.

RESULTS AND DISCUSSION

3.1. Analysis of input–output energy use in hazelnut production

Table 3 illustrated the amounts of inputs and output and their energy equivalents for hazelnut production. As it is seen, 174.82 h ha^{-1} human labor was consumed for hazelnut production. It is mainly used harvesting operations (76%). The amounts of machinery and diesel fuel used for hazelnut growing were 4.36 h ha^{-1} and 9.52 L ha^{-1}, respectively. From chemical fertilizers, nitrogen, phosphate and potassium used as 14.79, 18.94 and 25.93 kg ha^{-1}, respectively. Moreover, the total energy used in various orchard inputs was 2862.62 MJ ha^{-1}; while, average hazelnut yield was found to be 450.20 kg ha^{-1}; accordingly, total energy output was calculated as 11255.00 MJ ha^{-1} in the enterprises that were analyzed. In some of similar studies, total energy consumption has been reported as 42819.25 MJ ha^{-1} for apple (Rafiee et al., 2010), 26917.47 MJ ha^{-1} for maize (Abdi et al., 2012), 62260.90 MJ ha^{-1} for tangerine (Mohammadshirazi et al., 2012), about 810570 MJ ha^{-1} for alfalfa (Mobtaker et al., 2012), about 19248.04 MJ ha^{-1} for peanut (Nabavi-Pelesaraei et al., 2013a) and about 80170 MJ ha^{-1} for wheat (Khoshnevisan et al., 2013).

As can be seen in Table 3, the nitrogen consumption (with 34.18%) had the highest share of total energy use in hazelnut production; followed by diesel fuel (with 18.73%) and human labor (with 11.97%). Accordingly, the nitrogen and diesel fuel reduction can be save energy consumption of production processing. The contribution of energy inputs used in the production of hazelnut according to the direct, indirect, renewable and non-renewable forms are presented in Table 4. The share of direct input energy was 30.70% in the total energy input compared to 69.30% for indirect energy. On the other hand, 84.00% of total energy input used in hazelnut production was obtained from non-renewable energy resources which was strongly higher than the share of renewable energy resources (16.00%). Several studies have shown that the contribution of indirect energy was higher than that of direct energy, and the share of renewable energy was less than that of non-renewable energy in production of different agricultural and horticultural crops (Mohammadi et al., 2010; Samavatean et al., 2011). It is clear that the proportion of non-renewable energy use in surveyed farms is very high. Excessive use of non-renewable energy sources in the developing countries with low levels of technological knowledge, is not sustainable for a healthy agriculture in the long term and it can not only cause impacts on human health and ecosystems but also confront us with the dilemma of rapid rate of depletion of such invaluable resources; while renewable energy sources can serve us indefinitely with minimal environmental impacts as compared with fossil fuels (Fadai 2007; Khan et al. 2009). As can be seen, the energy indices of hazelnut production are demonstrated in Table 4. The results showed the energy use efficiency was found to be 3.93, indicating that the output energy was 3.93 times greater than total input energy in the hazelnut production. So the energy productivity was obtained as 0.16 kg MJ^{-1}. Moreover, net energy productivity, specific energy and energy intensiveness were calculated as 8392.38 MJ ha^{-1}, 6.36 MJ kg^{-1} and 1.82 MJ $\$^{-1}$, respectively, Specific energy indicates that implying that on average 6.36 MJ energy is required per 1 kg of soybean grain. In the previous studies the energy use efficiency for some agricultural crops was reported as 2.8 for wheat, 4.8 for cotton, 3.8 for maize, 1.5 for sesame (Canakci et al., 2005), 2.86 for barley (Mobtaker et al., 2010), 3.02 for canola (Mousavi-Avval et al., 2011b) and 0.51 for pear (Tabatabaie et al., 2013). Also, the specific energy was calculated as 8.27 and 12.52 MJ kg^{-1} for canola and sunflower productions, respectively (Sheikh Davoodi and Houshyar, 2009).

3.2. CO_2 emissions Analysis in hazelnut production

The results of CO_2 emissions of hazelnut production are given in Table 5. Accordingly, the amount of total CO_2 emissions in wheat production is 77.66 $kgCO_{2eq.}$ ha^{-1}. The results revealed the CO_2 emissions of machinery and diesel fuel were calculated as 20.61 and 26.28 $kgCO_{2eq.}$ ha^{-1}. Pathak and Wassmann (2007) reported a total emissions of 1038 $kgCO_{2eq.}$ ha^{-1} for wheat production. Khakbazan et al. (2009) calculated the CO_2 emissions from wheat production and found that it can be ranged from 410 $kgCO_{2eq.}$ ha^{-1} to 1130 $kgCO_{2eq.}$ ha^{-1} depending on fertilizer rate, location and seeding system. The total CO_2 emissions of hazelnut production is very low compared to other agriculture products. For example, Ghahderijani et al., (2013) reported the total CO_2 emissions of wheat production was 756.11 $kgCO_{2eq.}$ ha^{-1} (about ten times greater than the present value). In explanation of this phenomenon, it can be say the low level of mechanization operation for hazelnut production in this studied area was main reason for modicum of CO_2 emissions. So, It can be concluded the CO_2 emissions is one of agriculture mechanization disadvantages. In other hand, the low level of mechanization operation can cause stiffness and low productivity in agricultural activity. So, we proposed the appropriate machinery selection and timely maintenance can be improved the productivity and acceptable emissions for hazelnut production in Guilan province of Iran.

Fig 1 displays the distribution of CO_2 emissions for hazelnut production. The results indicated the highest share of CO_2 emissions was belonged to diesel fuel with %, followed by machinery and nitrogen. With respect to above-suggestion, reduction of diesel fuel and chemical fertilizers and selection of standard machinery is best solutions for CO_2 emissions reduction.

3.3. Econometric model estimation of hazelnut production

In order to investigate the relationship between energy inputs and hazelnut yield, the Cobb-Douglas production function was applied. Table 6 illustrated the regression coefficients of Model 1 (Eq. (8)) are, where the impacts of all inputs (except nitrogen) are statistically significant at the 1% level. The highest effect on output (hazelnut yield) belonged to pesticides energy input (1.68), followed by diesel fuel (1.06), chemical fertilizers (-0.94) and farmyard manure (-0.92). It should be mentioned that this analyze is a comparative analyze between different orchardists. In order to examine the autocorrelation, Durbin-

Watson test is done and the value was 1.92, which indicates that there is no auto correlation at the 5% significant level for estimated model. In this study, Durbin-Watson test was applied to survey of autocorrelation for data used (Hatirli et al, 2005). This test illustrated that Durbin-Watson value was 1.97 for Eq. (8), there was no autocorrelation at the 5% significance level in the estimated model. Based Eq. (8), the results of econometric estimation are given in Table 6. Accordingly, the coefficient of determination (R^2) was found to 0.92 for this linear regression model. Also, the impact of energy inputs could have positive effect on yield (except for human labor, machinery and pesticides). Moreover, seed had highest impact in production processing.

Moreover, the regression coefficients estimation of this model was done with R^2 of 0.80. For sensitivity analysis, MPP methods was applied. As can be seen in Table 6, the MPP values for human labor, machinery, diesel fuel, chemical fertilizers, farmyard manure and pesticides energies were estimated at 0.72, 0.70, 0.97, -0.29, -4.86 and 9.43, respectively, which means by additional usage of 1 MJ of their energies the yield will increase by 0.72, 0.70, 0.97, -0.29, -4.86 and 9.43 kg ha^{-1}, respectively.

CONCLUSION

The following conclusions were drawn from the study:

Total energy consumption of hazelnut production was calculated to be 2862.62 MJ ha^{-1} where chemical fertilizer and diesel fuel energy had the highest energy usage in all inputs. The hazelnut yield was 450.20 kg ha^{-1}. Also, the nitrogen had the highest share in total energy usage with 34.18%. Vice versa, the lowest share of energy inputs was belonged to insecticide with 1.28%.

With respect to energy forms analysis, the shares of direct and indirect energy calculated as 30.70% and 69.70%, respectively. In other hand, renewable and non-renewable energy resource covered the 16.00% and 84% of total energy consumption in hazelnut production.

The average value of energy indices including energy ratio, energy productivity, specific energy, net energy and energy intensiveness calculated as 3.93, 0.16 kg MJ^{-1}, 6.36 MJ kg^{-1}, 8392.38 MJ ha^{-1}, and 1.82 MJ $\$^{-1}$, respectively.

The CO_2 emissions analysis illustrated that the total CO_2 emissions of 77.66 $kgCO_{2eq.}$ ha^{-1}. Diesel fuel with share of 33.84% of total CO_2 emissions was in first rank and followed by machinery (26.54%) and nitrogen (24.76%), respectively. Using standard machinery, appropriate maintenance and utilizing chemical fertilizers based on plant needs and applying soil analysis to specify the soil needs are recommended to decrease high chemical fertilizer energy consumption and CO_2 emissions.

Econometric estimation results revealed that pesticides had the highest impact (1.68) among other inputs and significantly contributed on yield at 1% level.

The MPP estimated for human labor energy was the biggest among inputs of energy. As well, MPP of chemical fertilizers and farmyard manure energies were found negative, indicating that chemical fertilizers and farmyard manure energy consumption is high in hazelnut production.

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Table 1
Energy equivalent of inputs and output in agricultural production.

Inputs (unit)	Unit	Energy equivalent (MJ unit^{-1})	Reference
A. Inputs			
1. Human labor	h	1.96	(Mobtaker et al, 2010)
2. Machinery	h	62.70	(Abdi et al, 2012)
3. Diesel fuel	L	56.31	(Barber, 2003)
4. Chemical fertilizers	kg		
(a) Nitrogen		66.14	(Mousavi-Avval et al, 2011b)
(b) Phosphate		12.44	(Mobtaker et al, 2012)
(c) Potassium		11.15	(Rafiee et al, 2010)
5. Farmyard manure	kg	0.3	(Demircan et al., 2006)
6. Pesticides	kg		
(a) Insecticide		199	(Nabavi-Pelesaraei et al, 2013b)
(b) Fungicide		92	(Nabavi-Pelesaraei et al, 2013b)
B. Output			
Hazelnut	kg	25	(Kitani, 1999)

Table 2
GHG emissions coefficients of agricultural inputs.

Input	Unit	CO_2 Coefficient (kg $CO_{2eq.}$ unit^{-1})	Reference
1. Machinery	MJ	0.071	(Khoshnevisan et al., 2013)
2. Diesel fuel	L	2.76	(Ghahderijani et al., 2013)
3. Chemical fertilizers	kg		
(a) Nitrogen		1.3	(Khoshnevisan et al., 2013)
(b) Phosphate		0.2	(Nabavi-Pelesaraei et al., 2013c)
(c) Potassium		0.2	(Ghahderijani et al., 2013)
4. Pesticides	kg		
(a) Insecticide		5.1	(Nabavi-Pelesaraei et al., 2013c)
(b) Fungicide		3.9	(Nabavi-Pelesaraei et al., 2013c)

Table 3

Amounts of inputs, outputs and their energy equivalences in hazelnut production.

Inputs (unit)	Quantity per unit area (ha)	Total energy equivalent (MJ ha^{-1})	Percentages (%)
A. Inputs			
1. Human labor (h)	174.82	342.65	11.97
2. Machinery (h)	4.36	290.30	10.14
3. Diesel fuel (L)	9.52	536.16	18.73
4. Chemical fertilizers (kg)			
(a) Nitrogen	14.79	978.44	34.18
(b) Phosphate	18.94	235.59	8.23
(c) Potassium	25.93	289.12	10.10
5. Farmyard manure	384.53	115.36	4.03
6. Pesticides (kg)			
(a) Insecticide	0.18	36.64	1.28
(b) Fungicide	0.42	38.36	1.34
The total energy input (MJ)		2862.62	100
B. Output			
Hazelnut (kg)	450.20	11255.00	

Table 4

Quantity of energy forms and input-output ratio for hazelnut production in Guilan province, Iran.

Items	Unit	Hazelnut	Percentages (%)
Total energy consumption	MJ ha^{-1}	2862.62	100
Direct energy [a]	MJ ha^{-1}	878.81	30.70
Indirect energy [b]	MJ ha^{-1}	1983.81	69.30
Renewable energy [c]	MJ ha^{-1}	458.01	16.00
Non-renewable energy [d]	MJ ha^{-1}	2404.61	84.00
Energy use efficiency	-	3.93	-
Energy productivity	kg MJ^{-1}	0.16	-
Specific energy	MJ kg^{-1}	6.36	-
Net energy gain	MJ ha^{-1}	8392.38	-
Energy intensiveness*	MJ \$$^{-1}$	1.82	-

* Convert Rial to Dollar (Nabavi-Pelesaraei et al., 2013a).

[a] Includes human labor, diesel fuel.

[b] Includes chemical fertilizers, pesticides, farmyard manure, machinery.

[c] Includes human labor, farmyard manure.

[d] Includes chemical fertilizers, pesticides, diesel fuel, machinery.

Table 5
GHG emissions of inputs in hazelnut production.

Input	CO_2 emissions ($kgCO_{2eq.}$ ha^{-1})	Min	Max
1. Machinery	20.61	3.68	55.22
2. Diesel fuel	26.28	6.42	64.23
3. Chemical fertilizers			
(a) Nitrogen	19.23	5.88	44.45
(b) Phosphate	3.79	1.16	8.75
(c) Potassium	5.19	1.59	11.99
4. Pesticides			
(a) Insecticide	0.94	0.13	2.42
(b) Fungicide	1.63	0.89	2.22
Total CO_2 emissions	77.66	22.86	172.94

Table 6
Econometric estimation results of inputs.

Endogenous variable: yield	Coefficient	*t*-ratio	MPP
Exogenous variables			
Model 1: $\ln Y_i = a_0 + \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + \alpha_6 \ln X_6 + e_i$			
Constant	1.23	1.57	
Human labor	0.57	3.78^{**}	0.72
Machinery	0.35	5.79^{**}	0.70
Diesel fuel	1.06	3.18^{**}	0.97
Chemical fertilizers	-0.94	-1.84	-0.29
Farmyard manure	-0.92	-10.19^{**}	-4.86
Pesticides	1.68	9.08^{**}	9.43
Durbin-Watson	1.92		
R^2	0.80		
Return to scale ($\sum_{i=1}^{n} \alpha_i$)	3.03		

** Indicates significance at 5% level

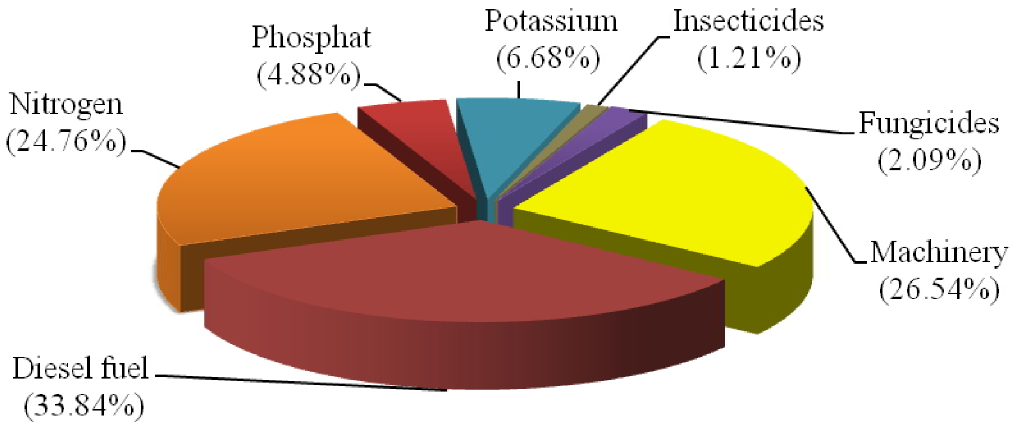

Fig. 1. Distribution of CO_2 emissions for hazelnut production in Guilan province, Iran.

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