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Energy utilization and greenhouse gas (GHG) emissions in cherry cultivation

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Abstract
This study was performed with the purpose of shedding light on the energy balance (EB) and greenhouse gas (GHG) emissions of cherry cultivation. It was performed in Gönen district of Isparta province of Türkiye during the 2021 production period. Data related to energy inputs (EI) and outputs (EO) were gathered in cherry cultivation. They were then usaged to reveal the EB and GHG in the process. According to the results of the study, EI in cherry cultivation were 8 141.40 MJ/ha (57.04%) chemical fertilizers energy, 3 575.69 (25.05%) diesel fuel energy, 1 186.02 (8.31%) machinery energy, 469.80 (3.29%) electricity energy, 366.25 (2.57%) human labour energy, 290.30 (2.03%) irrigation water energy, 231.30 (1.62%) chemicals energy and 13.20 MJ/ha (0.09%) lime energy, respectively. Total input energy was computed to be 14 273.96 MJ/ha while output energy was found to be 29 593 MJ/ha. Energy utilization efficiency (EUE), specific energy (SE), energy productivity (EP) and net energy (NE) values were found as 2.07, 1.41 MJ/kg, 0.71 kg/MJ and 15 319.04 MJ/ha, respectively. The total energy inputs that were involved in cherry cultivation were categorized as: 32.94% (4 702.04 MJ/ha) direct (IE), 67.06% (9 571.92 MJ/ha) indirect (IDE), 4.60% (656.55 MJ/ha) renewable (RE) and 95.40% (13 617.41 MJ/ha) non-renewable (NRE). Total GHG emission was computed as 550.71 kgCO_{2eq}/ha for cherry cultivation with the greatest share for diesel fuel (31.82%). GHG ratio value was computed as 0.05 kgCO_{2eq}/kg in cherry cultivation.
Keywords: Cherry, Energy balance, Energy utilization efficiency, GHG emissions, Specific energy

INTRODUCTION

Cherry tree, called 'Prunus avium' in Latin, is a member of the Rosaceae family (Çelik and Sarıaltın, 2019; İncekara and Selek, 2020). There are around 1 500 cherry varieties in the world and it is a sweet-flavored, juicy and stone fruit type. Cherry contains plenty of calcium, zinc, potassium, carotenoids, fiber, and vitamin C, iron, thiamine, riboflavin, niacin, magnesium, vitamins E and B6 (Anonymous, 2020a; İncekara and Selek, 2020). Cherry, a type of sweet-flavored, juicy and drupe fruit, is rich in calcium, zinc, potassium, fiber, vitamin C, iron, thiamine, riboflavin, niacin, magnesium, vitamins E and B6 (İncekara and Selek, 2020). Türkiye is home to many types of fruit. The climate zone in which Türkiye is located is suitable for the ecological demands of many fruit varieties. For this reason, Türkiye is one of the prominent countries in world fruit production and has a significant share in the world's production of hazelnut, fig, cherry, apricot, quince, pistachio and sour cherry. Compared to others, the importance of cherries in the Turkish economy is increasing due to reasons such as being consumed fresh, being usaged as raw material in the food industry, being subject to export, and contributing to employment (İşleyen and Erden, 2019).

Cherry production in Türkiye's neighbours remains low compared to Türkiye. In addition, due to its ecological diversity, Türkiye can offer higher quality products to foreign markets at earlier times. For this reason, the Middle East and Arab countries are good markets. Compared to the leading European countries in cherry cultivation, our country has a significant potential in high quality, early varieties with high market value. If the advantage in terms of ecological factors is usaged well, it is possible to become one of the prominent countries in cherry exports and generate high revenues (Sütyemez and Eti, 1999; Çelik and Sarıaltın, 2019).

According to FAO data, Türkiye ranks first in the world cherry production area and production amount with 83 thousand hectares of cherry planting area and approximately 725 thousand tons of production in 2020. Chile follows Türkiye in cherry planting area with 40 thousand hectares. The USA is in third place with 34 thousand hectares, and Syria is in fourth place with 30 thousand hectares. In terms of cherry production, Türkiye is followed by the USA in second place with 295 thousand tons, Chile in third place with 255 thousand tons, and Uzbekistan in fourth place with 185 thousand tons (Anonymous, 2023a).

In order to perform energy balance, it is necessary to carry out economic and technic comprehensive reseaches. However, it is basically done to examine whether the production of the product or service to be offered to the market is possible in terms of EUE. Comparing the total energy value of inputs usaged in agricultural cultivation processes to the energy value of the acquired product is a more realistic approach for the assessment of the productivity (Öztürk, 2011; Bayhan, 2016; Karaağaç et al., 2018). Climate changes are occurring in the world and in our country. Among these, increasing air temperatures attract attention. It is evaluated that this rise in air temperature will cause serious climate change in the world. Climate change due to global warming causes sea level rise, shifting climate zones, severe weather events, floods and floods to occur more frequently and their effects to become stronger. In addition, it is estimated that it will lead to significant consequences by directly or indirectly affecting socio-economic sectors and ecological systems, as well as deterioration of human health along with wildlife species due to drought, erosion, desertification, epidemic diseases, agricultural pests, and disruption of natural balance (Anonymous, 2001, 2002; Korkmaz, 2007).

There has been progress in agriculture in areas such as mechanization, fertilization, spraying and irrigation. As a result of these progress, significant increases have been achieved in the amount of product taken per unit area. However, production, income and productivity have not reached the desired level due to some basic problems such as the use of traditional agricultural techniques in the agricultural sector, the use of incomplete inputs, the small and fragmented agricultural lands and the ineffective use of existing production resources. In order to solve the current problems encountered in agricultural production, it is necessary to determine whether the current structures of agricultural enterprises, production processes and resources are usaged effectively. Studies carried out to determine the amounts and costs of materials, labour and power usaged in the production of agricultural products form the basis of the steps taken in this direction. Studies conducted in this direction reveal the details of the production process, determine the participation amounts and shares of production factors in production, and provide some basic data that can be usaged in agricultural cultivation planning and economic analysis (Anonymous, 1998; İşleyen, 2019).

Non renewable energy sources are usaged to increase input density. These include chemical fertilizers, chemical pesticides, diesel fuel and the like. Non renewable energy resources containing fossil fuels decompose due to their structure and spread into the environment. As a result, soil, water and air are polluted and GHG are released into the environment. As a direct result of this, GHG have negative effects on the environment and human health (such as climate change, the emergence of diseases and pests, and the extinction of species). In other words, with the increase in the use of input energy per unit area, the environment and nature are polluted and resources such as soil and water, which are essential for nutrition, are damaged (Gökırmaklı and Bayram, 2018; Anonymous, 2020b; Şahin and Külekçi, 2022). A number of studies were performed on EB and GHG of agricultural production. A number of various studies were conducted on cherry (Demircan et al., 2006; Kizilaslan, 2009; Vahid-Berimanlou and Nadi, 2021), apricot (Gezer et al., 2003), pomegranate (Ozalp et al., 2018), apple (Çelen et al., 2017), sunflower (Akdemir et al., 2017), lavender (Demir et al., 2022), pepper (Baran et al., 2022), tea (Yıldız, 2023), watermelon (Demir, 2023), garlic (Baran et al., 2023), among others. A research on the literature has revelaed that no studies were conducted on the energy balance and GHG emission of cherry emission in the area and therefore the significance of this current study is quite high.

MATERIALS AND METHODS

Isparta province is located in the lakes region in the north of the Mediterranean Region. The city has a surface area of 8 933 km^2 and an average altitude of 1 050 meters. 68.4% of the province includeds of mountains, 16.8% plains and 14.8% plateaus. Gönen district generally reflect the steppe climate, which is a characteristic feature of Central Anatolia (Anonymous, 2023b). Gönen district is in the north of Isparta and is surrounded by Atabey in the east, Uluborlu in the north, Burdur province in the southwest, and Keçiborlu district in the west. The district is 5 km away from the Isparta-Burdur highway. The district's surface area is 356 km^2. The district's altitude above sea level is 1 820 meters. It is 23 km away from Isparta city center. Agriculture and animal husbandry are important sources of income in the district (Anonymous, 2023c). The soils in Isparta generally have a calcareous main structure. Tectonic depression grooves in Isparta were filled with I. period alluviums. In the topsoil of agriculture, soils that constitute the basic source of 8-40 cm have emerged. According to temperature observations of Isparta over 30 years, the annual average temperature of the province is (12 °C). The highest temperature detected in the province is (38.7 °C) and the lowest temperature is (-21 °C). The average annual total rainfall in the city center is 508.3 mm (Anonymous, 2023d).

This current study was conducted in Gönen district of Isparta of Türkiye during the 2021 production period. The area that was studied spanned over a 2 ha cherry cultivation area. Randomized complete-block design with three replications was usaged. The amount of fuel consumption was computed and full-tank method was usaged to achieve this. The amount of fuel usaged per unit area was determined to measure the trial area and the amount of fuel that was placed in the tank (Göktürk, 1999; El Saleh, 2000; Sonmete and Demir, 2007). The work productivity for the area was computed and it was deemed to be an effective productivity. Work productivity in (ha/h) was achieved by calculating the effective working time (t_{ef}) (Güzel, 1986; Özcan, 1986; Sonmete, 2006). Time durations were measured in the study with the help of a chronometer (Sonmete, 2006). The energy equivalents and GHG equivalents of inputs in cherry cultivation are shown in Table 1 and Table 2, respectively. According to Mohammadi et al. (2010); EUE, SE, EP and NE were computed by using the formulates (Mandal et al., 2002; Mohammadi et al., 2008).

$$\text{Energy utilization efficiency} = \frac{\text{Energy output } (\frac{MJ}{ha})}{\text{Energy input } (\frac{MJ}{ha})} \quad (1)$$

$$\text{Specific energy} = \frac{\text{Energy input } (\frac{MJ}{ha})}{\text{Product output } (\frac{kg}{ha})} \quad (2)$$

$$\text{Energy productivity} = \frac{\text{Product output } (\frac{kg}{ha})}{\text{Energy input } (\frac{MJ}{ha})} \quad (3)$$

$$\text{Net energy} = \text{Energy output (MJ/ha) - Energy input (MJ/ha)} \quad (4)$$

Table 1. Energy Equivalents in Cherry Production.

Inputs	Unit	Energy Equivalent (MJ/unit)	References
Human labour	h	1.96	Mani et al. 2007; Karaağaç et al. 2011
Tractor	h	25.40	Singh, 2002; Akbolat et al., 2014
Rotary tiller	h	23.60	Singh, 2002; Akbolat et al., 2014
Disc harrow	h	19.60	Singh, 2002; Akbolat et al., 2014
Spraying	h	21.40	Singh, 2002; Akbolat et al., 2014
Chemical fertilizers			
N	kg	60.60	Singh, 2002; Ekinci et al., 2020
P	kg	11.10	Singh, 2002; Ekinci et al., 2020
S	kg	1.12	Nagy, 1999; Mohammadi et al., 2010
Chemicals			
Fungicide	kg	99	Fluck, 1992; Ekinci et al., 2020
Insecticide	kg	363.60	Pimentel 1980; Mrini et al., 2002
Diesel fuel	L	56.31	Singh 2002; Demircan et al., 2006
Lime	kg	1.32	Pimentel, 1980; Bilgili, 2012
Irrigation water	m^3	0.63	Yaldız et al., 1993; Ozkan et al., 2011
Electricity	kWh	3.60	Ozkan et al., 2004
Cherry fruit (Output)	kg	2.93	Proebsting (1980); Vahid-Berimanlou and Nadi (2021)

Table 2. GHG Emissions Coefficients in Cherry Cultivation.

Inputs	Unit	GHG Equivalent ($kgCO_{2-eq/}$unit)	References
Machinery	MJ	0.071	Dyer, J.A. and Desjardins, 2006; Ekinci et al., 2020
N	kg	1.300	Lal, 2004; Ozalp et al., 2018
P	kg	0.200	Lal, 2004; Ozalp et al., 2018
S	kg	0.370	Maraseni et al., 2010; Eren et al., 2019
Fungicide	kg	3.900	Graefe et al., 2013; Ozalp et al., 2018
Insecticide	kg	5.100	Lal, 2004; Ozalp et al., 2018
Diesel fuel	L	2.760	Clark et al., 2016; Eren et al., 2019
Electricity	kWh	0.608	Khoshnevisan et al., 2013; Ozalp et al., 2018

Eren et al. (2019) concluded that the GHG emissions ($kgCO_{2eq}$/ha) that take place through the inputs usaged to grow 1 ha of fruit were computed as follows, as adapted by Hughes et al. (2011).

$$GHG_{ha} = \sum_{i=1}^{n} R(i)\, x\, EF(i) \quad (5)$$

Eren et al. (2019) stated as follows ∑ where *R(i)* is the application rate of input *i* ($unit_{input}$/ha) and EF(*i*) is the GHG emission coefficient of input *i* ($kgCO_{2-eq}/unit_{input}$). However, an index is defined to evaluate the amount of emitted $kgCO_{2-eq}$ per kg yield. This is indicated in the following formula adapted Houshyar et al. (2015) and Khoshnevisan et al. (2014), where I_{GHG} is GHG ratio and Y is the yield as kg per ha.

$$I_{GHG} = \frac{GHG_{ha}}{Y} \quad (6)$$

The input energy can be categorized into into D, IDE, RE and NRE forms (Mandal et al., 2002; Singh et al., 2003; Koctürk and Engindeniz, 2009). Energy balance, energy utilization efficiency computations, energy inputs types, GHG emissions of inputs related to cherry cultivation are presented in Tables 3 to 6, respectively.

RESULTS AND DISCUSSION

As a result of the current study conducted in a cherry orchard, the average amount of cherry cultivated per hectare was computed as 10 100 kg for the 2021 production season. As Table 3 indicates, EI in cherry cultivation were, respectively: 8 141.40 (57.04%) chemical fertilizers energy, 3 575.69 (25.05%) diesel fuel energy, 1 186.02 (8.31%) machinery energy, 469.80 (3.29%) electricity energy, 366.25 (2.57%) human labour energy, 290.30 (2.03%) irrigation water energy, 231.30 (1.62%) chemicals energy and 13.20 MJ/ha (0.09%) lime energy. Total inputs energy was computed as 14 273.96 MJ/ha. Output energy (cherry fruit) was computed as 29 593 MJ/ha. In previous studies on the subject, Demircan et al. (2006) reported that fertilizer utilization energy had the biggest share by 40.82% in sweet cherry cultivation, while Ekinci et al. (2020) reported that diesel fuel energy had the biggest share by 24.69% in apple cultivation, etc. Cherry fruit, EI, EO, EUE, SE, EP and NE in cherry cultivation were computed as 10 100 kg/ha, 14 273.96 MJ/ha, 29 593 MJ/ha, 2.07, 1.41 MJ/kg, 0.71 kg/MJ and 15 319.04 MJ/ha, respectively (Table 4). In previous studies on the subject, Demircan et al. (2006) computed (cherry) EUE as 1.23, Vahid-Berimanlou and Nadi (2021) computed (cherry) EUE as 0.43, Oğuz et al. (2019) computed (nectarine) EUE as 1.86.

As indicated in Table 5, the total EI usaged in cherry cultivation can be classified as 32.94% (4 702.04 MJ/ha) DE, 67.06% (9 571.92 MJ/ha) IDE, 4.60% (656.55 MJ/ha) RE and 95.40% (13 617.41 MJ/ha) NRE. NRE was higher than the ratio of RE in EI of cherry cultivation. Similarly, in previous studies on sweet cherry (Demircan et al., 2006), on cherry (Vahid-Berimanlou and Nadi, 2021), on nectarine (Oğuz et al., 2019), among others, yielded results where the ratio of NRE was higher than the ratio of RE.

The results of GHG emissions of cherry cultivation are presented in Table 6. The total GHG emission was computed as 550.71 $kgCO_{2eq}$/ha (0.55 $tonCO_{2eq}$/ha). The results of the research pointed to the fact that the share of diesel in total GHG emissions had the highest value 31.82%, N (nitrogen) 21.25% and machinery 15.29% held the second and third place. GHG ratio (per kg) was computed as 0.05. In previous studies on the subject, Ekinci et al. (2020) computed the total GHG emission of apple cultivation as 1.46 $tonCO_{2eq}$/ha, Baran et al. (2023) computed the total GHG emission of garlic cultivation as 8.63 $tonCO_{2eq}$/ha, Demir (2023) computed the total GHG emission of watermelon cultivation as 0.43 $tonCO_{2eq}$/ha.

Table 3. Energy Balance in Cherry Production.

Inputs	Unit	Energy Equivalent (MJ/unit)	Input Per Hectare (Unit/ha)	Energy Value (MJ/ha)	Ratio (%)
Human labour	h	1.96	186.86	366.25	2.57
Tractor	h	25.40	24.75	628.65	4.40
Rotary tiller	h	23.60	15.84	373.82	2.62
Disc harrow	h	19.60	3.96	77.62	0.54
Spraying	h	21.40	4.95	105.93	0.74
Chemical fertilizers					
N	kg	60.60	90	5 454	38.21
P	kg	11.10	230	2 553	17.89
S	kg	1.12	120	134.40	0.94
Chemicals					
Fungicide	kg	99	0.50	49.50	0.35
Insecticide	kg	363.60	0.50	181.80	1.27
Diesel fuel	L	56.31	63.50	3 575.69	25.05
Lime	kg	1.32	10	13.20	0.09
Irrigation water	m^3	0.63	460.80	290.30	2.03
Electricity	kWh	3.60	130.50	469.80	3.29
Total inputs	-	-		14 273.96	100
Output	Unit	Energy equivalent (MJ/unit)	Output per hectare (unit/ha)	Energy value (MJ/ha)	Ratio (%)
Cherry fruit	kg	2.93	10 100	29 593	100
Total output	-	-	-	29 593	100

Table 4. EUE Computations in Cherry Cultivation.

Computations	Unit	Values
Cherry fruit	kg/ha	10 100
EI	MJ/ha	14 273.96
EO	MJ/ha	29 593
EUE	-	2.07
SE	MJ/kg	1.41
EP	kg/MJ	0.71
NE	MJ/ha	15 319.04

Table 5. EI in the Forms of Energy for Cherry Cultivation.

Energy Types	EI (MJ/Ha)	Ratio (%)
DE[a]	4 702.04	32.94
IDE[b]	9 571.92	67.06
Total	14 273.96	100
RE[c]	656.55	4.60
NRE[d]	13 617.41	95.40
Total	14 273.96	100

[a]Human labour, diesel fuel, electricity and irrigation water
[b]Chemical fertilizers, chemicals, lime and machinery
[c]Human labour and irrigation water
[d]Diesel fuel, chemicals, chemical fertilizers, machinery, lime and electricity

Table 6. GHG Emissions in Cherry Cultivation.

Inputs	Unit	GHG Coefficient ($kgCO_{2eq}$/unit)	Input usaged per area (unit/ha)	GHG Emissions ($kgCO_{2eq}$/ha)	Ratio (%)
Machinery	MJ	0.071	1 186.02	84.21	15.29
N	kg	1.300	90	117	21.25
P	kg	0.200	230	46	8.35
S	kg	0.370	120	44.40	8.06
Fungicide	kg	3.900	0.50	1.95	0.35
Insecticide	kg	5.100	0.50	2.55	0.46
Diesel fuel	L	2.760	63.50	175.26	31.82
Electricity	kWh	0.608	130.50	79.34	14.41
Total	-	-	-	550.71	100.00
GHG ration (per kg)	-	-	-	0.05	-

CONCLUSION

This current study aimed to reveal the energy balance and GHG emissions in cherry cultivation. EUE, SE, EP and NE in cherry cultivation were computed as 2.07, 1.41 MJ/kg, 0.71 kg/MJ and 15 319.04 MJ/ha, respectively. The highest energy input in cherry production was deemed to be chemical fertilizers energy by 57.04%. The total energy inputs usaged in cherry cultivation can be classified as 4.60% RE and 95.40% NRE. Use of chemical fertilizers usage should be decreased and use of farm fertilizers should be increased in order to rise EUE.

The total GHG emissions were computed as 550.71 $kgCO_{2eq}$/ha (0.55 $tonCO_{2eq}$/ha) and GHG rate (per kg) as 0.05. The findings of the research indicate that the rate of diesel fuel in total GHG emissions had the highest value by 31.82%. Eren et al. (2019) performed that it is recommended to make soil analysis to determine the type of soil fertilizer needed (to reduce high chemical fertilizers causing GHG emissions), and diesel fuel efficiency (to reduce the diesel fuel consumption).

According to the findings of this current study, cherry cultivation is a profitable production activity in terms of EUE (2.07). Machinery-use related fuel expenses can be decreased by using RE terms (Akbolat et al., 2014; Yıldız, 2023). The energy saving potential is huge. Observance of optimum requirement levels rises energy efficiency and decreases GHG (Imran and Ozcatalbas, 2021; Yıldız, 2023). Balanced fertilization programs based on soil and plant assessments can be important in reducing GHG (Seydoşoğlu et al., 2023). Energy utilization efficiency can be enhanced by taking the given recommendations into consideration.

The results of the energy balance given that cherry cultivation is a profitable production. Yılmaz and Bayav (2023) reported that; applications that improve profits should be encouraged; moreover, energy efficiency should be provided. Otherwise, it has not possible to talk about sustainability in agriculture production. It has important to support organic agriculture and good agricultural appliations, which some researches have defined to be highly energy efficient.

Compliance with Ethical Standards

Conflict of interest

The authors declare that they have no competing interests in this study.

Author contribution

The contribution of the authors to this study is equal. The authors read and approved the last manuscript. The authors approve that the manuscript are original and not been published before.

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Data availability

Not applicable.

Consent for publication

Not applicable.

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