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Energy Flow of Watermelon Production System for Optimizing Energy Efficiency

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ABSTRACT

This research, conducted in Gotvand, southwest Iran, evaluated the energy balance of a field system which watermelon produced in it. In the current research, energy inputs of watermelon planting were measured. To reach this goal, questionnaires were given to the farmers to record the amount of energy input to their watermelon planting field. Statistical analysis of the data revealed that nitrogen was the input with the highest consumption of energy (4175 MJ.ha^{-1}) followed by diesel fuel. About 90% of the consumed energy of watermelon planting system was seen for energies which cannot be renewed. The results showed that the efficiency of energy consumption was positive, indicating that the amount of output energy was higher than that of input energy. With each unit of energy was consumed, 4.86 units of energy were produced, which indicates high energy efficiency. For improving the efficiency of energy usage in the watermelon planting system, nitrogen application to the system should be reduced and it can be reached by suitable rotation which diminish the nitrogen needs.

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INTRODUCTION

Watermelon (*Citrullus lanathus*) is an important kitchen garden plant of the *Cucurbitaceae* family. According to the latest published statistics, the production of watermelon in Iran was nearly three million tons, which is the third country in the world in terms of watermelon production (after China and Turkey) (1). This indicates the importance of watermelon in the agriculture of Iran.

Although agriculture is an important source of energy supply, it is also considered as an energy consuming system. Agricultural ecosystems provide energy for human and animal populations. However, these systems face limited production resources .Therefore, there must be a balance between the amount of exploitation from these systems and the consumption of resources. This ensures energy supply for human populations. In addition, it makes production resources not destroyed and preserves them for future generations. This is called sustainable agriculture (2). Energy efficiency is a key factor for reaching sustainability (3). It has been reported that environmental conditions are also effective in energy input, and thus, energy efficiency of an agronomical system (4).

One of the most important goals of sustainable agriculture is the optimal use of environmental resources so that dependence on inputs and energy consumption decreases and energy efficiency increases. Accordingly, the optimal use of energy is one of the most important characteristics of sustainable agriculture (3, 5). On the other hand, economic and social development of countries has a direct relationship with energy supply. A look at energy consumption in developing countries shows that any development in these countries has been accompanied by an increase in energy consumption (4). Due to the limitation of energy supply sources, the necessity of optimal use of energy has been revealed. However, research has shown that the higher productivity of agricultural ecosystems has only been accompanied by the help and increase in energy consumption in various production sectors, such as seeds, pesticides, chemical fertilizers, and fuel (5, 6). In fact, the lack of optimal use of energy in agriculture in developing countries has created major limitations for the production of

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agricultural products, and thus, the realization of sustainable agriculture (7). Meanwhile, mechanized agriculture has also played an important role in increasing energy consumption in agriculture, so that mechanization has been introduced as a major consumer of non-renewable energy sources (8).

Since energy is mostly used inefficiently in developing countries, especially in agriculture, knowing the contribution of different production inputs in the final energy consumption in agricultural systems can greatly help planning for efficient use of energy. Accordingly, the present research was carried out with the following objectives: 1. What is the share of different production inputs in the final consumption of energy? 2. How to improve energy efficiency in watermelon production system?

MATERIAL AND METHODS

The experiment was carried out during the 2021and 2022 growing season in Gotvand, which is located in the southwest of Iran.

The climate of the experimental site is semi-arid, with an average annual rainfall of 268 mm. This area also has an average annual relative humidity of 48.1% and an average annual temperature of 25 ℃.

This research measured the energy balance of watermelon production systems. The energy balance was measured from the data recorded in questionnaires. Farmers were asked to record information about their watermelon planting system and specify what was the type of machinery they used and how much (in terms of hour) was the time of machinery application; how many workers worked in the field; how they planted and harvested watermelon; how much seed, pesticide and fertilizers they used; and how much did they harvest per hectare?

Determining the total input energy was performed, according to the below equations (3):

$$SI = EQ_S . S \quad [1]$$

in which SI is the amount of seed energy used for planting ($MJ.ha^{-1}$), EQ_S is the equivalent of seed energy ($MJ.Kg^{-1}$) and S is the final amount of seed which was used for planting ($Kg. ha^{-1}$).

$$PI = EQ_P . P \quad [2]$$

where, PI is the input of pesticide in terms of $MJ.ha^{-1}$. EQ_P is the equivalent of the energy of liquid herbicide in terms of $MJ.Lit^{-1}$ and P is the amount of pesticide used in terms of $Lit. ha^{-1}$.

$$EMI = (EQ_M.M.T)/N \quad [3]$$

in which EMI is the amount of energy allocated to machinery in terms of $MJ.ha^{-1}$, EQ_M is energy equivalent for machinery in terms of $MJ.Kg^{-1}$, M is the mass of machinery in terms of Kg, T is time (in terms of $h. ha^{-1}$) of the application of machinery and N is useful lifetime of machinery (h)

$$FI = EQ_F . F \quad [4]$$

in which FI is the amount of input energy which used by fuel ($MJ.ha^{-1}$), EQ_F is energy equivalent of the fuel ($MJ.Lit^{-1}$) and F is the amount of fuel which was consumed for watermelon production ($lit.ha^{-1}$)

$$DF = 0.223 . PTO \quad [5]$$

where DF is consumed fuel ($lit.h^{-1}$) and PTO is power of B.T.O. used in planting of watermelon (kW)

$$HLI = EQ_{HL} . HL \quad [6]$$

in which HLI is energy consumed by human in terms of $MJ.ha^{-1}$, EQ_{HL} is human energy equivalent in terms of $MJ.h^{-1}$ and HL is the time of human labor in terms of ha^{-1}.

The efficiency of watermelon planting system was measured by three indexes according to the following equations (3):

The efficiency of energy usage = consumed energy (MJ ha^{-1}) / produced energy (MJ ha^{-1}) [7]

Energy productivity = watermelon yield (kg ha^{-1}) / consumed energy (MJ ha^{-1}) [8]

Specific energy = consumed energy (MJ ha^{-1}) / watermelon yield (kg ha^{-1}) [9]

Net energy = produced energy (MJ ha^{-1}) – consumed energy (MJ ha^{-1}) [10]

The data of the experiment were analyzed by MSTAT-C statistical software. Excel software was used for drawing the figures.

RESULTS AND DISCUSSION

The equivalent of energy consumed and produced in the watermelon production system is summarized in Table 1.

Table 1. Equivalent of energy consumed and produced in watermelon production system

System input	Energy equivalent	Unit	Reference
Seed	14.70	$MJ.kg^{-1}$	(9)
Machineries	62.50	$MJ.kg^{-1}$	(2)
Diesel fuel	56.30	$MJ.lit^{-1}$	(3)
Nitrogen fertilizer (N)	66.14	$MJ.kg^{-1}$	(4)
Phosphorus fertilizer (P_2O_5)	12.44	$MJ.kg^{-1}$	(4)
Pesticide	102.00	$MJ.lit^{-1}$	(10)
Human labor	1.96	$MJ.hr^{-1}$	(11)
Electricity	3.6	$MJ.kw^{-1}$	(12)

The results revealed that the most energy consumption was allocated to nitrogen equal to 4175 MJ ha^{-1} (Table 1). Watermelon seed had the lowest energy consumption, because only one kilogram of seeds was needed for each hectare of watermelon cultivation.

Based on the results obtained, 57% of energy consumed by nitrogen, after which fuel was in the next rank, so that 21% of the total energy input was consumed through diesel fuel (Figure 1).

Phosphorous fertilizer in the field accounted for 8% of the total input energy. Also, 7% of energy consumption was allocated to organic fertilizer. These results state that the use of fertilizers (whether organic or chemical) in the watermelon production system has a high energy consumption, so that a total of 72% of the energy consumption in the field was related to the use of fertilizers (Figure 1).

In terms of renewable or non-renewable energy used for watermelon production, only 10% of the energy used belonged to renewable energy (human, organic fertilizer and seeds) and 90% of the energy used was non-renewable energy (poisons, nitrogen fertilizer, phosphorus fertilizer, fuel, electricity, machinery). (Figure 2).

Table 2. Amount of input energy of field cultivation system of watermelon

Input	Unit	Energy
Seed	MJ.kg	0.18
Pesticide	MJ. lit	536
Organic manure	MJ. kg	1500
Nitrogen fertilizer	MJ. kg	11575
Phosphorous fertilizer	MJ. kg	1555
Diesel fuel	MJ. lit	4175
Electricity	MJ. KW	10.27
Human labor	MJ. h	774
Machinery	MJ. kg	38.5
Total	MJ. ha	20164

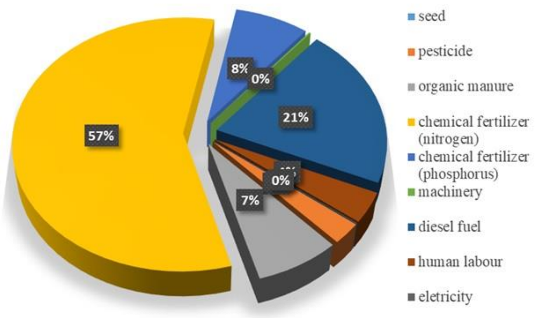

Figure 1. The effect of different inputs on energy consumption of watermelon production system

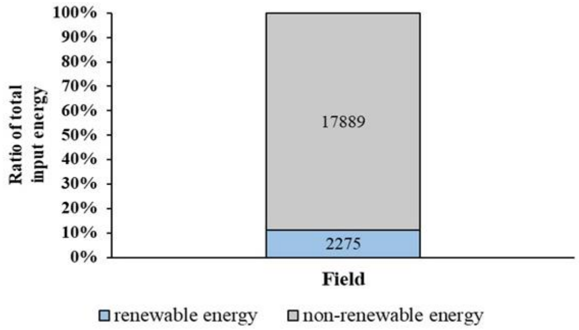

Figure 2. The proportion (%) of renewable energy and non-renewable energy in energy input of watermelon production system

The results showed that the efficiency of energy consumption was positive and more than the unit. This means that the amount of output energy was higher than the input energy, and with each unit of energy consumption, 4.86 units of energy were produced in the farm, which indicates the optimal efficiency of the production system in terms of energy consumption efficiency.

Energy efficiency was also obtained more than the unit. The results related to energy efficiency showed that by consuming each unit of energy, 2.56 kg of watermelons were produced in the field (Table 3). The specific energy in the field was 402.02, which shows that 0.402 MJ of energy are needed to produce one kilogram of watermelon in the field. Considering that the amount of specific energy was less than one, it can be said that watermelon production system was in a favorable condition in terms of production per unit of energy consumption. The numerical value of net energy shows that the output energy was much more than the input energy. So that by cultivating each hectare of watermelon, 74884 MJ of energy were produced (Table 3).

Two solutions were proposed to improve the efficiency of energy (13): first, increase of yield to increase the amount of energy output from the system, and second, to monitor the consumption of inputs to reduce energy consumption. It seems that considering that the yield potential of watermelon in this research was in a favorable condition according to the average yield of different watermelon stands, including the yield of 45 tons ha^{-1} (14) and the yield of 42 tons ha^{-1} (15–18). Therefore, it may not be possible to increase the

Table 3. Energy indicators of the system produced watermelon

Energy indicator	Unit	Value
Energy efficiency	---	4.86
Specific energy	MJ. kg	0.402
Net output energy	MJ. ha	74882
Energy productivity	Kg. MJ	2.56

efficiency of energy consumption in watermelon in the southwestern region of Iran by increasing the output energy.

However, it is possible to improve energy efficiency in watermelon production by reducing energy input to the system. It has been reported that the more the mechanization of watermelon cultivation increases, the more the amount of energy consumption increases, so that fuel accounts for up to 50% of the energy input (9), which is consistent with the results of the current research. In other words, by reducing the consumption of inputs such as nitrogen fertilizer and fuel, indicators related to energy efficiency can be improved in watermelon production. In another study, reducing the amount of irrigation was announced as a way to improve the energy efficiency in watermelon production (12), which seems to have little contribution to improving the efficiency of energy consumption in the southwestern region of Iran. Finally, the use of inputs, including nitrogen fertilizer and fuel, can be considered as basic solutions to reduce the energy input to the watermelon production system in southwest Iran.

CONCLUSION

The most energy input to the watermelon cultivation system was nitrogen (57%), followed by diesel fuel (21%). About 90% of the consumed energy in watermelon planting system belonged to the energy which cannot be renewed. For improving the efficiency of energy usage in the watermelon planting system, nitrogen application to the system should be reduced and it can be reached by suitable rotation which diminish the nitrogen needs which means the reduction of nitrogen fertilization use.

CONFLICT OF INTEREST

The author declares that he has no conflict of interest.

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Persian Abstract

چکیده

تحقیق، که در شهرستان گتوند در جنوب غربی ایران اجرا شد، مصرف انرژی در یک سیستم تولید مزرعه‌ای هندوانه را مورد ارزیابی قرار داد. در این تحقیق، انرژی ورودی سیستم کشت هندوانه اندازه‌گیری شد. برای این منظور، پرسش‌نامه‌هایی به کشاورزان داده شد تا مقدار انرژی ورودی به مزارع هندوانه خود را در آن ثبت کنند. نتایج تجزیه و تحلیل آماری نشان داد که نیتروژن نهاده‌ی بود که بیشترین انرژی را به خود اختصاص داد (۴۱۷۵ مگاژول در هکتار) و بعد از آن سوخت دیزل قرار گرفت. حدود ۹۰ درصد از انرژی مصرف شده در سیستم تولید هندوانه در مورد انرژی‌های تجدیدناپذیر دیده شد. نتایج نشان داد که کارآیی مصرف انرژی مثبت بود که نشان می‌دهد مقدار انرژی خروجی بیشتر از انرژی ورودی به سیستم بود. با هر واحد انرژی مصرف شده، ۴/۸۶ واحد انرژی تولید شد که کارآیی بالای انرژی را نشان می‌دهد. برای بهبود کارآیی انرژی در سیستم تولید هندوانه، کاربرد نیتروژن باید کاهش پیدا کند و این هدف با تناوب زراعی مناسب که نیاز به نیتروژن را کاهش می‌دهد، قابل دستیابی است.