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Energy Analysis for Two Production Systems of Cucumber

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P A P E R I N F O

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A B S T R A C T

This research, conducted in Gotvand, southwest of Iran, compared the energy consumption of two cucumber production systems: field and greenhouse production systems. In this study, energy inputs of two production systems of cucumber (including seed, pesticide, human labor, machinery, diesel fuel, electricity, organic manure, chemical fertilizer) were determined from questionnaires completed by farmers. The results of the experiment indicated that the energy input of the two cultivation systems was not significantly different in input energies. In both cucumber production systems, the most input energy was allocated to nitrogen fertilizer (57% and 53% for field and greenhouse, respectively) followed by diesel fuel (21% in both production systems). Non-renewable energies accounted for 90 and 88% of the total energy input to the farm and greenhouse systems, respectively. Total output energy of field and greenhouse cucumber production system was 33000 and 34000 MJ, respectively. Reducing the consumption of nitrogen fertilizer through the use of appropriate crop rotation is a suitable solution to improve energy efficiency in the cucumber production system.

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INTRODUCTION

Sustainability, in terms of obtaining maximum crop productivity from a system while maintaining conservation of its resources, is one of the most important components of an agricultural system. Energy efficiency is a key factor for reaching sustainability [1, 2]. Optimal use of energy resources, which is determined by calculating the energy balance of a system in terms of input and output energy, is an efficient factor for evaluating sustainability of an agricultural production system. Energy balance, the amount of input and output energy has been evaluated for different crop production systems and the effect of different traits has been tested on total energy efficiency. Eskandari and Attar [3] compared two rice production systems in terms of energy balance and concluded that seedbed preparation operations was an input with high energy consumption. Pimental [4] observed that increasing input energy does not always result in improved energy efficiency of a system and, thus, input energy must be used with high efficiency. Karimi et al [5] reported that per kilo production of sugar from sugarcane required 1.59MJ.ha^{-1} of energy. The report also concluded that irrigation was the input that exhibited the highest energy consumption. Thus, irrigation must be well managed in order to increase energy efficiency of that sugarcane production system. Cetin and Vardar [6], working on energy efficiency of a tomato production system, observed that diesel fuel had the highest energy consumption followed by that of fertilizer. In general, it can be declared that there is a difference between different crop plants in terms of particular inputs that determine the highest energy consumption. Therefore, determination and management of input energy is crucial for improving the energy efficiency of a production system. However, policies in reducing dependence on non-renewable energy inputs is also in high importance [1]. It has been noted that environmental conditions, such as precipitation and temperature are also effective in energy input of an agronomical system [7, 8].

It is clear that energy shortage leads to crisis. A crisis of energy shortage presents a serious threat to food production because it has an impact on fertilizer and

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pesticide production, irrigation pump and failure of field and transportation machinery [9, 10]. Thus, sustainable management of energy in agricultural systems is essential for sustainable agricultural production. This current research was carried out to evaluate energy consumption of two cucumber production systems to reach the best possible improvement of energy balance.

MATERIAL AND METHODS

The experiment was carried out during 2013-14 growing season in Gotvand, southwest Iran (32° 14′ 43″ N, 48° 48′ 50″ E and 74 m above sea level). The region has a semi-arid climate with mean annual precipitation of 268mm, annual mean relative humidity of 48.1% and mean annual temperature of 25.1 ° C. The energy balance of two cucumber production systems was determined from values for energy inputs and outputs including seed, pesticide, human labor, machinery, diesel fuel, electricity, organic manure, chemical fertilizer and cucumber yield per unit area.

Energy inputs were determined from questionnaires completed by farmers. Farmers were asked to provide the information on their cultivation system including technical specifications for type of machinery used, including motor capacity, total land area, planting and harvesting method, crop yield per unit area, number of workers, amount of seed, amounts of fertilizer and pesticides. The experiment included two cucumber production series: cucumber field and greenhouse. This research compared energy balance of these two types of cucumber production systems.

To achieve total energy input, energy equivalent of each input (Table 1) was multiplied with consumed input, using the following equations [11]:

$$SI= EQS.\ S \quad (1)$$

$$PI= EQP.\ P \quad (2)$$

$$EMI= (EQM.M.T)/N \quad (3)$$

$$FI= EQF.\ F \quad (4)$$

$$F= MH.\ DF \quad (5)$$

$$DF= 0.223.\ PTO \quad (6)$$

$$HLI= EQHL.\ HL \quad (7)$$

in which:
SI= seed input (MJ.ha^{-1})
EQS= seed energy equivalent (MJ.kg^{-1})
S= total consumed seed (kg. ha^{-1})
PI= pesticide input (MJ.ha^{-1})
EQP= energy equivalent of the pesticide (liquid herbicide) (MJ.L^{-1})
P= total consumed pesticide (L. ha^{-1})
EMI= machinery input (MJ.ha^{-1})
EQM= energy equivalent of the machinery (MJ.kg^{-1})
M= machinery mass (kg)
T= time of the machinery usage (h.ha^{-1})
N= useful lifetime (h)
FI= fuel input (MJ.ha^{-1})
EQF= energy equivalent of the fuel (MJ.L^{-1})
F= consumed fuel (L.ha^{-1})
MH= machinery usage (h.ha^{-1})
DF= consumed fuel (L.h^{-1})
PTO= power of B.T.O. used in cultivation operations (kW)
HLI= energy input of human labour (MJ.ha^{-1})
EQHL= human energy equivalent (MJ.h^{-1})
HL= human labour (h. ha^{-1})

According to input and output energy, energy use efficiency (energy ratio), energy productivity, specific energy and net output energy were calculated, using the following equations [12]:

Energy use efficiency = energy output (MJ ha^{-1}) / energy input (MJ ha^{-1})
Energy productivity = cucumber output (kg ha^{-1}) / energy input (MJ ha^{-1})
Specific energy = energy input (MJ ha^{-1}) / cucumber output (kg ha^{-1})
Net energy = energy output (MJ ha^{-1}) – energy input (MJ ha^{-1})

Data were subjected to statistical analysis of variance with MSTAT-C statistical software. Figures were drawn with Excel software.

RESULTS AND DISCUSSION

According to the results of the analysis of the variance of the data, no significant difference was observed between two systems of cucumber production (field and greenhouse production systems) in terms of all input energy indices including seed, pesticide, organic manure, chemical fertilizer, diesel fuel, electricity and energy

Table 1. Energy equivalent of input and output of cucumber production system

System input	Energy equivalent	Unit
Seed	14.70	MJ.kg^{-1}
Machineries	62.50	MJ.kg^{-1}
Diesel fuel	56.30	MJ.L^{-1}
Nitrogen fertilizer (N)	66.14	MJ.kg^{-1}
Phosphorus fertilizer (P_2O_5)	12.44	MJ.kg^{-1}
Pesticide	102.00	MJ.L^{-1}
Human labor	1.96	MJ.h^{-1}
Electricity	3.6	MJ.kW^{-1}

efficiency including energy use efficiency, energy productivity, specific energy and net energy (the table of analysis of variance is not shown). The only input that had a significant difference between the two planting systems was human labor, where the difference between the two systems was 143 MJ h^{-1} (equivalent to 24% difference), which was more in the greenhouse system than in the field production system (see Table 2). The difference between the two production systems in terms of phosphorus fertilizer and pesticide was in the next ranks, so that its value was 127 MJ kg^{-1} (equivalent to 20% difference) and 68 MJ L^{-1} (equivalent to 16% difference) respectively. In both cases, energy consumption was higher in the greenhouse production system (see Table 2).

In both cucumber production systems, the most input energy was allocated to nitrogen fertilizer (57% in the field and 53% in the greenhouse, respectively) followed by diesel fuel (21% in both production systems) (see Figure 1). Meanwhile, in both cucumber production systems, the proportion of non-renewable energy was higher than renewable energy. In the field, 90% and in the greenhouse, 88% of the energy input to the system were allocated by non-renewable inputs (see Figure 2).

Table 2. Total input energy of two cucumber production systems

Production system	**Seed (MJ.kg)**	**Pesticide (MJ. L)**	**Organic manure (MJ. kg)**	**Nitrogen fertilizer (MJ. kg)**	**Phosphorus fertilizer (MJ. kg)**	**Diesel fuel (MJ. L)**	**Electricity (MJ. h)**	**Mechinary (MJ. kg)**	**Human labor (MJ. h)**	**Total input (MJ. ha)**	**Total output (MJ. ha)**
Field	1	791	1500	16222	1555	4175	6.398	38.5	578	202277	33000
Greenhouse	1	918	1650	10748	1866	4175	6.677	38.5	721	20124	34000
Difference	0	68	281	586	127	0	0.303	0	143	153	1000

Data are the average of one hectare

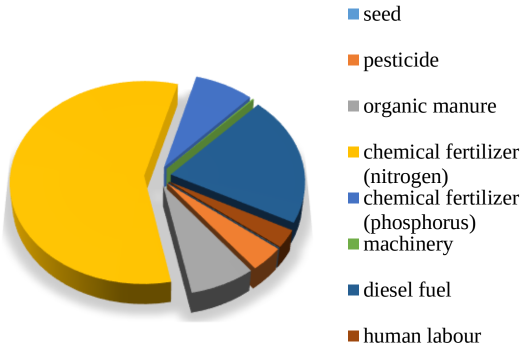

Figure 1. The proportion of different energy input (%) of field production system of cucumber

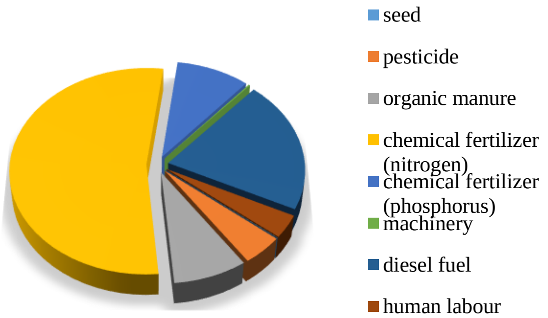

Figure 2. The proportion of different energy input (%) of greenhouse production system of cucumber

Figure 3 shows the proportion (%) of renewable energy (human labor, organic manure and seed) and non-renewable energy (machinery, electricity, diesel fuel, phosphorus fertilizer, nitrogen fertilizer and pesticides) in energy input to two cucumber production systems (total input energy of field and greenhouse production systems were 20277 MJ ha-1 and 20124 MJ ha-1, respectively).

Based on the results of energy consumption efficiency, the input of each unit of energy resulted in the production of 1.7 MJ in the field and 1.75 MJ in the greenhouse (Figure 4). Furthermore, each unit of input energy led to the production of 2.12 kg of cucumber in the field and 2.19 kg of cucumber in the greenhouse (energy productivity) (Figure 4). This means that the production of each kilogram of cucumber requires 0.492 MJ of energy in the field and 0.472 MJ of energy in the greenhouse (specific energy). Finally, field cucumber production resulted in 12733 MJ ha^{-1} net energy production, while greenhouse cucumber production resulted in 13877 MJ ha^{-}1 net energy production (net energy) (Figure 4).

Results showed that the highest energy input was nitrogen chemical fertilizer, followed by diesel fuel (see Table 2 and Figure 1) which is compatible with the findings in irrigated wheat by Eskandari [8] and potato by Ghaderzadeh and Pirmohamadyani [13] where fertilizer had high impact on total input energy. The distance between diesel fuel and nitrogen fertilizer with other energy inputs was very large, reaching at least 25% (the gap between diesel fuel and potassium chemical fertilizer). Mohammadi et al. [12], working on energy input analysis of kiwifruit in Iran, reported that the highest energy consumption was allocated to nitrogen fertilizer, which accounted for 36% of the total energy input to the production system. This conclusion in line with the findings of the current research. In the potato cultivation system, it was observed that the most input energy was allocated to diesel fuel [6] which is compatible with the findings of the current study. In another study, diesel fuel was introduced as the most important factor in increasing energy consumption in wheat production [14–17].

Although, Eskandari [8] and Rokicki [10] concluded that an effective method for reducing energy consumption in agronomical fields is reducing the consumption of diesel fuel, it seems that in cucumber production system, it may not be possible to reduce energy input through reduction of diesel fuel. Improving energy efficiency of

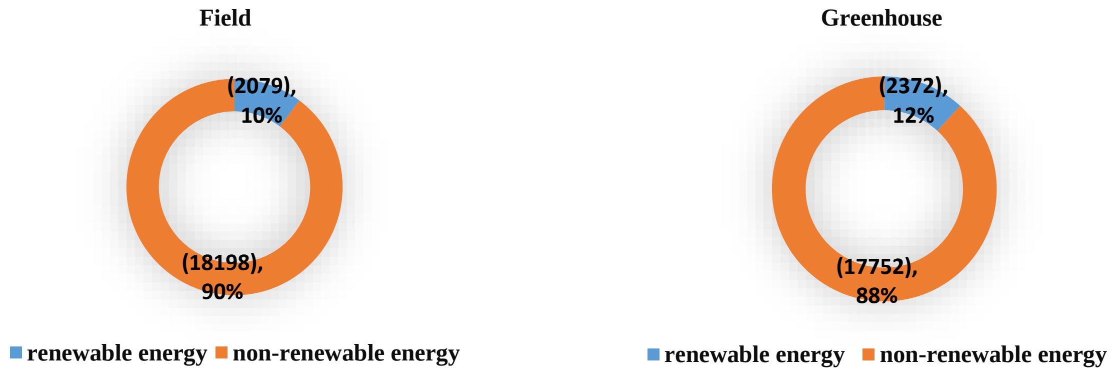

Figure 3. The proportion (%) of renewable energy (human labor, organic manure and seed) and non-renewable energy (machinery, electricity, diesel fuel, phosphorus fertilizer, nitrogen fertilizer and pesticides) in energy input to two cucumber production systems (total input energy of field and greenhouse production systems were 20277 MJ ha^{-1} and 20124 MJ ha^{-1}, respectively).

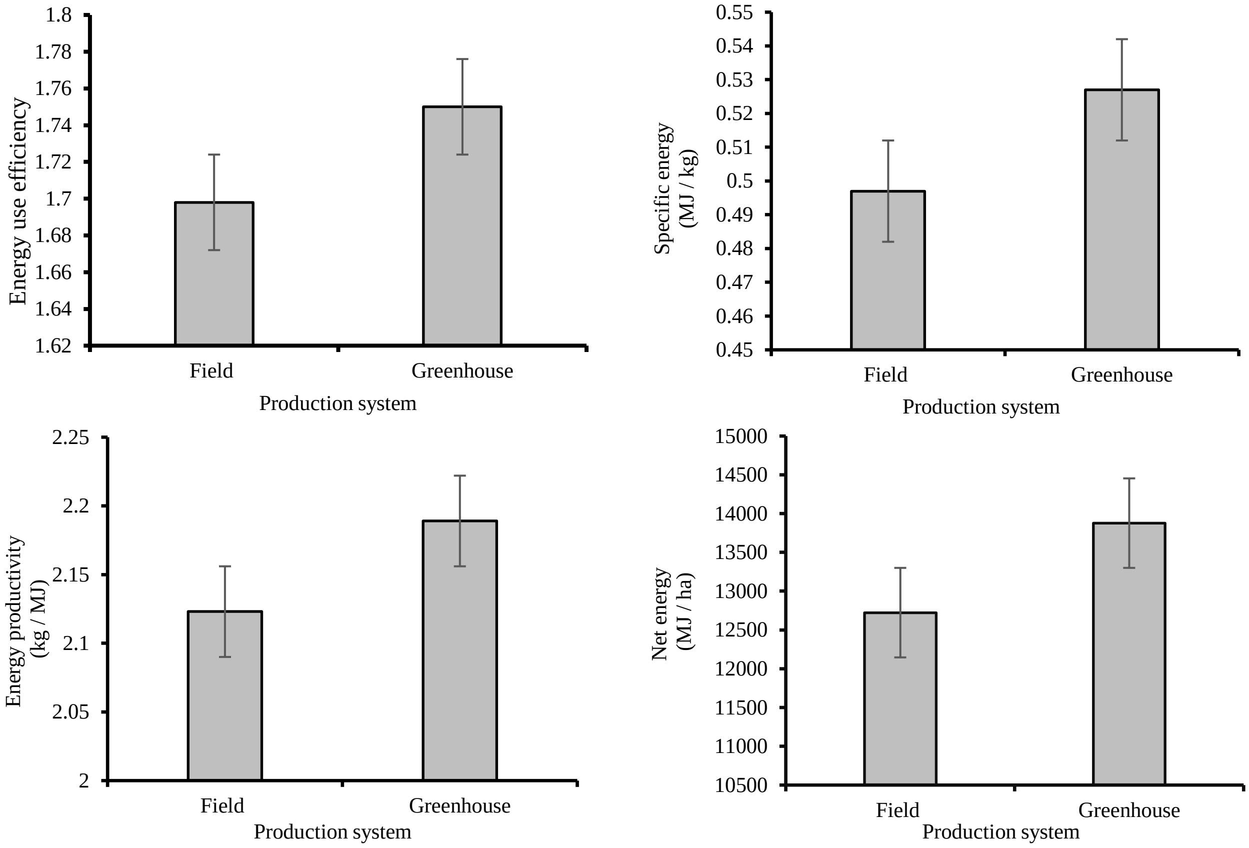

Figure 4. Energy efficiency indices of two production systems of cucumber

the system through the management of other energy inputs is more possible. In this case, research showed that the cultivation of leguminous plants increases soil nitrogen and thus reduces the need to use nitrogen fertilizers for the next plantations. Soybean cultivation adds 155-280 kg ha^{-1} nitrogen to the soil, which can be used for the next plant. In addition, it has been observed in cotton that if a leguminous plant is planted before cotton, 50-90 kg ha^{-1} of nitrogen is needed, but if no leguminous plant is planted before cotton, the application of at least 170 kg ha^{-1} of nitrogen fertilizer is necessary [18]. Based on this, it can be concluded that to improve the efficiency of energy consumption in cucumber production, it is better to reduce the consumption of chemical fertilizers by applying appropriate crop rotation.

Proper management of biomass for improving soil fertility, and also lowering the use of chemical fertilizers, can be also considered as way for improving energy efficiency of agricultural system through the reduction of chemical fertilizer input [19, 20].

CONCLUSION

Results determined that nitrogen fertilizer and diesel fuel consumption were the highest energy inputs. However, it is inevitable that some essential production activities will increase input energy. Reducing the consumption of nitrogen fertilizer in cucumber production system through applying appropriate rotation program, is a suitable solution to improve the efficiency of energy consumption in cucumber production. It was concluded that the efficiency of energy consumption in cucumber production was improved by reduction and consumption of chemical fertilizers by applying appropriate crop rotation.

CONFLICT OF INTEREST

The author declares that he has no conflict of interest.

REFERENCES

1. Esmaeili Shayan, M., Hayati, M.R., Najafi, G., and Esmaeili Shayan, S., 2022. The Strategy of Energy Democracy and Sustainable Development: Policymakers and Instruments. *Iranian Journal of Energy and Environment*, 13(2), pp.185–201. Doi: 10.5829/IJEE.2022.13.02.10
2. Abbas, A., Zhao, C., Waseem, M., Ahmed khan, K., and Ahmad, R., 2022. Analysis of Energy Input–Output of Farms and Assessment of Greenhouse Gas Emissions: A Case Study of Cotton Growers. *Frontiers in Environmental Science*, 9, pp.1–11. Doi: 10.3389/fenvs.2021.826838
3. Eskandari, H., and Attar, S., 2015. Energy comparison of two rice cultivation systems. *Renewable and Sustainable Energy Reviews*, 42, pp.666–671. Doi: 10.1016/j.rser.2014.10.050
4. Pimentel, D., 1992. Energy inputs in production agriculture. *Energy in farm production*, 6, pp.13–29
5. Karimi, M., RajabiPour, A., Tabatabaeefar, A., and Borghei, A., 2008. Energy analysis of sugarcane production in plant farms a case study in Debel Khazai Agro-industry in Iran. *American-Eurasian Journal of Agricultural and Environmental Science*, 4(2), pp.165–171
6. Çetin, B., and Vardar, A., 2008. An economic analysis of energy requirements and input costs for tomato production in Turkey. *Renewable Energy*, 33(3), pp.428–433. Doi: 10.1016/j.renene.2007.03.008
7. Aweda, F.O., and Samson, T.K., 2022. Relationship between Air Temperature and Rainfall Variability of Selected Stations in Sub-Sahara Africa. *Iranian Journal of Energy and Environment*, 13(3), pp.248–257. Doi: 10.5829/IJEE.2022.13.03.05
8. Eskandari, H., 2023. Contribution of Production Inputs to Energy Consumption in Wheat Production System for Providing a Solution to Improve Energy Consumption. *Iranian Journal of Energy and Environment*, 14(1), pp.53–57. Doi: 10.5829/IJEE.2023.14.01.07
9. Paris, B., Vandorou, F., Balafoutis, A.T., Vaiopoulos, K., Kyriakarakos, G., Manolakos, D., and Papadakis, G., 2022. Energy use in open-field agriculture in the EU: A critical review recommending energy efficiency measures and renewable energy sources adoption. *Renewable and Sustainable Energy Reviews*, 158, pp.1–17. Doi: 10.1016/j.rser.2022.112098
10. Rokicki, T., Perkowska, A., Klepacki, B., Bórawski, P., Bełdycka-Bórawska, A., and Michalski, K., 2021. Changes in Energy Consumption in Agriculture in the EU Countries. *Energies*, 14(1570), pp.1–20. Doi: 10.3390/en14061570
11. R. D. Grisso, M. F. Kocher, and D. H. Vaughan, 2004. Predicting Tractor Fuel Consumption. *Applied Engineering in Agriculture*, 20(5), pp.553–561. Doi: 10.13031/2013.17455
12. Mohammadi, A., Rafiee, S., Mohtasebi, S.S., and Rafiee, H., 2010. Energy inputs – yield relationship and cost analysis of kiwifruit production in Iran. *Renewable Energy*, 35(5), pp.1071–1075. Doi: 10.1016/j.renene.2009.09.004
13. Ghaderzadeh, H., and Pirmohamadyani, Z., 2019. Evaluation Efficiencies of Energy for Potato Production in Hamedan Province of Iran. *Agricultural Economics Research*, 11(42), pp.167–202. (In Persian)
14. Payandeh, Z., Jahanbakhshi, A., Mesri-Gundoshmian, T., and Clark, S., 2021. Improving Energy Efficiency of Barley Production Using Joint Data Envelopment Analysis (DEA) and Life Cycle Assessment (LCA): Evaluation of Greenhouse Gas Emissions and Optimization Approach. *Sustainability*, 13(11), pp.1–16. Doi: 10.3390/su13116082
15. Safa, M., and Tabatabaeefar, A., 2002. Energy consumption in wheat production in irrigated and dry land farming. In: Proceeding of the 2002 International Agricultural Engineering, Wuxi, China. pp 85–95
16. Maysami, M., and Jalali, A., 2020. Evaluation of Energy Input-Output in Wheat Crop Cultivation in Agro-industry Company of Mazare Novin Iranian (Agh Ghalla). *Journal of Agricultural Science and Sustainable Production*, 30(2), pp.333–346. (In Persian)
17. Yadav, R.N., Singh, R.K.P., and Prasad, S., 1991. An Economic Analysis of Energy Requirements in the Production of Potato Crop in Biharsharif Block of Nalanda District (Bihar). *Economic Affairs (Calcutta)*, 36(2), pp.112–119
18. Pandiaraj, T., Selvaraj, S., and Ramu, N., 2015. Effects of Crop Residue Management and Nitrogen Fertilizer on Soil Nitrogen and Carbon Content and Productivity of Wheat (*Triticum aestivum* L.) in Two Cropping Systems. *Journal of Agricultural Science and Technology*, 17, pp.249–260

19. Chen, J., Haijun, Y., Hao, L., Zhifang, Z., and Mei, L., 2019. Micro-properties of Molding Products between Modified Corn Stalk and Pulverized Coal. *Iranian Journal of Energy and Environment*, 10(2), pp.72–79. Doi: 10.5829/IJEE.2019.10.02.01
20. Sander, B.O., Quilty, J., Balingbing, C., Castalone, A.G., Romasanta, R., Alberto, M.C.R., Sandro, J.M., Jamieson, C., and Gummert, M., 2019. An assessment of irrigated rice production energy efficiency and environmental footprint with in-field and off-field rice straw management practices. *Scientific Reports*, 9(1), pp.1–12

Persian Abstract

چکیده

پژوهش حاضر، که در شهرستان گتوند در جنوب غربی ایران اجرا شد، مصرف انرژی در دو سیستم تولید خیار را مورد مقایسه قرار داد: سیستم‌های تولیدی در مزرعه و گلخانه. در این مطالعه، انرژی ورودی دو سیستم تولید خیار (شامل بذر، آفت‌کش‌ها، نیروی انسانی، ماشین‌آلات، سوخت، الکتریسیته، کود آلی، کود شیمیایی) با استفاده از پرسش‌نامه‌هایی که در اختیار کشاورزان قرار گرفت، تعیین شد. نتایج آزمایش نشان داد که انرژی ورودی بین دو سیستم کشت خیار، تفاوت معنی داری نداشت. در هر دو سیستم کاشت خیار، بیشترین انرژی ورودی به کود نیتروژنه (۵۷ درصد در مزرعه و ۵۳ درصد در گلخانه) اختصاص داشت که بعد از آن سوخت (۲۱ درصد در هر دو سیستم تولید) قرار داشت. انرژی‌های غیرقابل تجدید در مزرعه و گلخانه به ترتیب ۹۰ و ۸۸ درصد از کل انرژی ورودی به سیستم را به خود اختصاص دادند. انرژی خروجی کل در مزرعه و گلخانه به ترتیب ۳۳ هزار و ۳۴ هزار مگاژول بود. کاهش مصرف کودهای نیتروژنه از طریق کاربرد تناوب زراعی مناسب یک راه‌حل مناسب برای بهبود کارآیی انرژی در سیستم‌های تولید خیار می‌باشد.