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ORIGINAL ARTICLE

Energy Consumption Productivity to Optimize and Conserve Environmental Resources in Greenhouse Tomato Production Systems (case study: Qom city) – Iran

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ABSTRACT
The aim of this study is to determine the amount of input and output energy in tomato production at different levels of planting. The required data was obtained by a number of tomato growers of different areas of the city of Qom by completing the questionnaire. In this study, a method is provided by which the consumed energy in tomato production system will be reduced up to 27% and productivity in accordance with the standard greenhouses of the country will be reached. Also, using the fuel optimal pattern it is possible to reach a 16% reduction in electricity energy and 17% reduction in energy consumption in relation to irrigation and human resources. According to the results, energy use and productivity is moderate and low but due to the low price of inputs and the high price of tomato product, the production of greenhouse tomatoes is cost effective.
Keywords:*Tomato, Energy productivity, Productivity, Optimal pattern, Greenhouse, Consumed energy*

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INTRODUCTION

Planting tomato in the greenhouse can be performed directly by seeds or seedlings. Planting tomato seeds are done when the ambient temperature is above 10 degrees Celsius. Roughly every 300 grams of tomato seeds weigh one gram.

Germination and emergence monocotyledons leaves on the soil surface usually takes 6 days and from 4 to 6 weeks the seedlings are ready to be transferred to the main land. To make tomato seeds germinate and grow well it is advisable to keep it in nursery until plant favorable growth; this way will save in using greenhouse facilities and the plant will also have a good growth at the beginning.

Greenhouse plantation has high energy consumption due to the nature of production out of season; that is why the study of energy consumption and any success in increasing energy productivity in greenhouse cultivation can cause efficient use of energy and valuable resources.

Adverse climatic conditions, all or part of the year, seriously limits the growth of plants and to overcome it, it is necessary to control plant environmental conditions. Limitation of each environmental factor can obstruct the growth of plants, so environmental conditions should be adjusted depending on plant growth.The main objective of a greenhouse is providing the proper environment for growing plants. As a result, this provides the possibility for growers to optimize production and maximize their profits. Due to the efficient use of water and soil resources, off-season production and employment, this method has expanded in our country in recent years.

In developing countries the energy consumption has highly increased due to the economical growth [3].

With all these explanations a method can be proposed that can reach more productivity in the industry of tomato production with a reduction in consumed energy. To increase energy productivity and reduce energy consumption in production in this study some strategies are proposed to get us close to the goal including: proper energy management, periodic greenhouse cultivation, reforming the methods of using agricultural machinery, using smart greenhouse management, proper Irrigation to reduce electricity and fuel consumption, using biological methods to control pest and weeds and reducing the use of pesticides and chemical fertilizers without any reduction in product performance.

MATERIALS AND METHODS

This study was conducted in Qom city in 2014-2015 crop years.

The city's average annual rainfall is 135 mm, 74 % of which belonged to winter and spring and the least precipitation which was 1.9mm belonged to summer. Since the subject of this study is efficient use of energy and protection of environmental resources in tomato production system (case study in Qom city), of Iran, our selective approach to this study has been tried to be more based on documentary, library studies , internet resources, face-to-face and questionnaire.

The number of greenhouses in the province is about 120 rooms, among which 30 greenhouses grow tomatoes. The sample size was calculated using equation 1 [13].

Equation 1: $n = \frac{N(t.s)^2}{Nd^2}$

n= Sample size

N = size of statistical population

t = acceptable confidence coefficient that is obtained by assuming normal distribution of considered trait from t-test table.

S2 = estimating variance of the studied trait

d = desirable possible accuracy

To assess the reliability of the questionnaire designed by a preliminary study, 30 versions were completed by statistical population; for completed questionnaires Cronbach's alpha coefficient was evaluated using SPSS software and calculated as 87% which shows that questionnaire reliability is acceptable to carry out research. In order to calculate the energy of each input in tomato production, the amount of each consuming input is multiplied by equivalent energy of the same input; energy equivalent of input in tomato production is expressed in Table 1:

Inputs	Energy content	Unit	source
Tomato	0.8	MJ/Kg	7
Machine	62.7	MJ/Kg	5
Fuel	56.31	MJ/L	5
Nitrogen fertilizers	66.14	MJ/Kg	1, 12, 14
Phosphorus fertilizers	12.44	MJ/Kg	14
Potash fertilizer	11.15	MJ/Kg	1, 14
Manure	0.3	MJ/Kg	7, 10
Toxins	120	MJ/Kg	2, 10
Manpower	1.96	MJ/hr	10, 12, 14
Electricity	3.6	MJ/kWh	4
Water	1.02	MJ/m3	14

Table 1-Energy equivalent inputs to produce tomatoes

In order to analyze energy, the indices of energy ratio, energy productivity, net surplus energy and specific energy are applied.

Equation (2) is used to calculate energy ratio in production which presents the performance of the used energy (6).

Eq. (2) $ER^{12} = \frac{EnergyoutputbyMJ}{EnergyinputbyMJ}$

To calculate the energy productivity by kg/ MJ the Eq. (3) is used which presents the product per unit of input energy (10).

Eq. (3) $EP^{12} = \frac{\text{Performance in Kg}}{\text{Input energy in MJ}}$

In order to calculate the net energy per MJ the Eq (4) which represents net energy is used and represents the total remaining energy remaining the production process (10).

Eq. (4)

The input energy in MJ- The output energy in MJ= NE12

The input energies include all inputs that are converted to the equivalent energy by conversion coefficients. The output energy is obtained by multiplying the tomato production by its equivalent coefficient. In order to optimize energy productivity, the linear programming model was used.
Eq. (5) Max Z= f (Xj) j= (1… n)
Eq. (6) Min Z= f (Xj) j= (1,…, n)
Eq. (7) Z= c1x1+c2x2+…+cnxn
The decision variables based on the determined extension is based on the following conditions
Eq. (8) j= (1,…, n) xj≥0
xjcan obtain positive, negative or zero values
And the decision variable (regardless of its sign) and in this state the overall form of the linear programming model is as follows:
Eq. (9)
a11x1+a12x2+…+a1nxn (≤OR≥OR=) b1
a i1x1+a i2x2+…+a inxn(≤OR≥OR=)bi
am1x1+a m2x2+...+a mnxn(≤OR≥OR=)bm
x1+x2+…+xn≥0 OR(free markdecisionvariables)
Where:
X j (j = 1, ..., n) = The value of decision variables
Z = The value of the objective function
C 1, c 2, ..., c n = coefficients of the decision variables in the objective function
a1n, a 2n, ..., a in = coefficients of the decision variables in limitations
b1, b 2, ..., b m = (Constant values) or right numbers
n = number of decision variables
M = number of limitations
Therefore, the objective function is written as follows:
Eq. (10) Z= Maximize E p=Maximize $\frac{y}{\Sigma xiei}$ i= (1,2,…,8)
Eq. (11) Z= Minimize E in= Minimize Σxieii= (1,2,…,8
xiei ≥ ei(12)
xi ≥ A I (13)
ei≥ 0 (14)
E p = energy productivity
E in = total energy consumption
X i = the amount of inputs
A i = lowest consumed input
ei = the equivalent energy of each input
With regard to unite energy consumption each input mentioned in the third chapter is written as follows:

$$Z= Minimize\ (1/96_x+3/6x_9+1/02x_{10}+0/28x_{11}+0/8x_{12})_{1+}62/7x_2+56/31x_3+66/14x_4+12/44x_5+11/15x_6+0/3x_7+120x_8$$

C1:16≤X1≤35
C2:10≤X2 ≤23
C3:100≤ X3 ≤ 145
C4:49.5≤ X4 ≤ 99
C5:23≤ X5 ≤ 46
C6:17≤X6 ≤27
C7:300≤ X7 ≤400
C8:10≤ X8 ≤15
C9:19833 ≤X9 ≤29335
C10:1500≤ X10 ≤1900
C11:0.25≤ X11 ≤0.51
C12:5≤ X12 ≤10
C13:X1+X2+X3≥27
C14: X4+X5+X6+X7≥470
C15:X8+X11+X12≥20
C16:X9+X10≥3000
x1, x 2, x 3, x 4, x 5, x 6, x 7, x 8, x 9, x 10, x 11 and x 12 are the amount of input consumption of manpower, machinery, fuel, nitrogen fertilizer, phosphorous fertilizer, Potash fertilizer, manure, pesticide, electricity, water, seeds, tomato.

Table 2 – The input energy in tomato cultivation in 2014-2015

Input	Unit	Per 1 ha	Energy in MJ/ ha
Electricity	Mj	7700.5	27721.8
Fuel	L	2/152	382/8570
Irrigation water	M 3	6500	6630
Fertilizer	kg	400	2769.124
Manpower	H	2500	4900
Pesticides	L	10	1200
Manure	Kg	4000	1200
Agricultural Machinery	H	11	7/689
Seed	Kg	0.75	0.6
Total energy consumption			53681.722

Figure 1 - Share of each energy inputs in tomato production

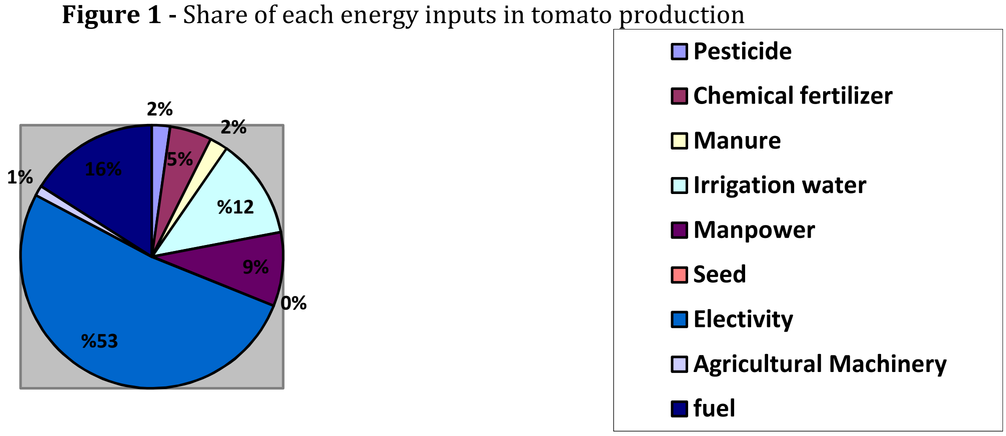


Table 3 - Input and output energies as well as tomato production indices in Qom city

Index	Unit	The value per ha
Input energy	MJ ha -1	53681.722
Output energy	MJ ha -1	36000
Ratio Energy	-	0.6706
Energy productivity	Kg / MJ	0.8382
Net energy	MJ ha -1	-17681.722
Special energy	MJ / Kg	1.1929

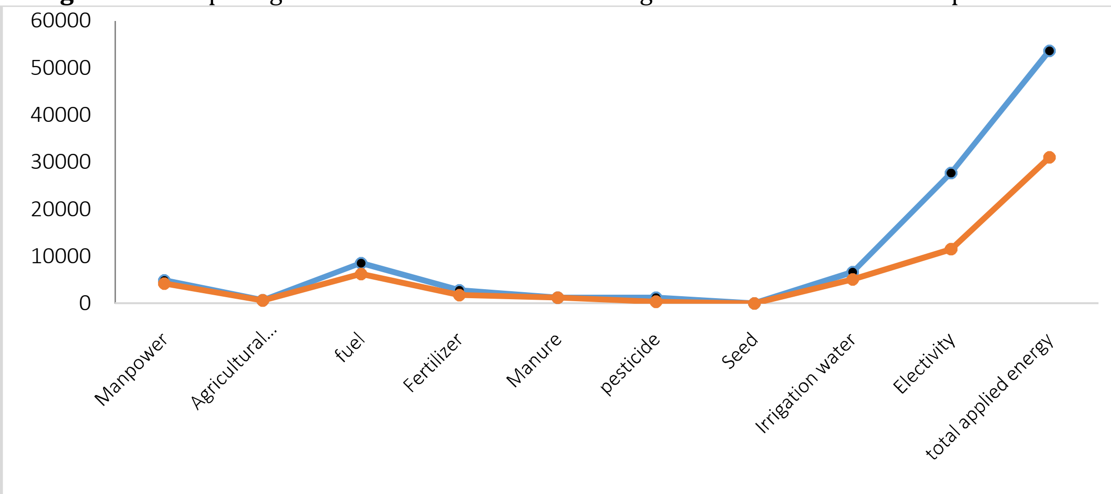
In Table 4 determining the optimal energy consumption in tomato a function with the purpose of minimizing the use of energy inputs was defined to determine optimal consumption energy to plant tomato.

Input	Unit	The value per ha	Energy(MJ per ha)	Saved value (MJ per ha)
Manpower	H	2140	4194.4	705.6
Agricultural Machinery	H	10	627	62.7
Fuel	L	110.5	6222.255	2348.127
Fertilizer	Kg	245	1772.868	996.256
Manure	Kg	4000	1200	-
Pesticide	L	3	360	840
Seed	Kg	0.5	0.4	0.2
Irrigation water	M 3	5000	5100	1530
Electricity		3200	11520	16201.8
Total energy consumption	Mj		30996.923	22684.683

Table 5 -Optimal amount of energy of each index

Index	Unit	The value per ha
Power input	Mj ha -1	30996.923
Power output	Mj ha -1	36000
Energy ratio	---	1.1614
energy productivity	kg / mj	1.451
Pure Energy	Mj ha -1	5003.077
Special energy	Mj ha -1	0.688
Operation	Kg / ha	45000

Figure 6 –Comparing the amounts of consumed energies before and after the improvement



The amount of the energy of each inputs per ha
The Optimal amount of the energy of each inputs per ha

DISCUSSION AND CONCLUSION

The results showed that the total input energy of tomato greenhouses in Qom city is 53681.722 MJ ha. Average tomato yield in a period is 45,000 kilograms in a space of 2,000 square meters of greenhouse. Due to this amount of harvested product and energy equal to every kilogram, greenhouse output energy will be obtained which is 0.8 that is equal to 36000 MJ ha. Energy ratio is also equal to 0.6706 (without unit) and energy productivity is 0.8382 kg of tomatoes/ MJ consumed energy. Pure energy was also calculated as -17681.722 MJ ha. In this study, the amount of input energy in greenhouses producing tomatoes in Qom province has been calculated as 53681.722 MJ ha. Considering that the total amount of input energy of tomato greenhouses in the city of Marand is equal to 65238.9 MJ ha [9], total energy input for the production of tomatoes in greenhouses of Qom province is relatively less. This, itself, indicates better management of greenhouses in this province. In another study conducted in Turkey, the total energy input in the production of organic tomatoes is equivalent to 30194.70 MJ. [11]. in this study, obtained energy output is 36,000 MJ which is less compared with output energy of Marand greenhouses that was equal to 38581.9 MJ. (9). Also in greenhouse tomato cultivation in the province of Kermanshah this amount has been estimated as 121873.1733 MJ that is much more than the amounts of Qom province and city of Marand [8]. In Turkey also this amount was equal to 3287 MJ; therefore it can be concluded that this amount will vary depending on the weather conditions [11]. In Turkey Tokat province calculated pure energy is equal to 1678.7824 MJ ha [11] Also in the province of Kermanshah was calculated as -26657 [8].

The net result of energy in the tomato greenhouses of Qom is relatively less than these amounts. The negative number indicates that the energy net surplus in these greenhouses is reducing because the output energy of products is much lower than the input, so the result is a negative number and compared to other mentioned greenhouses, they need better management with more appropriate methods. The amount obtained from energy ratio is 0.6706, which is a moderate amount compared to the amounts of other provinces including the city of Marand [8] and Turkey [11] which were respectively 0.59 and 2.73. Therefore, efficiency (energy ratio) in tomato greenhouses of Qom province is relatively good. In order to determine the optimal pattern of energy use in the production of greenhouse tomatoes, a functional was defined using linear programming with the aim of minimizing energy consumption. The results showed that the optimal use of inputs can decrease total energy to 30996.923 MJ ha and same 22684.683 MJ ha i.e. 27% of input energy without negatively impacting product performance. The results also showed that with optimal use of fuel, the consumption of electricity can be reduced 16% and a good irrigation and human resources management can decrease energy consumption for 17%.

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