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ENERGY REQUIREMENT FOR GREENHOUSE CULTIVATION

Pitam Chandra and Mathala J. Gupta*

ABSTRACT

Input energy assessment has been carried out for the greenhouse cultivation of tomato and it has been compared with the input energy for the open field cultivation. The assessment indicates that the energy input per unit produce is 1.7 MJ/kg under open field cultivation. The input energy requirements for greenhouse cultivation increase due to the greenhouse frame, glazing, inorganic fertilizers and environmental control and are estimated to be 4.2 MJ/kg at the minimum. The energy requirements under north Indian plains are likely to be 32 MJ/kg or more with the traditional methods of environmental control. The assessment of input energy in the two crop production systems indicates the priorities for input energy optimizations.

1. INTRODUCTION

Application of Greenhouse technology for crop production in India is a recent phenomenon. The total greenhouse area in India was about 5 ha by 1983 (Chandra, *et al.* 1984a) which has increased to about 500 ha by 1998. The 35 per cent annual rate of growth has been achieved through indigenous development of greenhouse technology, Government popularization programmes, liberation of economy and encouragement of agricultural experts. The growth is likely to continue at the annual rate of 35 per cent or more because greenhouse crop cultivation in India has been found to be useful under the following situations.

i) Cultivation of horticultural crops under inclement agro-climatic conditions.
ii) Round the year cultivation of horticultural crops near big cities to meet the perennial demand of fresh vegetables, fruits and flowers.

* The authors are Principal Scientist & Head, National Phytotron Facility and Scientist, Division of Agril. Engineering, Indian Agricultural Research Institute, Pusa, New Delhi-110 012.
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iii) Export of fresh horticultural produce.

iv) Raising of high quality seedlings through both seed and vegetative propagation.

v) Hardening of genetically engineered plant material.

vi) Intensive cultivation of medicinal and aromatic plants.

vii) Hybrid seed production to high purity.

Greenhouses permit very high input use efficiencies. As a result, crop productivities are several times of those obtained in the open field agriculture. The net financial returns per unit area are also 10 to 100 times higher in comparison to open field agriculture. It is useful to assess the energy inputs in greenhouse crop production systems so that it could be compared with corresponding open field cultivation systems. The assessment of energy inputs will also permit the planning for adoption of this technology in the country on sustainable basis. Besides, this information should permit utilization of alternate energy resources, and, finally, the optimization of the greenhouse crop production system.

Assessment of energy inputs and output in the crop production system has the advantage that it is invariant with time unless technological upgradations take place. The information could readily be converted into monetary terms by incorporating the monetary values of the relevant energy resources prevalent at that time.

Chandra (1984b) studied the gross energy utilization in greenhouse crop production. As compared to the open field cultivation, the following components of inputs energy were identified additionally for greenhouse crop production.

i) Greenhouse structure

ii) Glazing material

iii) Greenhouse environmental control

Besides, the nutritional requirements in greenhouse are higher as compared to open field cultivation. Since, most of the cultural operations in greenhouse are manual, the labour requirement per unit area for greenhouses is higher. Biondi *et al.* (1991) presented the energy requirement for Italian greenhouse crop production. Their results indicated that energy requirement for crop production under open field cultivation was 0.7 - 14.9 MJ/kg (21.2 - 200.3 GJ/ha) and under environmentally controlled greenhouses was 9.4-44.8 MJ/kg (1058 - 1618 GJ/ha) for different crops. Jensen and Matter (1995) quoted an Ohio study where energy requirement for tomato production in the open was estimated to be 17 MJ/kg and in greenhouse, it was 50.4 MJ/kg (Arizona) & 170 MJ/kg (Ohio). The higher energy input for Ohio conditions is due to very high heating costs that eventually made the imported tomatoes cheaper there. The US greenhouse energy input can be noted to be higher than that for Indian greenhouses. Celis and Hetz (1992) compared the energy use for tomato cultivation in plastic greenhouse and outdoors. Energy efficiency was noted to be 0.6 for greenhouse cultivation as compared to 2.5 for the open field crop. About 74 per cent of energy required to produce the tomator crop in a plastic greenhouse was due to the structure.

There are not many studies on greenhouse energy requirements for crop production. The few studies, that are available, give varialble results. The only thing which can be said for sure is that greenhouse crop production requires higher energy input as compared to open field cultivation and that the energy input as compared to open field cultivation and that the energy for environmental control vary greatly from one location to another.

2. METHODOLOGY

This study on assessment of energy requirement has been conducted for the tomato crop. The information related to crop production under openfield and greenhouse conditions has been collected from literature (Biondi, *et al.* 1991, Stanhill, 1980) and personal discussions with vegetable scientists. Various energy coefficients have been selected from Biondi *et al.* 1991, Binnings *et al.* (1983) and Stanhill (1980) and summaried in Table No.1.

Table 1 : Equivalent energy coefficients for inputs to tomato cultivation.

S. No.	Particulars	Unit	Equivalent energy, MJ	Reference
1.	Steel pipe frame	kg	42	Biondi *et al.* (1991)
2.	Plastics film	kg	126	Biondi *et al.* (1991)
3.	Seedlings ready for transplanting in open field	1000 plants	29	Biondi *et al.* (1991)
4.	Seedlings ready for transplanting in greenhouses	One plant	0.3	Biondi *et al.* (1991)
5.	Chemical fertilizers			Binning *et al.* (1983)
	a) Nitrogen	kg	60.6	
	b) P_2O_5	kg	1.1	
	c) K_2O	kg	6.7	
6.	Human labour	Man-hour	1.96	Binning *et al.* (1983)
7.	Irrigation	m^3	11.2	Stanhill (1980)
8.	Chemical			
	a) Superior chemicals	kg	120	Binning *et al.* (1983)
	b) Inferior chemicals	kg	10	

For open field cultivation of tomato crop, a plant population of 20,000 has been assumed. The recommended NPK doses are 200 kg, 100 kg, and 60 kg respectively. The irrigation requirement for the winter crop has been estimated to be 5000 m^3/ha. It has been assumed than on an average 5 persons remain employed for the entire duration of the crop for nursery raising, transplanting, interculture, plant protection, irrigation and harvesting operations. The tomato crop in the open is expected to yield 50 tonnes of fruit per hectare. All the inputs have been assumed to be available locally to obviate the need for transportation of these inputs. The energy for field preparation has been assumed to be 200 MJ/kg on the basis of the range of values available for various food crops (Singh, *et al.* 1998). The quantity of pesticides, fungicides, etc. used for tomator cultivation has been assumed to be the minimum required i.e. 3.0 lit/ha of fungicide and 150 g of Thiran / Kaptan / Furadan.

A greenhouse tomato production facility is assumed to require 100 tonnes of steel for its frame and other fittings. the greenhouse frame has an estimated life of 20 years. Besides, the use of UV stabilized platics film for double roof glazing is estimated at 8000 kg with a service life of 3 years. The labour requirement for greenhouse crop production is expected to be higher than that for open field due to essentially higher intensity of cropping. Ten persons are assumed to be employed full time for the cropping activities. The nutrient requirements in a greenhouse are considerably higher than those for open field cultivation. The NPK requirements for a greenhouse tomato crop have been assumed as 1200, 150 and 3250 kg respectively (Stanhill, 1980). The use of agro-chemicals for plant protection has been assumed to be minimum, i.e. only 3 lit of fungicide and 150 g of Thiran / Kaptan / Furadan.

In the absence of any specific data, the irrigation requirement for the greenhouse tomato crop has been assumed to be the same as that for the traditional tomato crop. A well managed tomato crop in a greenhouse should yield 150 tonnes/ha. The requirement of energy for environment control depends on the local climatic conditions. A greenhouse located in milder climates may require only about 25 per cent of total operating energy for environmental control. The same greenhouse located in a harsher climate would require as much as 90 per cent of the total operating energy for environmental control.

In the present analysis, both these cases have been considered. It should, however, be noted that technological upgradation could significantly reduce the energy requirements for environmental control.

3. RESULTS AND DISCUSSION

The results of energy assessment are presented in Tables 2 and 3. The energy input per hectare of tomato cultivation is 86.5 GJ where as the energy cost of production per kg of produce is 1.73 MJ/kg. The values for a greenhouse located in a milder climate are 629.5 GJ/ha and 4.2 MJ/kg. When a greenhouse is located in harsher climate of north Indian plains, the energy costs are 4721.2 GJ/ha and 31.5 MJ/kg.

It should, however, be noted that greenhouses in India are generally unheated due to paucity of heating fuels. Besides, efforts are made to use as much natural ventilation as possible for cooling and humidity reduction. The greenhouse design effort are also directed towards reducing the energy intensiveness of greenhouse environmental control.

Table 2 : Energy requirement for tomato cultivation under open field conditions.

S.No.	Component	Energy required, MJ/ha
1.	Preparation of seedling for transplanting @ 20,000 plants/ha	580.0
2.	Field preparation	200.0
3.	Transplanting	28.5
4.	Fertilizer/nutrient application	
	a) FYM @ 20 t/ha	6000.0
	b) N @ 200 kg/ha	12120.0
	c) P @ 100 kg/ha	1110.0
	d) K @ 100 kg/ha	56,000.0
5.	Irrigation @ 5000 m^3/ha	56,000.0
6.	Pesticide/insecticide etc. @ 3 lit/ha	360.0
7.	Soil treatment with Thiran and Kaptan 50-60 g, Furadan 50-100 g	1.5
8.	Man power @ 5 persons/ha for 4 months.	9408.0
	Total	**86478.0**

Assuming 50 t/ha production, energy requirement per kg of tomato is 1.73 MJ/kg.

It is clear from Table 2 that the major components of energy input are irrigation, fertilizers and human labour. If drip irrigation is used, the total water requirement for irrigation could be reduced to half and the inorganic nutrient requirement could also be reduced to less than half. Besides, if efficient agricultural tools are employed, the human labour requirement could be reduced considerably. Resultantly the energy cost of tomato production in the open fields could be reduced to about 1.0 MJ/kg.

The input energy use in greenhouse tomato cultivation is greatly influenced by the requirements of nutrients and environmental control. Although the greenhouse tomato production is going to be costlier in comparsion to open field cultivation, it should be comparable to the energy cost of tomatoes transported from other places. In India, although the rail, road and air transport has improved to a great deal, it is till heavily crowded. There is a need to decongest the transportation system for human safety and environmental quality. It is, therefore, desirable to promote greenhouse cultivation to meet local requirements under harsh climatic conditions. Greenhouse production for exports may be encouraged where the energy expenditure for climatic control is minimum and the air transport facilities exist. The energy assessment makes it clear as to where the emphasis for optimization should be placed.

Area under greenhouse cultivation has been increasing at the rate of more than 35% annually during the last decade. Maintaining the same rate, the greenhouse area by 2010 is expected to be 10000 ha and 100,000 ha by 2020. The inputs in terms of steel, plastics, nutrients, environmental control systems, and fuel need to be arranged to meet projections of greenhouse area expansion.

There are many remote places where it is not easy to make fresh vegetables available even from other parts of the country. Promotion of simple forms of greenhouse cultivation in those areas could improve the human nutrition and quality of life there. Leh in J & K is a case in point. Greenhouses there are unheated but these structures have permitted the production of fresh vegetables even during severe winter conditions. Needless to say that the local population gets financially benefited in the process.

The energy intensiveness of the greenhouse crop production could be considerably improved by adoption of upgraded technologies. Energy efficient greenhouse could be designed and renewable energy resources could be utilized to reduce the dependence on conventional energy resources.

It should be realized that higher productivities do require higher energy intensiveness as exemplified by the experiences for food grain crops. The higher food grain yields in Punjab and Haryana are very well correlated with the higher mechanical energy use in these states.

Table 3 : Energy requirement for Greenhouse tomato cultivation.

S.No.	Component	Energy required, MJ/ha
1.	Steel pipep frame @ 2 crops/year for 20 years	105000.0
2.	Plastics	
	a) Glazing @ 8000 kg/ha for 3 years and 2 crops/year	168000.0
]	b) Drip irrigation system @ 2500 kg/ha @ 2 crops/year for 5 years	3150.0
3.	Preparation of seedling for transplanting @ 30,000 plants/ha	9000.0
4.	Field preparation	200.0
5.	Transplanting	28.5
6.	Fertilizer/nutrient application	
	a) FYM @ 20 t/ha	6000.0
	b) N @ 1200 kg/ha	72720.0
	c) P @ 150 kg/ha	1665.0
	d) K @ 200 kg/ha	21775.0
7.	Irrigation @ 5000 m^3/ha	56000.0
8.	Pesticide/insecticide etc. @ 3 lit/ha	360.0
9.	Soil treatment with Thiran and Kaptan 50-60 g, Furadan 50-100 g	1.5
10.	Man power @ 10 persons/ha for 6 months.	28224.0
11.	Environmental control	
	a) Mild climate @ 25% T.E.	157374.7
	b) Harsh climate @ 90% T.E.	4249116.0
	Total	
	a) Mild climate @ 25% T.E.	**629498.7**
	b) Harsh climate @ 90% T.E.	**4721240.0**

Assuming 150 t/ha production, energy requirement per kg of tomato

a) For mild climate is 4.20 MJ/kg.

b) For harsh climate is 31.5 MJ/kg.

4. CONCLUSION

The input energy requirement for tomato production in the open field cultivation is about 1.7 MJ/kg. In greenhouse cultivation, the energy cost varies with the local climate, 4.2 MJ/kg being the input under mild climatic conditions.The energy cost for greenhouse tomato cultivation under north Indian plains has been worked out to be 32 MJ/kg. The need for efficient environmental control systems has been demonstrated. The availability of conventional energy sources being severely constrained in India, the possibilities of passive and active solar greenhouses along with other renewable energy technologies should be explored for competitiveness of the crop production system.

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