International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(3): 1564-1570

Received: 20-03-2020
Accepted: 22-04-2020

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Studies on environmental parameters, energy requirement and techno-economics of capsicum grown under greenhouse

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DOI: https://doi.org/10.22271/chemi.2020.v8.i3u.9416

Abstract
An experiment was conducted during winter season in a semi-cylindrical greenhouse of size 4m x 25m for cultivation of capsicum at Bhubaneswar in coastal Odisha, India. Greenhouse was effective in raising the temperature during cold night period inside the greenhouse thereby creating a better microclimate for production of higher yield and quality fruits than open field cultivation. The growth and yield of capsicum was better under greenhouse than open field cultivation. The yield of capsicum per sq. m. inside the greenhouse was 2.17 times more over open field condition. The study indicates that the input energy per unit of capsicum produce is 3.38 MJ/kg under open field condition and 4.1 MJ/kg under greenhouse cultivation. The higher energy requirement for greenhouse cultivation is mainly due to the framed structure and the glazing materials used in the greenhouse. The assessment of input energy establishes the priorities for input energy optimization. The greenhouse was evaluated in terms of its techno-economic analysis, which was carried out by using different economic indicators such as Net Present Value, Benefit Cost Ratio, Internal Rate of Return and Pay Back Period and compared with open field cultivation. The net present value of investment made on greenhouse for cultivation of capsicum was Rs.119110 as compared to Rs.43239 when grown in the open field. The benefit cost ratio for greenhouse was 2.61 and 2.58 for open field cultivation. The internal rate of return for greenhouse was 40 and 35 per cent for open field cultivation. The pay back period for capsicum under greenhouse was 4 years. It was observed that, techno-economically; cultivation of capsicum in winter under greenhouse will be acceptable by the farmers of Odisha.

Keywords: Greenhouse, tomato, energy, net present value, benefit cost ratio, internal rate of return, pay back period

Introduction
Presently in India 10.25 million ha area is cultivated with vegetable with an annual production of 184 million tonnes. It is estimated that, by 2025 the vegetable demand of the country would be around 192 million tonnes. To achieve this target, attention must be focused on the vertical expansion, strengthened with the boon of the technology instead of horizontal expansion just by increasing the crop area (Rai and Pandey, 2008) [13]. The working group on horticulture constituted by the Planning Commission of India had recommended deployment of hi-tech horticulture and precision farming for achieving vertical growth in horticulture. Hi-tech interventions in horticultural crops proposed by National Committee on Plasticulture Applications in Horticulture, Government of India is greenhouse technology and the crops selected are capsicum, chilli, tomato and flowers like rose, carnation and gerbera (Samuel and Singh, 2004) [14]. In general, micro-climatic control in greenhouse permits raising of plants anywhere at any time of the year. The crop productivity per unit area, per unit volume and per unit input basis is at the maximum level. The micro-climatic condition also implied superior quality of produce, free from pathogens, insect bites and chemical residues (Anonymous, 2005) [1]. Capsicum (*Capsicum annum* L.) or bell pepper is an important cool season vegetable crop of India. In India, it is grown mainly during cooler parts of the year (autumn-winter) when the temperature is low (Singh *et al.*, 2004) [15]. The mean air temperature of Odisha varies from 14.8 to 28.3 ^{0}C during winter season. Mean growing temperature of capsicum crop is between 18 to 30 ^{0}C (Pandey *et al.*, 2005) [12]. Hence there is a need to increase the temperature for safe growing of this vegetable in winter season, as it is grown under open field in Odisha.

As greenhouse allows faster temperature increase during sunny day and slower temperature decrease in night hours, it is considered to be the most suitable structure for cultivation of capsicum (Mishra and Paul, 2003) [8]. But higher installation and operating cost of high-tech controlled greenhouse will be a constraint for popularization of this technique in a state like Odisha where 75 to 85 per cent of farmers are small and marginal (Anonymous, 2005) [1]. With this in background, present study was undertaken to study the effect of low-tech naturally ventilated greenhouse environment, energy requirement and techno-economics of capsicum crop grown under greenhouse in Odisha.

Materials and Methods

The experiment was conducted inside and outside greenhouse erected by Precision Farming Development Centre, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India. The place is situated at 20° 15" N latitude and 85° 52" E longitude with an elevation of 25.9 m above the mean sea level and nearly 64 km west of the Bay of Bengal. The experimental greenhouse was a naturally ventilated single span greenhouse made up of G.I. structure covering an area of 100 sq m oriented in East-West direction (Fig. 1). The greenhouse was covered with ultra violet (UV) stabilized low density polyethylene (LDPE) film of 200-micron thickness. The height of the greenhouse from the floor to the roof top was 3 meters at the centre. The four sides of the greenhouse were covered with nylon made shade net of 50% opening (Fig. 2). The soil of the area is clay loam and acidic in nature having p^H of 6.1. Capsicum seedlings (variety California Wonder) of 25 days were planted with a spacing of 60 cm x 45 cm. The cultural practices of the crop were followed as per the recommendations by Indian Council of Agricultural Research, New Delhi (Thamburaj and Singh, 2003) [17].

Fig 1: Outside view of the experimental greenhouse

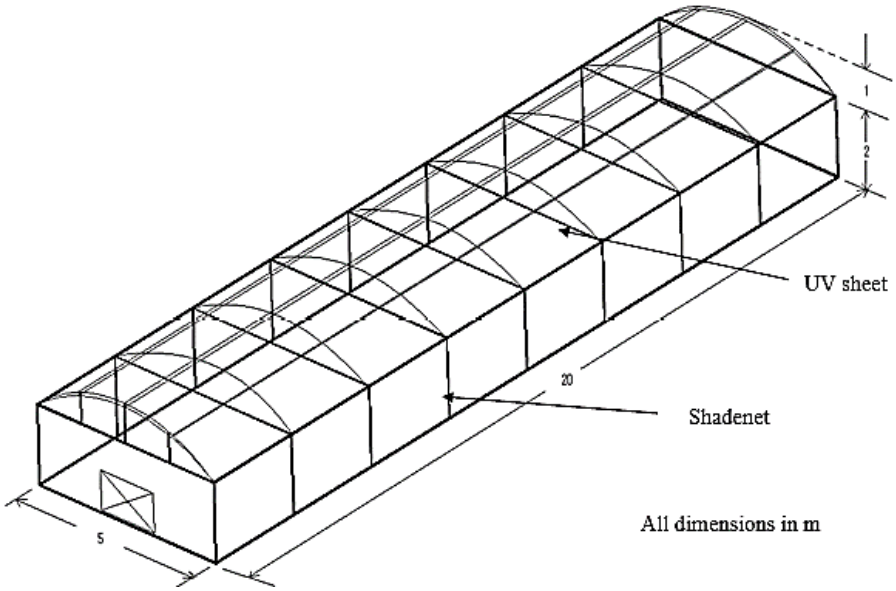

Fig 2: Isometric view of the greenhouse

Observations on growth character and yield of capsicum crop were recorded inside the greenhouse and under open field cultivation. To study the effect of greenhouse on capsicum crop, observations on environmental parameters like air temperature, relative humidity and soil temperature both at 7.30 A.M. and at 1.30 P.M. were recorded inside and outside the greenhouse.

The energy for field preparation has been assumed to be 200 MJ/ha on the basis of the range value available for various food crops (Mishra *et al*., 2011) [9]. The various energy coefficients or equivalent energy were collected from the literature and summarized in Table 1.

Table 1: Equivalent energy coefficient for inputs to capsicum cultivation

S. No.	Particulars	Unit	Equivalent Energy, MJ	Reference
1.	Steel pipe frame	Kg	42	Biondi *et al.* (1991) [3]
2.	Plastics film	Kg	126	Biondi *et al.* (1991) [3]
3.	Seedlings ready for transplanting in open field	1000 plants	29	Biondi *et al.* (1991) [3]
4.	Seedlings ready for transplanting in greenhouses	One plant	0.3	Biondi *et al.* (1991) [3]
5.	Chemical fertilizers a) Nitrogen b) P_2O_5 c) K_2O	 Kg Kg Kg	 60.6 11.1 6.7	Binning *et al.* 1983) [2]

6.	Human labour	Man-hour	1.96	Binning *et al* 1983) [2]
7.	Irrigation	m^3	11.2	Stanhill (1980) [16]
8.	Chemical a) Superior chemicals b) Inferior chemicals	Kg Kg	120 10	Binning *et al* 1983) [2]

Techno-economic analysis

Attempt was made to determine the economics of the cultivation of capsicum under greenhouse. Four economic indicators i.e. net present value (NPV), benefit-cost ratio (BCR), internal rate of return (IRR) and pay back period (PBP) were used in the study. Several research workers in the past have used these indicators for different agricultural systems (Kothari *et al*., 2001; Jain *et al*., 2004; Mishra *et al*., 2011) [7, 5, 9]. Values of all these indicators were computed as:

$$NPV = \sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t} \quad (1)$$

$$BCR = \frac{\sum_{t=1}^{t=n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{t=n} \frac{C_t}{(1+i)^t}} \quad (2)$$

Where, B_t and C_t are the benefit and cost, respectively in each year; t= 1, 2, 3,…. N years and i is the discount rate in percent. IRR is the discount rate that makes the NPV to the incremental net benefit stream or incremental cash flow equal to zero. It is computed by equation (3) as:

$$\sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t} = 0 \quad (3)$$

Pay back period is the length of time between cumulative net cash outflow recovered in the form of yearly net cash inflow.

Assumptions made for economic consideration:

The following parameters have been considered for carrying out economic analysis.

i) The life of greenhouse structure is 20 years.
ii) The life of greenhouse cover is 5 years.
iii) Discounting rate is assumed to be 8 per cent as compared to bank lending rate of interest (Kothari *et al*., 2001 and Paul *et al*., 2012) [7, 11].

Results and discussions

Growth parameters and yield

Overall growth of capsicum in terms of plant height and days to flowering inside the greenhouse was better as compared to open fields (Table 2). Early flowering was noticed in protected conditions saving nearly 15 per cent of less time as compared to outside condition. Plant height at harvest inside the greenhouse was 125 per cent higher than open field condition respectively. Considering the quality aspects, the length and diameter of fruits grown inside greenhouse is 103 and 123 per cent higher under greenhouse than open field cultivation respectively. The number of fruits per plant was also 93 per cent more under greenhouse than outside. The fruit yield per sq. m. inside the greenhouse was 2.17 times more over open field conditions respectively. The capsicum sown under greenhouse produced 117 percent higher fruit yield than the normal sowing date in open field (2.26 kg/m^2). The light intensity inside the greenhouse was less as compared to ambient condition due to the layer of UV sheet facilitating cell elongation resulting in production of thicker and healthy plants inside the greenhouse.

Table 2: Growth and yield of capsicum under greenhouse and open field cultivation

S. No.		Greenhouse	Open field
1	Plant height, cm	100.4	44.5
2	Days to first flowering	40	47
3	Fruit diameter, cm	6.37	2.85
4	Fruit length, cm	7.17	3.52
5	Fruit weight, gm	120.32	84.65
6	No. of fruits per plant	10.17	5.25
7	Fruit yield / plant, kg	1.22	0.56
8	Fruit yield / m^2, kg	4.91	2.26

Environmental parameters

The variation of environmental parameters like air temperature, relative humidity and soil temperature at 7.30 A.M. are presented in Fig. 3 to 5 respectively. It was observed that, at 7.30AM the air temperature inside the Greenhouse was about 1 to 3 ^{0}C more than the open condition during the cropping season (Fig 3). The soil temperature inside the greenhouse was 1 to 4 ^{0}C at 7.30 A M than the outside during the crop growing period. The variation in relative humidity in open condition ranged from 30.7 to 53.8% and inside greenhouse it varied from 46.2 to 59.1% (Fig 5).

The variation of environmental parameters like air temperature, relative humidity and soil temperature at 1.30 P.M. are presented in Fig. 6 to 8 respectively. Similarly, at 1.30 PM the air temperature inside the greenhouse was 0 to 7 ^{0}C more than outside during all the weeks (Fig. 6). The soil temperature inside the greenhouse was 1 to 7 ^{0}C higher than outside during observation period (Fig. 7). The variation in relative humidity in open condition ranged from 35.2 to 57.6% and inside greenhouse it varied from 42.5 to 63.1% (Fig 8).

The day and night temperature was high in greenhouse in comparison to open condition. The cladding material exerted a blanket effect at the top resulting in less fluctuations of day and night temperature than open condition. In open condition the higher variation in day and night temperature resulted in lower yield. It was also effective in raising the temperature during cold night period inside the greenhouse thereby creating a better microclimate for production of higher yield and quality fruits (Koning, 1988) [6]. The shade net in four sides of the greenhouse provided natural ventilation resulting in reduction of relative humidity inside the greenhouse. The yield is in agreement with findings in capsicum and capsicum (Nimji *et al*. 1990) [10].

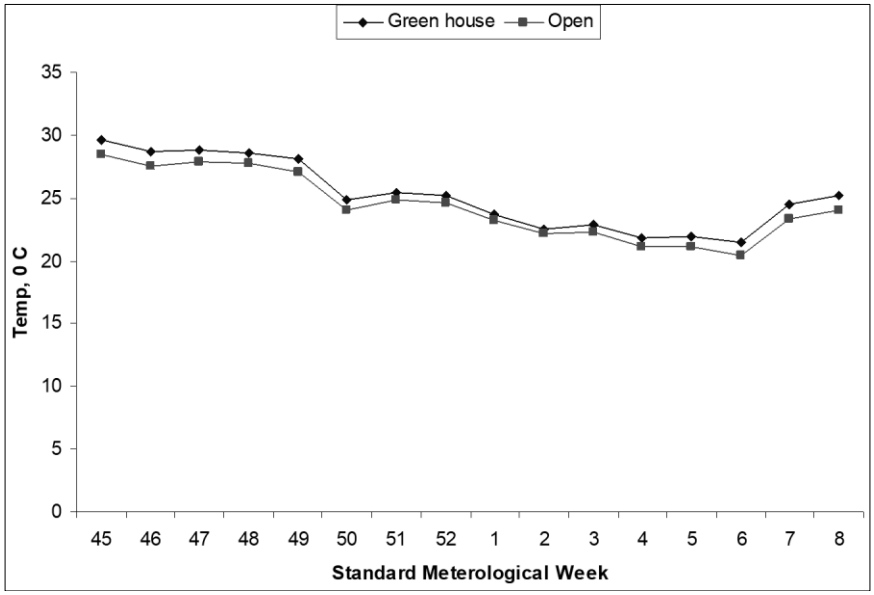

Fig 3: Weekly average air temperature at 7.30 A.M.

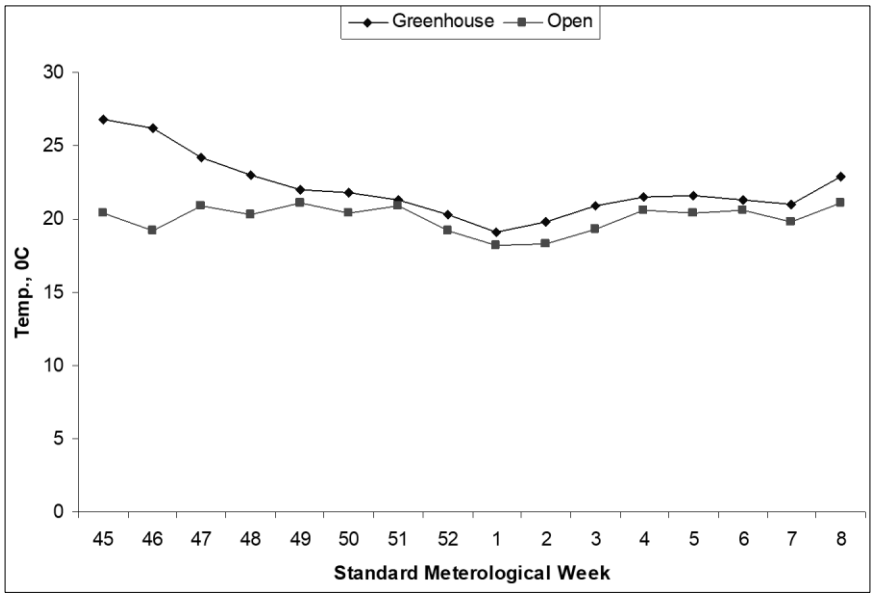

Fig 4: Weekly average soil temperature at 7.30 A.M.

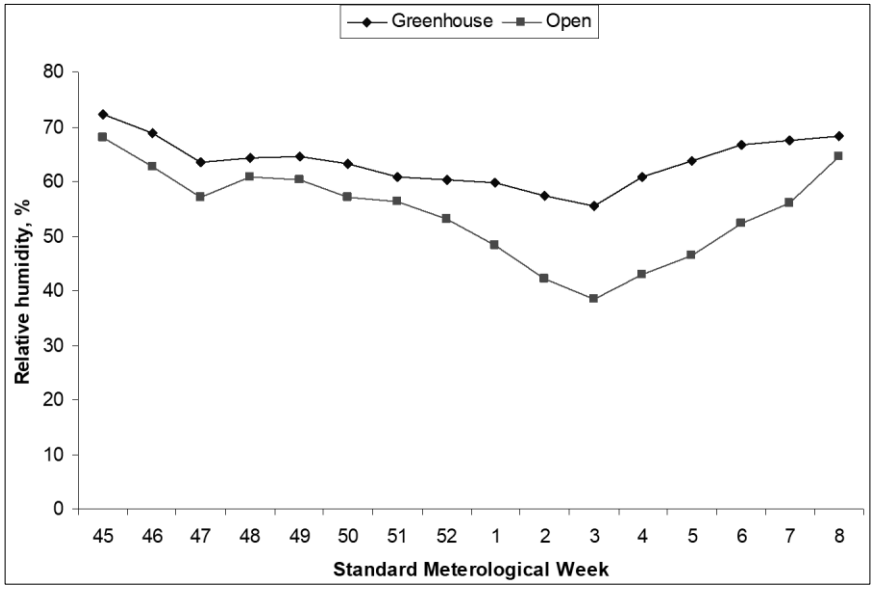

Fig 5: Weekly average relative humidity at 7.30 A.M.

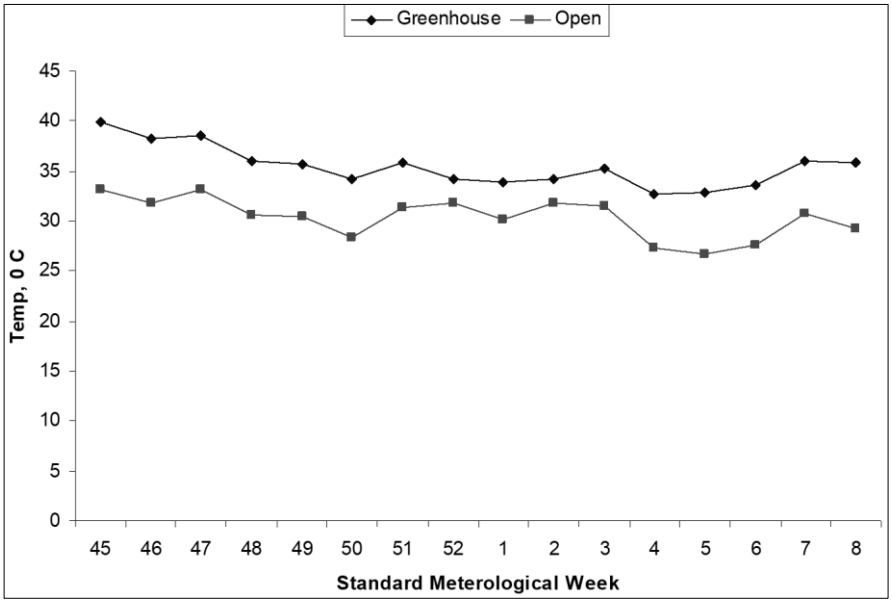

Fig 6: Weekly average air temperature at 1.30 P.M.

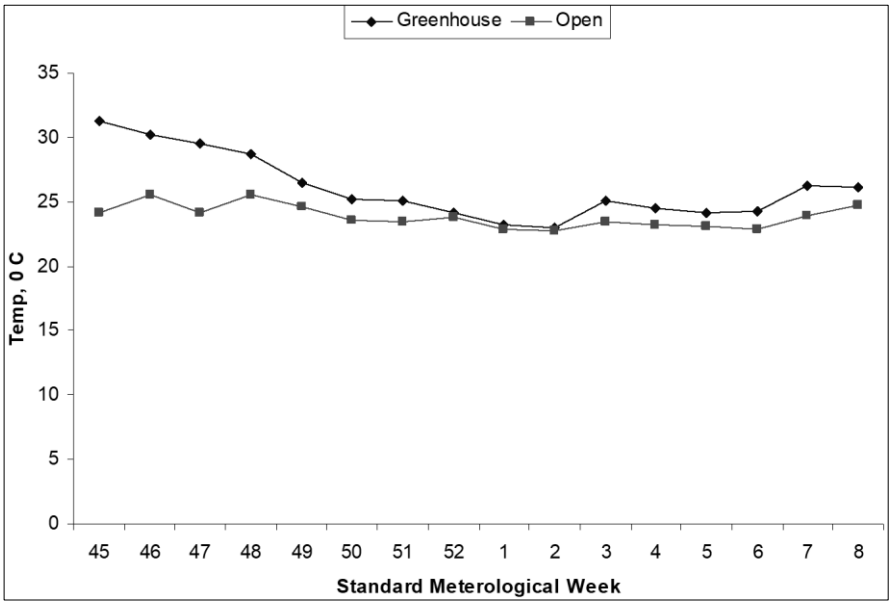

Fig 7: Weekly average soil temperature at 1.30 P.M

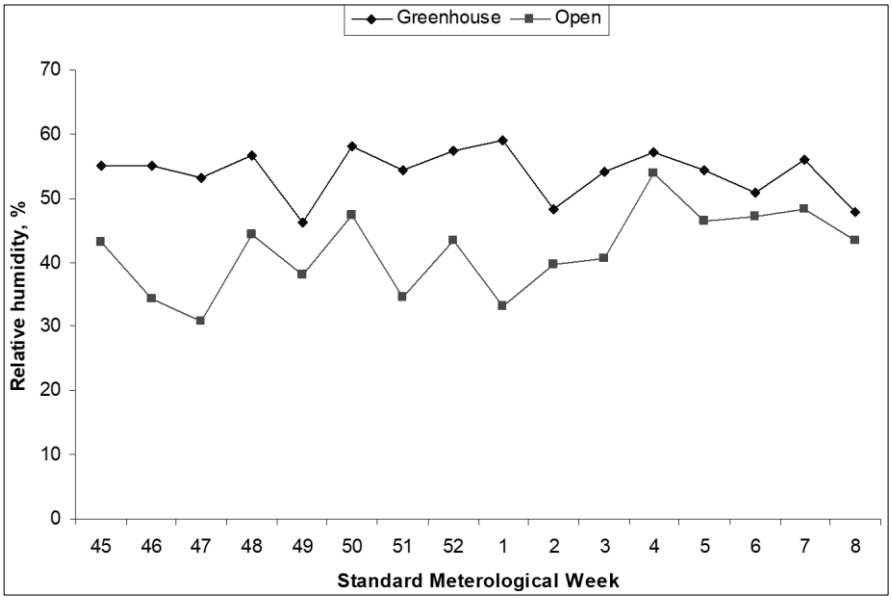

Fig 8: Weekly average relative humidity at 1.30 P.M.

Energy requirement

The energy requirement of capsicum cultivation in open field is given in Table 3. The energy input per 100 sq.m in open field is 765 MJ. The yield of capsicum obtained in open field is 226 kg per 100 sq.m under open field condition. Hence the energy requirement for production of capsicum per kg is 3.38 MJ. The major components for energy requirement for capsicum in open field were irrigation, fertilizer and labour requirement.

The input energy requirement for capsicum production in naturally ventilated greenhouse is presented in Table 4. The yield obtained in this experiment is 491 kg per 100 sq.m. The energy requirement was 2015 MJ and so the energy consumed for production of one kg of capsicum was 4.1 MJ.

Table 3: Energy requirement for capsicum cultivation under open field condition

S. No.	Component	Energy requirement (MJ/100 m^2)
1.	Preparation of seedling for planting @ 400 plants	11.60
2.	Field preparation	2.00
3.	Planting	0.29
4.	Fertilizer/nutrient application	
	a) FYM @ 25 t/ha	0.75
	b) N @ 120 Kg /ha	72.72
	c) P @ 80 Kg/ha	8.88
	d) K @ 50 Kg/ha	3.35
5.	Irrigation @ 5000 m^3 /ha	560.00
6.	Pesticide/insecticide @ 3 liter/ha	0.04
7.	Man power @ 5 persons /ha for 4.5 months	105.84
Total		765.47 or say 765.00 MJ

Similar results obtained for input energy requirement for cultivation of tomato at New Delhi under hi-tech greenhouse was 32 MJ/kg and under open field cultivation was 1.7 MJ/kg (Chandra and Gupta, 2000) [4].

It is obvious from Table 3 that the major components of energy input are irrigation (560 MJ/100 m^2), fertilizers (84.95 MJ/100 m^2) and human labour (105.84 MJ/100 m^2). If drip irrigation is used, the total water requirement for irrigation could be reduced to almost half and also the fertilizer requirement could be reduced to less than half by the method of fertigation. Besides, if efficient agricultural tools are employed, the man power requirement could be reduced considerably. As a result the energy cost of capsicum production in open fields could be reduced to about 1.25 MJ/kg instead of 3.38 MJ/kg.

Table 4: Energy requirement for capsicum cultivation under greenhouse

S. No.	Component	Energy requirement (MJ/100 m^2)
1.	Steel pipe frame @ 2 crops/yr. for 20 years	656.25
2.	Glazing materials for 5 years and 2 crops /yr.	340.20
3.	Preparation of seedling for planting @400 plants	120.00
4.	Field preparation	2.00
5.	Planting 400 plants	0.29
6.	Fertilizer/nutrient application	
	a) FYM @ 25 t/ha	0.75
	b) N @ 300 Kg/ha	181.80
	c) P @ 200 Kg/ha	22.2
	d) K @ 125 Kg/ha	8.83
7.	Irrigation @ 4000 m^3/ha	448.00
8.	Pesticide/insecticide @ 3 liter/ha	0.04
9.	Man power @ 10 persons /ha for 5 months	235.20
Total		2015.11 MJ or say 2015 MJ

The input energy utilized in greenhouse capsicum cultivation is mainly influenced by the framed structure, glazing material, labour requirement and irrigation, which is clear from Table 4. If fertigation can be done by the use of drip irrigation, the energy input can be reduced. Besides this, if efficient agricultural tools are used, the human labour requirement can be reduced considerably. Although the greenhouse capsicum production is costlier in comparison to open field cultivation, it can be comparable to energy cost of capsicum transported from other places. Also, the product obtained in greenhouse cultivation is much more qualitative than the same obtained from open field cultivation. It is, therefore, desirable to promote greenhouse cultivation to meet the local requirement under harsh climatic conditions. The energy assessment makes it clear as to where the emphasis for optimization should be placed.

Economic feasibility

The yield of capsicum were 982 kg and 452 kg under greenhouse and open field cultivation respectively. The cost of greenhouse was computed to be Rs 40000/-. The cost of UV sheet of greenhouse and shade net for greenhouse were Rs 2160/- and Rs 2520/- respectively which were to be changed in every fifth year. The cost of cultivation of capsicum were Rs 2800/- and Rs 2200/- under greenhouse and open field cultivation respectively. Total return from greenhouse and open field cultivation were Rs 19640/- and Rs 6780/- respectively per year. During the study the following results related to economic viability were obtained for cultivation of capsicum under different growing conditions (Table 5).

The NPV for capsicum crop was Rs.119110/- under greenhouse, whereas it was Rs.43239/- outside the greenhouse. Based on NPV it can be concluded that the

construction of greenhouse for cultivation of capsicum crop is economical and there is substantial increase in the income of farmer by growing this crop inside the structure (Table 6).

The benefit cost ratio is 2.61 inside the greenhouse and 2.58 open field cultivation. The IRR is another important factor frequently used by economists for evaluation of the performance of different projects. It is computed as that interest rate at which the BCR is just 1.0. The IRR is 40 per cent when grown inside greenhouse as compared to 35 per cent when grown in open field (Table 3). As these IRR were more than the bank lending interest rate (8%), the project is economically viable. The payback period is 4 years when grown inside greenhouse which was less than the life span of the greenhouse (20 years). Thus farmers could pay back their investment in 4 years.

Table 5: Details of income and expenditure for capsicum crop under greenhouse and open condition

S. No.	Particulars	Greenhouse	Open
1	Yield considering two crops in a year (kg)	982	452
2	Total revenue per year (Rs.)	19640	6780
3	Cost of cultivation	2800	2200
4	Initial investment (Rs.)	40000	Nil
5	Cost of UV sheet and shade net in every fifth year (Rs.)	4680	Nil

Table 6: Economic indicators for capsicum under greenhouse and open field cultivation

S. No.	Economic indicator	Greenhouse	Open field
1	NPW, Rs	119110	43239
2	BCR	2.61	2.58
3	IRR, %	40	35
4	PBP, years	4	-

Conclusion

Greenhouse was effective in raising the temperature during cold night period inside the greenhouse thereby creating a better microclimate for production of higher yield and quality fruits than open field cultivation. The growth and yield of capsicum was better under greenhouse than open field cultivation. The yield of capsicum per sq. m. inside the greenhouse was 2.17 times more over open field condition. The input energy requirement for capsicum production was 3.38 MJ/kg and 4.1 MJ/kg of produce in open field and greenhouse conditions respectively for Odisha. The higher energy requirement for greenhouse cultivation is mainly due to the framed structure and the glazing materials used in the greenhouse. NPV of investment made on greenhouse was Rs.119110/-, as compared to only Rs.43239/- for open condition for capsicum. The benefit cost ratio for capsicum in greenhouse was 2.61. The internal rate of return in greenhouse was 40 per cent. The payback period for greenhouse was 4 years. From the above study, the economic indicators suggest that cultivation of capsicum under greenhouse is economical in Odisha climate.

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