Journal of Applied Horticulture, 24(2): 190-194, 2022

DOI: https://doi.org/10.37855/jah.2022.v24i02.35

Journal of Applied Horticulture

ISSN: 0972-1045

Economic analysis of production of commercial vegetables with saline water drip irrigation in naturally ventilated polyhouse

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Abstract

Production of vegetables under protected cultivation is necessary to meet the continuous seasonal demand. Due to capital and labour intensive nature of the polyhouse technology, majority of Indian farmers with small and marginal categories (>85%) cannot afford it. On the other hand, 6.73 million hectare of land area in India is affected by salinity, which hampers crop production and hence the area under vegetable cultivation is shrinking as most vegetables are sensitive to salinity stress. This study assessed the effect of saline water drip irrigation on the production of capsicum, green chilli and tomato crops in naturally ventilated polyhouse. The economic analysis revealed that the estimated cost of polyhouse construction (300 m^2) with a drip irrigation system was ₹4,71,563 and the overall cost (cost C_3) of vegetable production under polyhouse was estimated to be ₹2,15,623. Among capsicum, green chilli and tomato crops grown in the polyhouse, overall net returns over cost C_3 was highest from tomato, followed by capsicum and green chilli. The economic indicators were encouraging, with positive net present value, higher benefit-cost ratio and higher internal rate of returns and shorter payback period. The investigation also suggests the viability of saline water drip irrigation for commercial cultivation of vegetables in naturally ventilated polyhouse, which is not possible under the natural environment for growing crops with saline water drip irrigation.

Key words: Capsicum, green chilli, tomato, polyhouse, saline water drip irrigation, vegetable

Introduction

India is the second largest producer of vegetables, next to China. During 2017-18 the area under vegetables was 10.26 million hectares with a production of 184.40 million tonnes. India's share in the world vegetable market is around 11.2 per cent. The country's fruits and vegetable production economic value accounts for ₹4,516.49 billion during 2015-16. Despite all these achievements and high availability of fruits and vegetables at 393.76 gms/person/day (GOI, 2018), per capita consumption of vegetables in India is very low, *i.e.* 173 and 99 gms/person/day in urban and rural areas, respectively (ICMR-NIN, 2019) as against 300 gms/person/day recommended by ICMR in 2009.

Vegetables play a prominent role in human health and provide an opportunity for higher farm income from the limited land resources. However, vegetable cultivation is mainly affected by environmental factors, *viz.*, soil type, light, temperature, rainfall *etc.* About 6.73 million hectare of land is salt affected in the country, out of which 2.96 million hectares (44%) is saline and about 32 to 84 percent of groundwater development is poor quality in nature (Minhas, 1999). In India, vegetables are generally cultivated in an open environment, but most are sensitive to climatic variations and hence yield low productivity. Protected cultivation is a viable option to overcome the vagaries of natural calamities, including soil and irrigation water salinity. Cultivation of vegetables in polyhouse protects the crop against biotic (pests, disease and weeds) and abiotic (temperature, humidity, light, rainfall) stress and ensures high-quality crop production throughout the year (Murthy *et al.*, 2009). Vegetable cultivation in polyhouse not only enhances productivity and quality but also balances the production and supply and regulates the price fluctuation of vegetables even in the off-season (Kumar *et al.*, 2016).

Polyhouse structure costs play a decisive role in adopting and sustaining vegetable production. It mainly depends on the quality of materials used for the polyhouse structure and glazing and other systems like drip and mist (Murthy *et al.,* 2009). Depending on the requirement, polyhouses are of various sizes ranging from 1000 to 10,000 m^2. The present study was taken up to examine the economic feasibility of the production of commercial vegetables (capsicum, green chilli and tomato) with saline water drip irrigation in a naturally ventilated polyhouse constructed in an area of 300 m^2.

Material and methods

The current study is based on data from an experiment conducted at ICAR-CSSRI, Karnal. The investigation was carried out on standardization of production and protection technologies for selected vegetables under saline water drip irrigation in polyhouse during 2015-16 to 2017-18. Three vegetables, capsicum, green chilli and tomato, were selected, as these are known to be best suitable and most commonly grown under polyhouse/greenhouses worldwide. Capsicum is a season-specific crop, winter being the best suitable season in the tropics. It is a high volume and high-value vegetable. On the other hand, tomato and green chilli are relatively low value crop, but in demand throughout the year. Though tomato and green chilli are grown nearly in all seasons, their yields are low during summer and monsoon.

To study the effect of salinity on production of capsicum, green chilli and tomato crops under polyhouse, saline water was applied through drip irrigation. The experiment was carried out with the best available water (BAW; EC_{iw} 0.8 dS/m) and application of irrigation water with different salinity levels, *viz.* EC_{iw} 2, 4, 6, 8 and 10 dS/m.

The cost accounting method generated the production data for three crop seasons from 2015-16 to 2017-18. The capsicum, green chilli and tomato crops were simultaneously grown in one season in a year by equally dividing the polyhouse area into 100 m^2. In first year (2015-16), vegetable seedlings were planted in August, harvesting was started in October (capsicum and green chilli) and November (tomato) and harvested up to April (Capsicum and green chilli) and May (tomato) in the next year. Whereas in the second (2016-17) and third (2017-18) years, the planting was done in September, harvesting was started from November (Capsicum and green chilli) and December (tomato) and continued upto May (Capsicum and green chilli) and June (tomato). The annual cash flow was considered for economic analysis.

For estimating the cashflows, the actual average production data of three crop seasons/years (2015-16 to 2017-18) was used for the first year and for the remaining years, the cash flows were extrapolated appropriately based on the available information. An attempt was also made to estimate the cost of production of capsicum, green chilli and tomato under polyhouse cultivation. It was estimated by accounting for all costs included in cultivating vegetables under polyhouse of 300 m^2 and compared with the prevailing market price. After estimating the annual costs of all items, the cost of production (₹/kg) per crop (season) was calculated. The price that prevailed in the market during the production period was considered for estimating the profitability of capsicum, green chilli and tomato crops produced under polyhouse.

Economic analysis: Different cost concepts are estimated for the study, *viz.*, Cost A_1, Cost A_2, Cost B_1, Cost B_2, Cost C_1, Cost C_2, and Cost C_3 (CSO, 2008) and returns over different costs are also analyzed to assess the economic benefits such as farm business income, family labour income, net income over cost C_1, C_2 and C_3.

The economic feasibility of investment in the production of capsicum, green chilli and tomato under polyhouse conditions was estimated by using project evaluation measures *viz.*, payback period (PBP), benefit-cost ratio (BCR), net present value (NPV) and internal rate of returns (IRR). Except for PBP, which is an undiscounted measure, all other methods, BCR, NPV and IRR, are discounted measures of project worthiness (Gittinger, 1982; Murthy *et al.,* 2009; Raju *et al.,* 2016; Franco *et al.*, 2018). A discount rate of 12 percent was used to estimate these parameters (Swathy Lakshmi *et al.,* 2017; Senthilkumar *et al.,* 2018), considering the life of polyhouse as ten years.

Results and discussion

Polyhouse technology is capital- and labour-intensive and requires a substantial investment, especially during the initial establishment period. The cost of polyhouse construction (Table 1) revealed that the total capital cost of ₹4,71,563 was invested for erecting polyhouse in an area of 300 m^2. Generally, commercial polyhouses are constructed in an area of 4000 m^2 (one acre), so

Table 1. Cost of establishment of a polyhouse structure

Particulars	Cost (₹/300 m^2)	Cost (₹/4000 m^2)
Structural frame with GI Pipes	1,87,318 (39.72)	24,97,575
Entry room (2mx2m) with locking arrangement	18,000 (3.82)	18.000
Covering/Polyfilm with 200 micron thickness	46,508 (9.86)	2,76,170
Profile (Aluminium) & spring lock to fix plastic film	13,230 (2.81)	1,76,400
Thermal screen (manually operated)/Top net for ventilation	26,325 (5.58)	33,750
Side vent with bottom apron	15,525 (3.29)	67,275
Insect proof net on sides	10,463 (2.22)	56,025
Drip irrigation & Fertigation system	43,875 (9.30)	1,00,969
Rain water harvesting gutter	40,095 (8.50)	2,67,300
Foundation cost	24,750 (5.25)	2,31,660
Sprayers & other equipments	14,853 (3.15)	1,98,040
Electric installations	1,448 (0.31)	19,307
Miscellaneous cost	29,174 (6.19)	39,425
Total	4,71,563 (100.00)	39,81,895

Figures in parenthesis indicates percentage to total cost

Miscellaneous cost: Initial land preparation cost including cleaning and leveling, preparing bunds and furrows, arrangements for saline water irrigation, incidental charges, *etc.*)

the study has estimated the cost required for the construction of polyhouse with drip irrigation in one-acre area to be ₹39.82 lakhs. The initial establishment includes the cost of a structural frame with GI pipes, polyfilm sheet, nylon net, drip irrigation, fertigation system and construction costs *etc.* The polyfilm covering with 200 micron thickness normally lasts 4-5 years and must be replaced depending on wear and tear.

The break-up of establishment costs indicates that the major cost was involved in the structural frame of polyhouse with GI pipes followed by polyfilm covering with 200 micron thickness, drip irrigation and fertigation system, rainwater harvesting gutter and miscellaneous cost, which includes the cost of initial land preparation (cleaning, leveling, preparing bunds and furrows, arrangements for saline water irrigation, incidental charges *etc.*). Other important costs involved in the establishment of polyhouse were manually operated thermal screen, foundation cost, side vent with bottom apron, sprayers and other permanent types of equipment purchased for use in the polyhouse, aluminium profile and spring lock to fix polythene sheet, insect proof net on sides and electric installation. In the current study, the life of polyhouse was assumed as 10 years with polythene sheets replacement for every 5 years.

The cost of vegetable production under polyhouse was estimated considering the major cost concepts *viz.*, Cost A_1, Cost A_2, Cost B_1, Cost B_2, Cost C_1, Cost C_2 and Cost C_3. The total estimated cost of production of capsicum, green chilli and tomato under polyhouse was ₹2,15,623 per 300 m^2 (Table 2). The break-up of

Table 2. Cost of production of vegetables under polyhouse

Particulars	Cost of cultivation (₹/300 m^2)	Cost of cultivation (₹/4000 m^2)	Cost of production (₹/crop)
Human Labour	67,500 (31.30)	9,00,000	22,500
Machine Labour	800 (0.37)	10,667	267
Seedlings	3,830 (1.78)	51,067	1,277
Vermicompost	1,750 (0.81)	23,333	583
Fertilizer	2,466 (1.13)	32,444	811
Plant protection chemicals	2,940 (1.36)	39,200	980
Irrigation charges	2,250 (1.04)	30,000	750
Miscellaneous cost (twines, staking, packing material costs, transportation costs, etc)	14,954 (6.94)	1,99,387	4,985
Interest on working capital @7%	2,251 (1.04)	30,009	750
Depreciation on fixed capital	47,156 (21.87)	6,28,751	15,719
COST A_1	1,45,864 (67.65)	19,44,857	48,621
Rent paid for leased-in land	0.00	0.00	0.00
COST A_2	1,45,864 (67.65)	19,44,857	48,621
Interest on owned capital (excluding land rent) @10%	47,156 (21.97)	6,28,751	15,719
COST B_1	1,93,021 (89.52)	25,73,608	64,340
Rental value of owned land	3,000 (1.39)	40,000	1,000
COST B_2	1,96,021 (90.91)	26,13,608	65,340
Imputed value of family labour	0.00	0.00	0.00
Cost C_1	1,96,021 (90.91)	26,13,608	65,340
Cost C_2	1,96,021 (90.91)	26,13,608	65,340
Cost C_3	2,15,623 (100.00)	28,74,969	71,874

production cost revealed that the maximum amount was spent on human labour followed by depreciation on fixed capital and interest on owned capital, each remaining the same. Rent paid for leased in land and imputed value of family labour was not considered as the experiment was conducted at the institute land and human labour was hired. Cost A_1 (working expenses) and cost A_2 remained the same as land rent was unpaid as the experiment was conducted on the institute premises. Cost B_2, cost C_1 and cost C_2 remained the same as the imputed value of family labour was not included in the study. The production under polyhouse was restricted to one season (9-10 months) and all three vegetables were cultivated by equally dividing the polyhouse area. The inputs were equally utilized for all the crops. Hence the total production cost, *i.e.*, cost C_3 per 300 m^2 was equally divided among all the crops grown under polyhouse. Thus the production cost of capsicum, green chilli and tomato crops remained the same.

Table 3. Crop-wise yield under different irrigation water salinity levels

Irrigation water EC_{iw} (dS/m)	Average Yield (qtl/300 m^2) Capsicum	Green Chilli	Tomato
BAW	14.99 (19.38)	10.59 (16.36)	23.39 (12.28)
2	13.52 (17.48)	11.18 (17.27)	26.65 (13.99)
4	12.92 (16.71)	12.54 (19.38)	35.91 (18.85)
6	13.43 (17.36)	12.22 (18.88)	35.42 (18.60)
8	12.60 (16.29)	9.32 (14.40)	32.74 (17.19)
10	9.88 (12.77)	8.87 (13.71)	36.37 (19.09)
Total	77.34 (100.00)	64.72 (100.00)	190.48 (100.00)
Average yield	12.89	10.78	31.75

BAW=Best Available Water, Figures in parenthesis indicates percentage to total

The average yield of capsicum, green chilli and tomato, produced under polyhouse in an area of 300 m^2, were 12.89, 10.78 and 31.75 qtls, respectively. The tomato crop obtained the maximum yield, followed by capsicum and green chilli (Table 3). Among different levels of saline water irrigation, the highest yield of capsicum was obtained with BAW followed by saline water irrigation with 2 dS/m EC_{iw}. The yield of green chilli was highest under 4 dS/m EC_{iw} followed by 6 dS/m EC_{iw}. However, the yield of both capsicum and green chilli decreased with irrigation of EC_{iw} 10 dS/m, indicating their sensitivity to irrigation water salinity beyond 6.0 dS/m. In contrast, tomato yield was highest at 10 dS/m EC_{iw} followed by 4 dS/m EC_{iw}, showing the higher tolerance of tomato crop to saline water irrigation.

The gross returns from capsicum, green chilli and tomato crops were estimated by considering the farm gate price prevailing during the crop season. The farm gate prices were ₹1,785 per quintal each for capsicum and green chilli and ₹1,040 for tomato crop. The treatment-wise yield of each crop was multiplied with their respective farm gate prices and the values across the treatments were added to obtain gross returns from the individual crop. Overall, estimated gross returns of ₹4,51,676 were received from the production of capsicum, green chilli and tomato under polyhouse in an area of 300 m^2 (Table 4). Out of total returns, tomato crop contributed the highest gross returns, followed by capsicum with green chilli.

Table 4. Crop-wise gross returns under different irrigation water salinity levels

Irrigation water EC_{iw} (dS/m)	Gross Returns (₹/300 m^2) Capsicum	Green Chilli	Tomato	Overall
BAW	26,757 (38.23)	18,903 (27.01)	24,326 (34.76)	69,986 (100.00)
2	24,133 (33.61)	19,956 (27.79)	27,716 (38.60)	71,806 (100.00)
4	23,062 (27.86)	22,384 (27.04)	37,346 (45.11)	82,793 (100.00)
6	23,973 (29.01)	21,813 (26.40)	36,837 (44.58)	82,622 (100.00)
8	22,491 (30.74)	16,636 (22.73)	34,050 (46.53)	73,177 (100.00)
10	17,636 (24.74)	15,833 (22.21)	37,825 (53.06)	71,294 (100.00)
Total	1,38,052 (30.56)	1,15,525 (25.58)	1,98,099 (43.86)	4,51,676 (100.00)

BAW=Best Available Water, Figures in parenthesis indicates percentage to total

The overall net returns over different costs varied from Cost A_1 to Cost C_3. The overall farm business income and family labour income were ₹3,05,812 and ₹2,55,656, respectively (Table 5). The net return was highest from tomato crop followed by capsicum. The net return obtained from green chilli was much less than tomato and capsicum.

Gross returns from vegetable production under polyhouse were estimated (Table 6) based on two assumptions: (i) utilizing total polyhouse area (300 m^2) for the production of only one vegetable (any of capsicum, green chilli and tomato) and (ii) utilizing total polyhouse area (300 m^2) for production of vegetables using each category of saline water for irrigation. The estimates revealed that maximum returns can be obtained from capsicum production with BAW. Similarly, the maximum returns can be obtained from green

Table 5. Net returns over different costs of vegetable cultivation under polyhouse (300 m^2)

Particulars	Capsicum	Green Chilli	Tomato	Overall
Average yield (qtl)	12.89	10.78	31.75	-
Average output price (₹/qtl)	1,785	1,785	1,040	-
Gross returns	1,38,052	1,15,525	1,98,099	4,51,676
Net returns over				
Cost A1 (Farm business income)	89,430	66,904	1,49,478	3,05,812
Cost A2	89,430	66,904	1,49,478	3,05,812
Cost B1	73,712	51,185	1,33,759	2,58,656
Cost B2 (Family labour income)	72,712	50,185	1,33,759	2,55,656
Cost C1	72,712	50,185	1,32,759	2,55,656
Cost C2	72,712	50,185	1,32,759	2,55,656
Cost C3	66,178	43,651	1,26,225	2,36,054

Table 6. Estimated gross returns from vegetable production under polyhouse with respective irrigation water salinity

Irrigation water EC_{iw} (dS/m)	Gross returns (₹/300 m^2)			
	Only Capsicum	Only Green Chilli	Only Tomato	Overall
BAW	4,81,629	3,40,257	4,37,861	4,19,915
2	4,34,398	3,59,213	4,98,888	4,30,833
4	4,15,120	4,02,910	6,72,235	4,96,755
6	4,31,506	3,92,629	6,63,062	4,95,732
8	4,04,838	2,99,452	6,12,893	4,39,061
10	3,17,444	2,84,993	6,80,846	4,27,761

BAW=Best Available Water

chilli and tomato production at irrigation water salinity of 4 dS/m and 10 dS/m, respectively. By growing all three vegetables at the given salinity level, the gross returns were highest at 4 dS/m. The study indicates that, among the selected vegetables, capsicum is sensitive to saline water irrigation as compared to green chilli and tomato. Overall, the tomato crop gave higher returns than capsicum and green chilli.

The economic feasibility analysis of vegetable production was carried out with the actual production of capsicum, green chilli and tomato crops under a naturally ventilated polyhouse in an area of 300 m^2. The capital cost of polyhouse ₹4,71,563 (Table 1) and the total cost of vegetable production ₹2,15,623 (Table 2) were used for economic feasibility analysis. In addition to the capital cost, the polythene sheets replacement cost was also accounted for analysis. The replacement cost is the total cost of polyfilm, aluminium profile and spring lock system, side vent with bottom apron and insect-proof net on sides (Table 1).

The feasibility analysis revealed the NPV, BCR, IRR and payback period of ₹6,25,711, 1.41, 46.32 percent and 2 years, respectively (Table 7). These indicators provide evidence for the economic feasibility of the commercial cultivation of vegetables. Therefore, vegetable production under polyhouse with saline water drip irrigation may be encouraged. It will help not only in the productive utilization of the area under saline soil and water in the country for the commercial production of different vegetables but also regulates the supply and prices of vegetables even in the off-season.

The alternate feasibility analysis was also carried out using data estimated based on certain assumptions (Table 6). The study revealed that capsicum gives significantly better results under BAW for all the economic indicators *viz.*, NPV (₹7,68,206), BCR (1.50), IRR (53.24%) and payback period (1.77 years). Though all the economic indicators indicated promising results, the returns from capsicum production at ECiw 10 dS/m were lesser than lower salinity levels (Table 8). The economic feasibility of green chilli was highest at EC_{iw} 4 dS/m indicating the best possible results with NPV (₹3,93,713), BCR (1.26), IRR (34.63%) and payback period (2.52 years). However, green chilli is not profitable at saline water irrigation with EC_{iw} 8 and 10 dS/m, indicating its sensitivity to higher salinity than capsicum. Tomato revealed the highest returns at EC_{iw} 10 dS/m with an acceptable value of NPV (₹17,15,957), BCR (2.13), IRR (97.23%) and payback period (1.19 years). Overall, the economic feasibility indicator for all three vegetables produced under polyhouse area

Table 7. Economic feasibility of vegetable production under polyhouse (300 m^2) (Based on actual production values)

Economic Indicators	Values
Net Present Value (NPV) (in ₹)	6,25,711
Benefit-Cost Ratio (BCR)	1.41
Internal Rate of Returns (IRR) (in %)	46.32
Payback period (PBP) (in years)	2.00

Table 8. Alternate economic feasibility analysis of vegetable production under polyhouse

Irrigation water (EC_{iw} (dS/m)	Economic Indicators			
	NPV	BCR	IRR	PBP
Total Capsicum				
BAW	7,68,206	1.50	53.24	1.77
2	5,43,510	1.36	42.25	2.16
4	4,51,798	1.30	37.62	2.36
6	5,29,753	1.35	41.56	2.18
8	4,02,884	1.26	35.11	2.49
10	-1,28,79	0.99	11.13	4.63
Total Green Chilli				
BAW	95,647	1.06	18.08	3.78
2	1,85,831	1.12	23.38	3.28
4	3,93,713	1.26	34.63	2.52
6	3,44,800	1.23	32.07	2.66
8	-98,477	0.94	4.92	5.63
10	-1,67,262	0.89	-0.90	6.80
Total Tomato				
BAW	5,59,986	1.37	43.07	2.12
2	8,50,315	1.56	57.16	1.66
4	16,74,991	2.10	95.36	1.03
6	16,31,352	2.07	72.66	1.05
8	13,92,677	1.91	82.45	1.19
10	17,15,957	2.13	97.23	1.19
Overall				
BAW	4,74,613	1.31	38.78	2.31
2	5,26,552	1.35	41.40	2.19
4	8,40,167	1.55	56.68	1.68
6	8,35,302	1.55	56.45	1.68
8	56,5695	1.37	43.35	2.11
10	51,1939	1.34	40.67	2.22

BAW=Best Available Water

of 300 m^2 revealed that the highest benefit could be obtained at EC_{iw} 4 dS/m with positive NPV (₹8,40,167), BCR (1.55), IRR (56.68%) and least payback period (1.68 years).

The estimated economic indicators of the study proved that producing commercial vegetables like capsicum, green chilli and tomato in naturally ventilated polyhouse with saline water drip irrigation is an economically viable option. Apart from utilizing available saline resources, being labour-intensive, polyhouse cultivation of commercial vegetables creates employment opportunities for farm families even in the off-season.

Acknowledgements

The authors thank the Project Coordinator, ICAR-AICRP, on Management of Salt Affected Soils and Use of Saline Water Agriculture, for the financial support. The authors are also thankful to the Head, Division of Soil and Crop Management and the Director, ICAR-CSSRI, Karnal, for their continuous guidance and encouragement during this study.

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Received: January, 2022; Revised: February, 2022; Accepted: April, 2022