ZIBELINE INTERNATIONAL™ PUBLISHING
ISSN: 2716-6678 (Online)
CODEN: FAMOCP

Food & Agribusiness Management (FABM)

DOI: http://doi.org/10.26480/fabm.01.2024.01.10

CrossMark

RESEARCH ARTICLE

ECONOMICS OF TOMATO CULTIVATION INSIDE BAMBOO PLASTIC TUNNEL IN LALITPUR DISTRICT OF NEPAL

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ARTICLE DETAILS

Article History:

Received 18 November 2023
Revised 20 December 2023
Accepted 23 January 2024
Available online 26 January 2024

ABSTRACT

Plastic tunnel cultivation technology in mid-hills is emerging as a lucrative alternative to open-field cultivation in Terai for enforcing the self-sustenance of tomatoes in Nepal. A study was, therefore conducted in 2021 to evaluate the economic profitability of producing tomatoes using bamboo plastic tunnel in Lalitpur. Sixty tomato growers identified from purposive and snowball sampling were examined using a pre-tested semi-structured questionnaire. The data collected was further supplemented by key informant interviews, focus group discussions and different secondary data sources. The average area, production, and productivity at the household level were determined as 0.43 ha, 30.42 MT, and 69.90 MT/ha respectively. The average cost of constructing a bamboo plastic tunnel (20×6 m^2) and producing tomatoes inside them were NRs.35,800 & NRs.24,715 respectively. Labor was prominent variable cost component with share of 41.72%. The average annual gross revenue was NRs.1,82,729/ropani. Cobb-Douglas production function analysis exhibited significant relationship of inputs: labor, chemical fertilizer, seed, and irrigation costs with gross revenue and a decreasing return to scale of 0.406 indicated gross return reduces by 0.406 with a unit increase in inputs. Benefit-cost ratio (1.11), gross margin (NRs.1, 19,198), and net margin (NRs.1, 08,584) indicated tomato production inside a plastic tunnel is lucrative.

KEYWORDS

cost; gross revenue; labor; profitability; questionnaire

1. INTRODUCTION

Tomato (*Lycopersicum esculentum*) is a commercial vegetable crop in Nepal with total acreage, production, and productivity of around 22,911ha, 422,703 MT, and 18.45 MT/ha respectively (MoALD, 2022). It is mostly cultivated in open fields during winter in Terai, inner Terai, and foothills and as an off-season crop inside protected structures like plastic tunnels during summer and rainy seasons in the mid-hills of Nepal (Ghimire, 2017). Production in an open field condition during the rainy season in Terai is very difficult due to massive rain, hailstones, and specifically high temperature (Day: >32°C and Night: 21°C) gradually limiting fruit set (Bhattarai and Subedi, 1996). Bacterial wilt disease is another major threat limiting survivability and tomato stand at harvest in open field conditions (Pandey, 2006). The national demand for tomatoes cannot be satisfied by domestic production alone, and supply from terai is frequently restricted (Chapagain, 2011). Additionally, reports of massive tomato imports are also common. For example, during the 2019–20 fiscal year, 44 million kg of fresh and chilled tomatoes were imported, costing NRs. 531 million in total (MoALD, 2019/20). Thus, growing evidence points to the viability of growing summer-rainy tomato crops under plastic tunnels in the hills as a means of reducing the difficulties associated with open-field tomato farming in terai and promoting tomato self-sufficiency in Nepal.

Plastic tunnels are protected structures known to extend the crop production by providing shelter from intense summer heat, heavy rainfall during the rainy season, and bitter winter cold and frost. It thereby provides crops with controlled temperature and humidity resulting in their highest quality and quantity and increased profits. It also maintains the land fertility, conserves water, protects against extreme climate hazards thereby reducing the need of crop insurance (Belasco et al., 2013; Bhattarai and Subedi, 1996; Lamichhane, 2017). In Nepal, plastic house technology was first dispersed from the Regional Agriculture Research Station (RARS), Lumle in 1996 (Kafle and Shrestha, 2017). The tunnels introduced were rather a simple structures constructed from bamboos/ GI (galvanized iron) pipe framework with its roof covered by a Silpaulin plastic (normally 45-90GSM) as opposed to scientific structures in developed nations. Since its introduction, it was increasingly adopted in several other districts such as Kaski, Palpa, Kathmandu valley thereby increasing the area under the protected structure cultivation. The variety of crops grown in the plastic house has also expanded. Tomato, cucumber, zucchini, sweet pepper, and bitter gourd are among the economically promising crops.

Tomato is a high value crop, well adapted to high house production technology and providing higher economic returns relative to open-field grown crops (Lamont, 2009). The yield per ropani of tomatoes was 2-5 times higher when cultivated inside plastic houses than in open fields in studies conducted by HRD, Khumaltar from 2000 to 2003. A group researchers also reported 44% higher profitability of tomatoes under plastic tunnel than in open field conditions (Bhandari et al., 2021). The offseason cultivation of tomatoes in plastic tunnels from Ashad to Mangsir thus has huge market potential, and can be a substantial income generation activity for small-scale hill farmers (Budhathoki et al., 2004;

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	Website: www.fabm.org.my	**DOI:** 10.26480/fabm.01.2024.01.10

Cite the Article: Sampada Wagle, Ananta Raj Devkota, Priyambada Joshi (2024). Economics of Tomato Cultivation Inside Bamboo Plastic Tunnel in Lalitpur District of Nepal. *Food & Agribusiness Management, 5(1): 01-10.*

Pokharel, 2021). Walk-in and High tunnels constructed of bambooes or GI pipe framework are the most employed structures in off-season tomatoes cultivation. Depending on the elevation of the location, the proposed dimensions for such structures are 12-25 m (length) * 5-6 m (width) * 2-4 m (height) with a minimum walking path of 75cm (MoALD, 2016). In cool areas, it is fully covered to maintain the warm temperature while in hilly areas, plastic is laid only on the top to allow for ventilation and prevent the build-up of fungus.

Because of their enormous potential to increase tomato quality, quantity, and sales, as well as the fact that the area under cultivation is growing annually, plastic tunnel adoption in tomato farming is high in the midhills. Lalitpur is one of the major vegetable hubs for tomatoes in Nepal, with 181 ha devoted to tomatoes production (MoALD, 2019/20). However, tunnel farming being a relatively new phenomenon, one major impediment to adoption of tunnels for off-season tomato production in Lalitpur is that farmers are unaware of the economic profitability of using tunnels, costs incurred in their construction, cost of producing tomatoes inside them, and production and marketing situation of tunnel-grown tomatoes. Keeping all these factors in consideration, this study aimed to ascertain the input use, associated costs and profitability, and current production and marketing status of tunnel grown tomatoes in Lalitpur. Its major objective was to analyze the costs and returns situation by estimating major cost component, benefit-cost ratio, gross margin, net margin, return to scale, and SWOT (Strengths, Weaknesses, Opportunities, and Threats). Besides, it also sought to identify the production and marketing status of tomatoes in Lalitpur. It is expected that this information will be very useful as it reflects the need of the present tomato industry of Nepal and will contribute significantly to advancing the adoption of plastic tunnels in tomato production as well as developing policies and guidelines in the country.

2. Methodology

2.1 Study location

Lalitpur District, a part of Bagmati Province in Nepal is situated at latitude: 27° 32' 31.0812"N and longitude: 85° 20' 3.4692"E. Three municipalities were specifically chosen for the study: Godawari municipality, Kyonjyosom rural municipality, and Mahalaxmi municipality due to their high percentage of tomato production and widespread use of tunnels (See Figure 1).

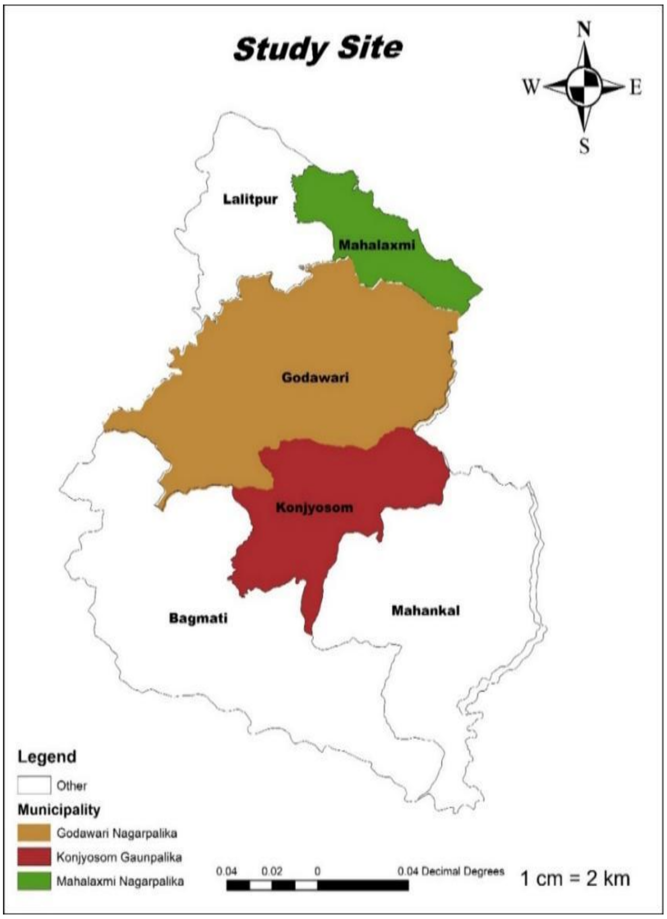

Figure 1: Map illustrating the study site in the Nepal's Lalitpur district

2.2 Selection of participants of the study

A list of farmers who cultivated tomatoes using plastic tunnels in at least one ropani of land was identified and a representative sample size of 60 (20 each from three selected municipalities) tomato growers were purposely selected employing the snowball method of sampling. A pretested semi-structured questionnaire was used to obtain first-hand information on qualitative (sociodemographic characteristics, existing production practices, major drive for production, major diseases & pests, major production & market constraints) and quantitative (agricultural land holdings, cost of plastic tunnel construction, cost incurred in production inputs and marketing, production amount, income from tomato production) parameters. Key informant interviews with 2 key farmers (farmers with high acreage and experience in tomato farming inside tunnels), focus group discussions (FGDs) with 3 focus groups (4 farmers per group selected based on their experience in growing tomatoes inside tunnel), and field observations were also performed to generate necessary information. Information collected from field visits was further supplemented by information gathered from desk studies of various published and unpublished literature, and annual reports of different governmental agencies e. g. ABPMDD, and MoALD. The obtained information was tabulated and analyzed using indexing techniques, simple descriptive statistics, economic parameters estimation, Cobb-Douglas production function analysis, and return to scale analysis.

2.3 Importance/Problem Indexing

A simple six-point indexing technique (1, 0.84, 0.67, 0.51, 0.34, and 0.17) was applied to determine the major driver of tomato production inside a plastic tunnel. Likewise, a five-point scaling method was employed (1 being the most serious, 0.8 being serious, 0.6 being moderate, 0.4 being a little less serious, and 0.2 being the least serious) to analyze the relative seriousness of the main production and marketing problems. Equation (1) from was used to compute the index of importance/problems (Miah, 1993).

$$I_{imp/prob} = \sum(S_i F_i)/N \quad (1)$$

where, $I_{imp/prob}$ = Index value for intensity

Σ = Summation

S_i = Scale value of i^{th} intensity

F_i = Frequency of i^{th} response

N = Total number of respondents

2.4 Economic Analysis

The majority of tomato growers in Lalitpur cultivated tomatoes inside bamboo plastic tunnels of dimension 120 sq. m (20m*6m). Therefore, it was regarded as a standard size for economic analysis viz. costs and returns estimation, B/C ratio, gross margin, net margin, production function, and return to scale analyses. The overall cost of production included initial cost of construction of plastic house, fixed cost and variable costs for tomato production. To obtain the total cost (TC) of production Eq (2), the variable cost (VC) and fixed cost (FC) incurred per year were added together.

$$Total\ cost = Fixed\ cost + Variable\ cost \quad (2)$$

where, Fixed cost (FC) = Land rent+ land tax

Variable cost (VC) = Labor cost + non-labor cost (Seed cost + Fertilizer cost + Micro nutrient cost + Pesticide cost+ Tractor cost+ Irrigation cost)

Total returns/Gross revenue was calculated as the average total volume of tomatoes (MT/ropani) produced times the selling price of tomatoes (Rs. / MT) Eq (3).

$$Gross\ Revenue = Amount\ of\ tomato\ (MT) \times Price\ per\ unit\ of\ tomato\ (Rs./MT) \quad (3)$$

2.4.1 Benefit Cost Analysis

The net benefit to total cost ratio for tomato production was used to calculate the benefit-cost ratio, or BCR. It provides an indication of the profit made per rupee invested in tomato production (Eq (4)).

$$BCR = \frac{Net\ benefit}{Total\ cost} \quad (4)$$

where, Net benefit = Gross Revenue – Total cost

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2.4.2 Gross margin analysis

The difference between gross revenue/ropani and variable cost/ropani was used to calculate the gross margin (Eq (5)). It was used to determine whether tomato cultivation inside a plastic tunnel might satisfy producers' needs both financially and technically.

$$Gross\ Margin = Gross\ revenue\ (GR) - Variable\ cost\ (VC) \quad (5)$$

2.4.3 Net Margin Analysis

Likewise, net margin was computed by deducting total cost/ropani from gross revenue/ropani Eq (6).

$$Net\ margin = Gross\ revenue\ (GR) - Total\ cost\ (TC) \quad (6)$$

2.4.4 Cobb-Douglas Production Function analysis

The Cobb-Douglas production function was utilized to ascertain the input-to-output efficiency in the tomato production process. It is expressed as Eq (7) (Cobb and Douglas, 1928).

$$Y = aX_1b_1X_2b_2X_3b_3X_4b_4X_5b_5X_6b_6X_7b_7 \quad (7)$$

where, Y= Total returns (NRs/ha)

a= Intercepts/constant

X_1= Seed cost (NRs/ha)

X_2= Organic fertilizer cost (NRs/ha)

X_3= Chemical fertilizer cost (NRs/ha)

X_4= Micronutrient cost (NRs/ha)

X_5= Pesticide cost (NRs/ha)

X_6= Irrigation cost (NRs/ha)

X_7= Labor cost (NRs/ha)

b_1 to b_7= coefficients

All of the variables were logarithmically transformed and the aforementioned function was converted into a linear form, which can be represented as:

$$\log Y = \log A + a_1 logX_1 + a_2 \log X_2 + a_3 logX_3 + a_4 logX_4 + a_5 logX_5 + a_6 logX_6 + a_7 logX_7 \quad (8)$$

2.4.5 Return to scale analysis

The qualitative change in output resulting from a proportionate increase in inputs at constant technology utilized for the production process was measured using return to scale (RTS). It was calculated as the sum of regression coefficients i.e. individual production input elasticities obtained from the Cobb-Douglas production function Eq (9).

$$RTS = \sum b_i \quad (9)$$

where, b_i = regression coefficient of i^{th} variables.

Decision rule: RTS<1 indicates a decreasing return to scale, RTS=1 indicates a constant return to scale, and RTS>1 indicates an increasing return to scale.

2.4.6 SWOT analysis

Analysis of the research area's SWOT for tomato production inside plastic tunnels was done using data from key informant interviews, household surveys, and focus group discussions (FGDs).

2.5 Data Analysis and Interpretation

The acquired data were imported, processed, and analyzed using MS Excel 2019 and statistical tools such as STATA version 12.1 and the Statistical Package for Social Sciences (SPSS version 20). Charts, graphs, and tables are used to display the analyzed data.

3. Results and Discussion

3.1 Socio-demographic characteristics of respondents

The respondents were distributed by socioeconomic characteristics that include gender, age, ethnicity, religion, education, family type, family size, primary occupation, migration status, and household decision-making status (See Figure 2).

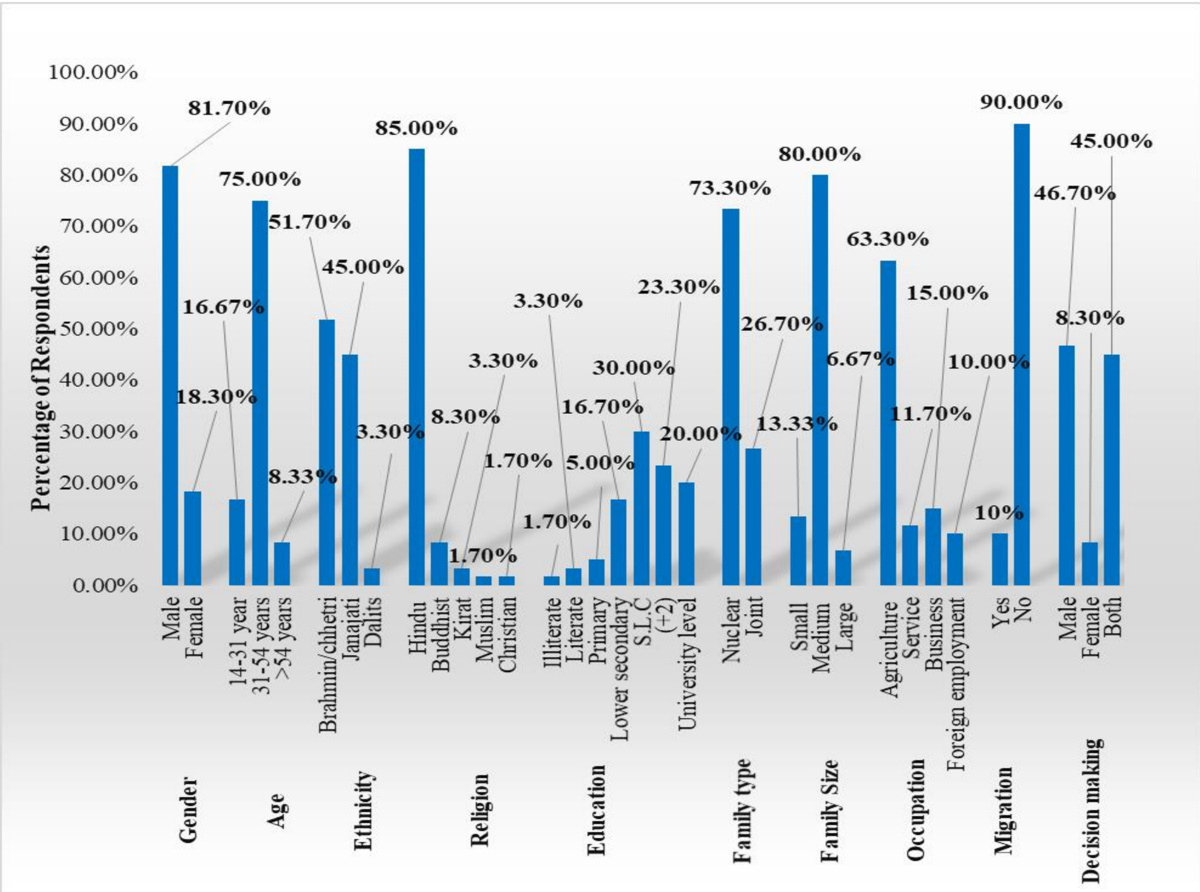


Figure 1: Distribution of respondents by socio-demographic characteristics.

3.2 Landholding status of respondents

The average landholding was 18.26 ropani with a minimum of 2 ropani and a maximum of 150 ropani. The respondents were categorized into two groups, small and large by using a statistical tool (mean) based on their allocation of land to tomato farming. The majority of respondents had small-size tomato farms (70%) which explained their lack of confidence in scaling up their farms (See Table 1).

Table 1: Distribution of respondents based on their tomato farm size.

Tomato farm size	Frequency	Percent (%)
Small (<8.6ropani)	42	70
Large (>8.6 ropani)	18	30
Total	60	100.0
Mean	8.62 ropani	
Standard deviation	13.08 ropani	
Range	1-90	

3.3 Production status of tomatoes inside plastic tunnel

Tomato farming was major income source for the respondents. The average annual household income from tomatoes was NRs. 1079788.46. The average area, production, and productivity at the household level were estimated as 0.43ha, 30.42MT, and 69.90MT/ha respectively. (See Table 2). Majority of them (43.3%) were growing tomato in a commercial scale for 5-10 years. It is also interesting to note that 8.3% of tomato growers had more than 10 years' experience. Findings so obtained revealed the progressive trend of using plastic tunnels for producing tomatoes in Lalitpur. Srijana was the highly preferred variety (65%) followed by Improved Srijana (18.3%). In light of improved production practices, 51.7% of respondents had adopted drip method of irrigation and 38.3% had used plastic mulch.

Table 2: Area, production, and productivity of tomatoes in the study area.

Variables	Unit	Minimum	Maximum	Sum	Mean
Area	ha	0.25	4.5	28.7	0.43
Production	MT	0	260	1825.44	30.42
Productivity	MT/ha	2	360	4194.5	69.90

Good returns followed by a comparative advantage over cereals and other horticultural commodities were the major drivers for adoption of plastic tunnel in tomato production (See Table 3).

Table 3: Determinants of tomato production inside a bamboo plastic tunnel in Lalitpur.

Major drivers	1	0.84	0.67	0.51	0.34	0.17	N	Total score	Index	Rank
Good returns	22	25	6	1	4	2	60	49.23	0.82	I
Comparative advantage	26	9	14	3	6	2	60	46.85	0.78	II
High market demands	7	18	23	8	0	4	60	42.29	0.71	III
Land suitability and favorable climate	0	5	12	24	9	10	60	29.24	0.48	IV
Neighbors influence	5	2	4	16	22	11	60	26.87	0.45	V
Government subsidy and extension services	0	1	1	9	18	31	60	17.49	0.30	VI

Agrovets and input dealers were the major sources of inputs viz. seeds, manures, fertilizers, pesticides, tools & equipment for intercultural operations and harvesting (e. g. Secateurs), and construction materials (bamboo, GI wire, Nails, etc.) (See Figure 3).

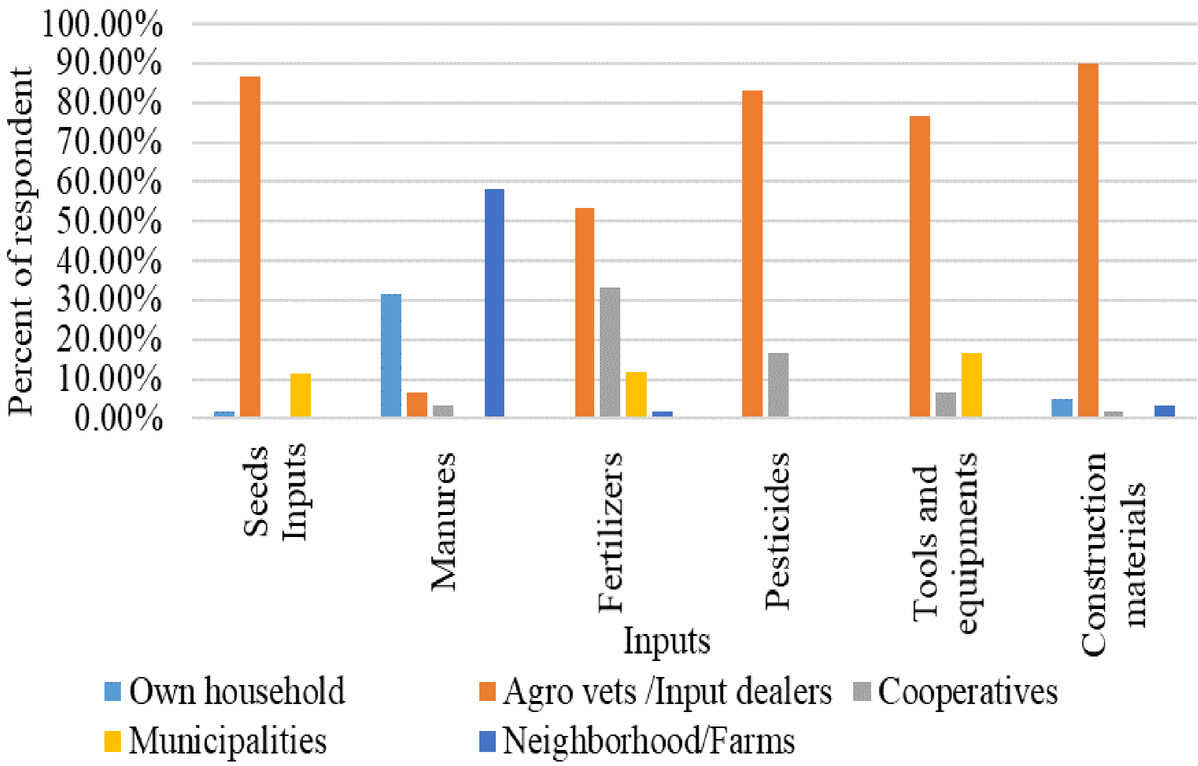


Figure 3: Sources of inputs in Lalitpur.

3.4 Economic Analysis of tomato cultivation inside bamboo plastic tunnel (20*6 m²)

3.4.1 *Cost of construction of plastic tunnel*

The total cost incurred in constructing one tunnel was estimated as NRs. 35,799.5 (See Table 4). In one ropani land, 3 such tunnels could be erected, thereby, the total cost per ropani would be nearly NRs. 1,07,400. The tunnels were found to be durable for 4-5 years. The cost incurred for maintenance including bank interest was estimated as NRs. 7705/tunnel and NRs. 23,113/ropani from the second year onward.

Table 4: Average cost of construction of bamboo plastic tunnel of size 20*6 m² in 2021.					
S.N.	**Particulars**	**Unit**	**Quantity**	**Per unit cost (NRs.)**	**Total cost (NRs.)**
1	Bamboo	Piece	49	235	11515
2	Silpaulin plastic (70 GSM)	Square meter	142	50	7100
3	GI wire (binding)	kg	3	170	510
4	GI wire (netting)	kg	8	170	1360
5	Rope	kg	5	200	1000
6	Nails (1.5, 3 inch)	kg	2	130	260
7	Skilled labor	MD	4	1350	5400
	Unskilled labor	MD	3	800	2400
8	Transport cost	NRs.			3000
	Total cost				**32545**
	Annual repair cost (From 2nd year)	NRs.		4450	4450
	Bank interest	Percent	10%		3254.5
	Total cost for the first year				**35799.5**
	Total cost from second year				**7704.5**

3.4.2 Cost of cultivation of tomato

The major production inputs in tomatoes cultivation along with their costs are depicted in Table 5. Organic sources (farmyard manure, bone meal, poultry manure, mustard and neem oilcakes) and chemical sources (urea, DAP, potash) were major fertilizer sources. Ash was sometimes used as a substitute of potash. Some farmers also applied micronutrients (e. g. zinc, borax), vermicompost and Krishi lime. IPM practices as lure and traps were frequently employed by farmers in conjunction with pesticides. Power tillers and tractors were mostly employed in land preparation, labor being used in absence of them. The total cost for tomato cultivation including land rent was estimated as NRs. 24,715/tunnel and NRs. 74,145/ropani and excluding land rent was estimated as NRs. 21,215/ tunnel and NRs. 63,645/ropani respectively (See Table 5). The cost of production was found higher in Lalitpur because it was calculated for tomatoes grown under plastic tunnel in off-season.

Table 5: Average cost of cultivation of tomato inside bamboo plastic house of size 20*6 m² in 2021.					
S.N.	**Particulars**	**Unit**	**Quantity**	**Per unit cost (NRs.)**	**Total cost (NRs.)**
	Variable cost items				
1.	Seed	gram	3	160	480
2.	Farmyard manure	[1]Doko	31	150	4650
	Poultry manure	[2]Bora	1	260	260
	Bone meal	Kg	3	65	195
	Oil cakes	Kg	9	60	540
3.	Urea	Kg	3	27	81
	DAP	Kg	4.5	52	234
	Potash	Kg	3.5	42	147
4.	Micronutrients				1310
5.	Pesticides				2370
6.	Tractor	Hour	1	600	600
7.	Irrigation				610
8.	Labor	MD	11	650	7150
9.	Equipment maintenance				2550
	Total variable cost				**21177**
	Fixed cost items				
1.	Land tax	NRs.			38
2.	Land rent	NRs.			3500
	Total fixed cost				**3538**
	Total cost (without land rent)				**21215**
	Total cost (with land rent)				**24715**

[1]Doko, 1 Doko equals 50 kg

[2]Bora, 1Bora equals 50 kg of poultry manure

3.4.3 Major cost component

Labor was the most prominent production input costing about 41.72% of the total variable cost (See Figure 4). It was required in activities from nursey bed and land preparation, planting, weeding, hanging, irrigation, fertilizers and pesticides application to harvesting. The average number of labors required and cost for labor was found to be 33 MD and NRs. 21,450 per ropani. Two sources of labor were identified: household labor and hired labor. About 48.67% of the farmers in the research area relied on hired labor during the production season, whereas 51% of them cultivated tomatoes using labor from their households. Hence, the tomato was found as a labor-intensive enterprise. It is supported by several studies (Kafle and Shrestha, 2017; Lamichhane, 2017; Adhikari, 2018; Gautam, 2019; Basyal, 2019; Subedi et al., 2020).

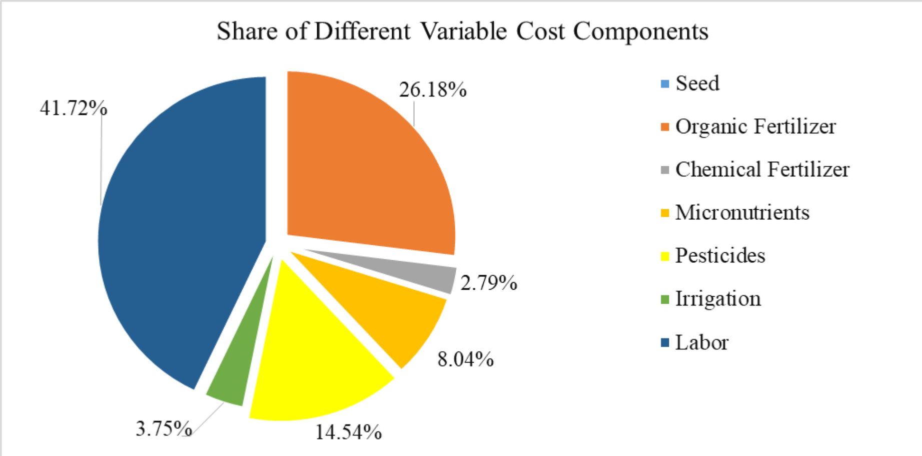


Figure 4: Share of each variable cost component to the overall cost of production

3.4.4 Estimation of Gross returns/revenue

The average production and selling price of 2020 was used for gross revenue analysis. Among the surveyed respondents, the average tomato produced was 3.495 MT/ropani and an average selling price of NRs. 52,283/MT resulted in the average gross income of NRs. 1, 82,729 in 2020 (See Table 6). Increased awareness among growers regarding improved production practices such as drip irrigation method, plastic mulching, and use of IPM techniques provided higher tomato productivity in Lalitpur relative to other vegetable hubs of Nepal as inferred from the study.

Table 6: Quantity of tomato produced and selling price.

Year	Production (MT/ropani)	Selling price (NRs/MT)	Gross income (NRs/ ropani)
2020	3.495	52,283	1,82,729

3.4.5 Benefit-cost ratio, Gross margin and Net margin analysis

BC ratio, net margin, and gross margin were calculated to estimate the profitability of tomatoes as a monocrop inside a plastic tunnel. BC ratio was found negative (-0.0065) for the first year possibly due to the high costs incurred on the construction of a plastic tunnel. However, it was greater than one (i. e. 1.11) from the second year onwards indicating benefit of 11 paisa per rupee cost invested. It can be inferred that deduction of construction costs and addition of maintenance expense increased net benefit and thereby the BC ratio. Tomato cultivation inside the plastic tunnel was therefore proven profitable after the second year. The findings of this study are supported by the results of (Basyal et al., 2019; Gautam, 2019; Kafle and Shrestha, 2017; Pokharel 2021). The gross margin of NRs. 119198 and net margin of NRs. 108584 further suggested tomato cultivation inside plastic tunnel as a profitable venture.

Net benefit (for 1st year) = Gross revenue (GR)-Total cost (TC)

=182729-181543 = - 1186 (negative benefit)

BC ratio (1st year) = Net benefit/Total cost= -1186 /181543= **-0.0065**

Net benefit (from 2nd year) = Gross revenue (GR) -Total cost (TC)

=182729 -86758 = 95971(positive benefit)

BC ratio (from 2nd year) = Net benefit/Total cost=95971/86758 = **1.11**

Gross margin (NRs.) = Gross revenue (GR) - Total variable cost (TVC)

= 182729-63531

= **119198**

Net margin (NRs.) = Gross revenue (GR)-Total cost (TC)

= 182729- 74145

= **108584**

3.4.6 Production function analysis

To determine if all input expenses used in tomato production jointly contributed to the gross return from tomatoes produced, the Cobb-Douglas production function model was employed (See Table 7). The estimated production function's coefficient of multiple determination (R^2) was 0.279, meaning that the independent variables in the equation could account for 27.9% of the variability in tomato production. Among the seven independent variables viz. seed cost, labor cost, organic fertilizer cost, micronutrient cost, pesticide cost, and irrigation cost, irrigation cost and labor cost were found to be significant at the 5% level, whereas seed cost and chemical fertilizer cost were significant at the 10% level. The positive coefficients of organic fertilizer, chemical fertilizer and labor costs indicated direct effect on gross returns from tomato while negative coefficients of seed, irrigation, micronutrients and pesticides costs indicated reverse effect on returns received from tomatoes sale. Organic fertilizer cost had positive but non-significant contribution to gross returns which implied farmers were over-using organic fertilizers and same returns could be obtained by decreasing these costs to certain calculated limit thereby reducing production cost.

Table 7: Estimated value of coefficients and related statistics of Cobb-Douglas production function of tomato production inside bamboo plastic tunnel.

Log return	Coefficient	Standard error	t-value	p-value
Constant	15.602	2.099	7.429	1.142
Log seed cost	-0.586*	0.303	-1.934	0.058
Log organic fertilizer cost	0.115^{ns}	0.132	0.876	0.385
Log chemical fertilizer cost	0.147*	0.079	1.850	0.070
Log micronutrients cost	-0.061^{ns}	0.063	-0.962	0.340
Log pesticides cost	-0.012^{ns}	0.078	-0.159	0.873
Log irrigation cost	-0.130**	0.059	-2.182	0.033
Log labor cost	0.118**	0.057	2.072	0.043
F-value	0.000			
R-square	0.279			
Adjusted R-square	0.165			

Note: ns: non-significant, *: significant at 5%, **: significant at 10% level

3.4.7 Elasticity of Production and Return to scale

The production function exhibited decreasing returns to scale, meaning that for every unit increase in the inputs specified in the production function, the gross return will drop by roughly 0.409 (See Table 8). It therefore necessitates the optimization of inputs for maximizing production in the long run (Kunwar and Maharjan, 2019; Samshunnahar et al., 2016).

Table 8: Elasticity of production and return to scale.

Variable	Input Elasticity
Seed	-0.586
Organic Fertilizer	0.115
Chemical Fertilizer	0.147
Micronutrients	-0.061
Pesticides	-0.012
Irrigation	-0.130
Labor	0.118
Return to scale	-0.409

3.5 Production problems

Diseases and pest attacks were identified as a major production constraint (See Table 9). It is worthwhile here to mention that higher input cost was the least problematic issue. In contrast, high input costs and timely unavailability of agricultural inputs were found as major production problems in Lalitpur 10 years back. (Chaudhary, 2010). Hence, it can be inferred that production problems varies with time, so continuous efforts towards the exact identification and management is needed through research at regular intervals.

Table 9: Major production problems of tomato cultivation inside bamboo plastic tunnel in Lalitpur

Major production constraints	1	0.8	0.6	0.4	0.2	Total score	Index value	Rank
Diseases and pests	33	13	8	2	4	49.8	0.83	I
Unavailability of credit and extension services	11	16	11	15	7	37.8	0.63	II
Lack of knowledge on farming practices and appropriate technology	10	14	13	7	16	35	0.58	III
Labor shortage	3	8	15	17	17	28.6	0.48	IV
Higher input costs and inputs from unverified sources	2	8	15	19	16	28.2	0.47	V

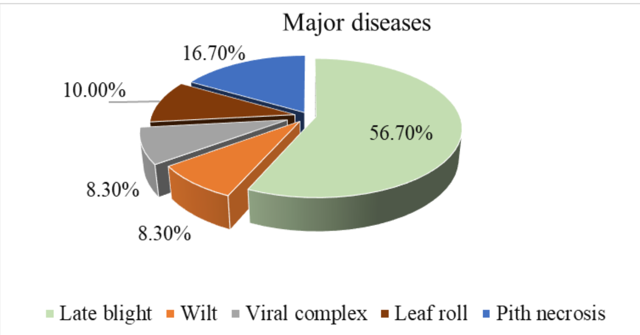
3.6 Major Disease and insect/pest problems

Three categories were used to classify the intensity of diseases and pests: low (<10%), medium (10–30%), and high (>30%) (See Table 10). The average loss due to disease was 21.48% while that due to pests was 14.32%. It might be attributed to sudden outbreaks and delay in diagnosis and management of the diseases and pests. Moreover, farmers apply the improper dose and method of pesticides application resulting in even greater diseases and pest's incidence and losses. Besides, 33.3% of respondent famers also faced physiological disorder i. e. blossom end rot reported to be caused by Ca deficiency.

Table 10: Major diseases, insects and pest incidence.

Incidence	Diseases		Pests	
	Frequency	Percent	Frequency	Percent
Low (<10%)	8	13.3%	7	11.7%
Medium (10-30%)	33	55.0%	42	70.0%
High (>30%)	19	31.7%	11	18.3%
Total	60	100.0%	60	100.0%

Late blight and pith necrosis were the major diseases while tomato leaf miner (*Tuta absoluta*) was the major insect problem in Lalitpur (See Figure 5). Chemical method of disease and pest management was the most preferred method of management. Moreover, IPM practices (using yellow traps and lures) was also widely followed by the growers.



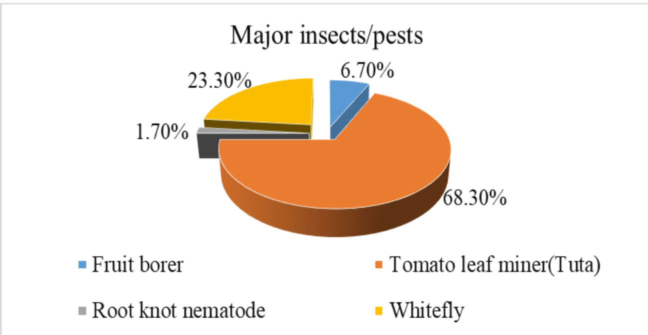


Figure 5: Major diseases and insect pests of tomatoes inside plastic tunnel in Lalitpur.

3.7 Market channels and intermediaries

Market and its intermediaries are key determinants of price of any commodity. In the study area, six marketing channels for tunnel-grown tomatoes were identified among which Channel no 5 (Producers-Collection Centers-Wholesalers-Retailers-Consumers) was the most widely used channel with a share of 31.7% (See Table 11). Balkhu and Kalimati Fruits and Vegetables Market were the top collection centers for the accumulation and distribution of tomatoes. The majority (81.7%) of the respondents were satisfied with the available market channels. Similar market channel was identified as a major marketing channel for tomatoes in neighboring district Kathmandu and ABPMDD (2016) in Nepal (Bhandari et al., 2021).

Table 11: Market channels of tomato followed in Lalitpur

Market channels	Channel No.	Frequency	Percent
Producers-Consumers	1	7	11.7%
Producers-Retailers-Consumers	2	11	18.3%
Producers-Wholesalers-Retailers-Consumers	3	15	25.0%
Producers-Middlemen-Wholesalers-Retailers-Consumers	4	1	1.7%
Producers-Collection Centers-Wholesalers-Retailers-Consumers	5	19	31.7%
Producers-Local Traders-Wholesalers-Retailers-Consumers	6	7	11.7%
Total		60	100.0%

3.8 Marketing problems

Lack of organized markets was the major marketing problem (See Table 12). Insufficient government concern toward the establishment of collection centers was responsible for unorganized markets. Perishability and lack of storage facility was found to be least serious problem probably because they directly sold tomato on same day of harvest. Farmers also mentioned an urgent need for an agricultural marketing act to reduce imports and encourage domestic consumption for making the nation self-sufficient in tomatoes.

Table 12: Major marketing problems of tomato in Lalitpur

Marketing constraints	1	0.8	0.6	0.4	0.2	Total Score	Index value	Rank
Lack of organized markets	16	30	9	5	0	47.4	0.79	I
Fluctuations in market price	27	11	15	4	3	47	0.78	II
Poor bargaining power and monopoly in price fixation	10	13	22	8	7	38.2	0.64	III
Lack of market information system	7	2	9	24	18	27.2	0.45	IV
Perishability and lack of storage facility	1	4	6	20	29	21.6	0.36	V

3.9 Access of household to credit and sources of credit

Credit accessibility is essential for effective production and marketing of tomatoes. About 65% of the respondents had access to credit. Out of total respondents, 32(53.3%) farmers had taken credit, bank being their dominant source (See Figure 6).

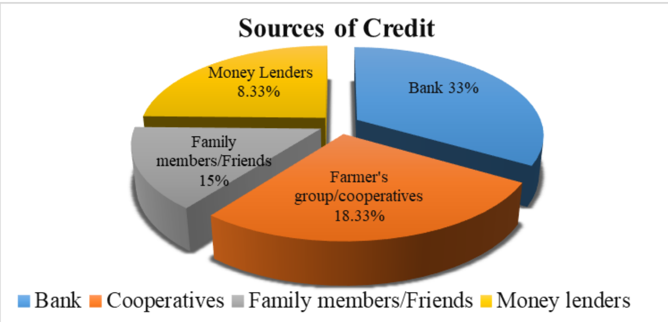


Figure 6: Sources of credit in the study area

3.10 Training, support and subsidy received and visit of extension workers

Training had a direct influence in the adoption of tunnels in tomatoes cultivation along with their higher tomato production in the study area. The types of training received included: Integrated Pest Management (IPM), commercial tomato farming inside the plastic tunnel, and Good Agricultural Practices (GAPs) training. Inputs (seeds, fertilizers, pesticides, manures, compost), 50% subsidy in equipment, loans at a low-interest rate, and training were the kind of support provided to the households. Cooperatives, service centers, and farmer's groups were among the sources of support. The Agriculture Knowledge Center (AKC), Lagankhel, the municipality, and the Prime Minister Agriculture Modernization Project's pocket program were the main providers of subsidies (PMAMP). Out of these, AKC was the prominent organization to provide incentives in the form of agricultural machinery, sprays, plastic ponds, plastic tunnels, etc. followed by loan and market information support. Farmers also mentioned lack of enough subsidy, which suggests the scope of intervention from the government to encourage existing growers through incentives. Majority of the tomato farms were often visited by the extension workers in the study area (See Figure 7).

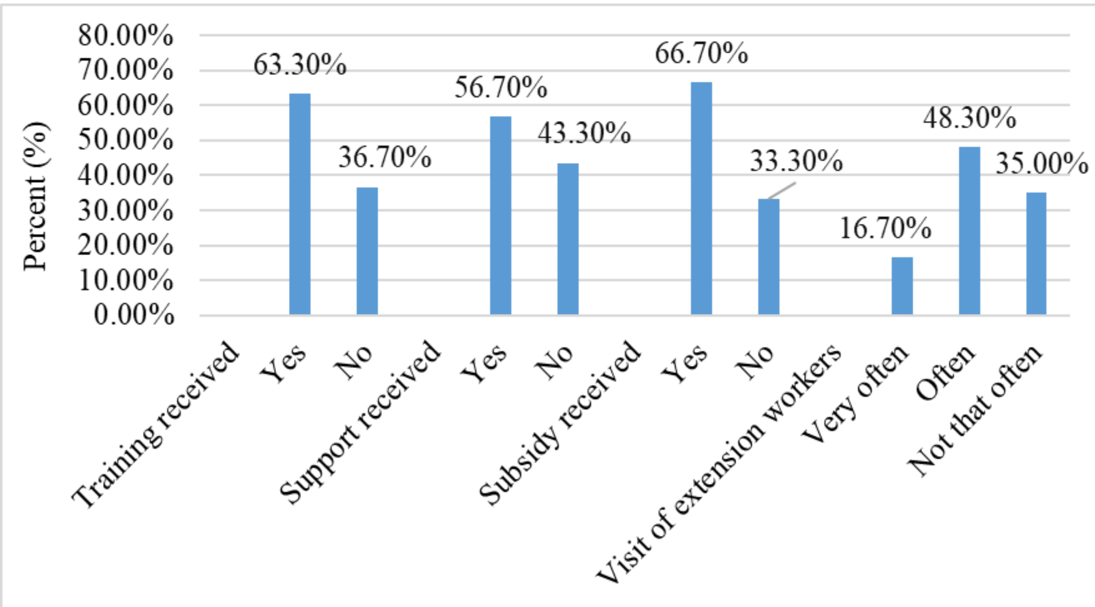


Figure 7: Training and support received and visit of extension workers in study area

3.11 SWOT Analysis

The major strengths, weaknesses, opportunities, and threats associated with tomato cultivation inside plastic tunnel identified from the study at Lalitpur are depicted in Table 13.

Table 13: SWOT Analysis of tomatoes production inside bamboo plastic tunnels in Lalitpur district

	Strengths	**Weaknesses**	
Strengths	Protection from damaging weather fluctuations such as rain Controlled temperature and humidity Better water conservation Enhanced quality and quality of the harvest Better maintenance of land fertility	Need of huge initial cost for plastic tunnel construction Plastic is sensitive to natural forces and gets damaged easily Higher incidence of certain pests and diseases, requiring high use of pesticides leading to high production cost High humidity and moisture levels in the early and late growing season are quite difficult to control	**Weaknesses**
	Opportunities	**Threats**	
Opportunities	Longer production duration Nearby market and timely availability of construction materials Government subsidies to construct a plastic tunnels and plastic ponds A transition towards offseason farming Availability of new farm technologies & machinery Limited supply from terai	Shortage of skilled labor Damage of tomatoes from unfavorable weather situation Damage of plastic due to wind, hailstones, and, other climatic hazards	**Threats**

4. Conclusion

Tomato cultivation inside plastic tunnel was identified as a labor-intensive yet remunerative enterprise for employment and income generation among small-scale farmers in the Lalitpur district. Profitability was evident from the higher gross returns per unit area, positive BC ratio, estimated net margin and gross margin. Labor cost and chemical fertilizer cost showed positive and significant relationship while seed cost and irrigation cost exhibited negative but significant relationship with gross revenue from tomatoes. Organic fertilizers, micronutrients, and pesticides cost had no significant effect on gross revenue from tomatoes. Farms were operating at decreasing return to scale indicating a decrease of 0.406 in gross returns with unit increase in input costs. Good returns were a major impetus for commercializing tomato production inside the plastic tunnel while the incidence of diseases and pests and lack of organized markets were major bottlenecks to the production and marketing of tomatoes on a commercial basis.

It highlights the exigency of market-oriented policies and programs linked with production to enhance production and marketing efficiency, in particular. Improved cultivation practices such as drip method of irrigation, plastic mulching, and IPM practices were regularly employed by tomato growers. Meanwhile, several biotic stresses such as tomato leaf miner (*Tuta absoluta)* and late blight were major limitations for tomato production. Producers selling tomatoes at farm gates and traders (collection centers, wholesalers, and retailers) involved in buying, assembling, transporting, and selling tomatoes were the main actors of the marketing system. Training, support, subsidies, and credits were available in sufficient amounts for the financial stability of growers. Controlled environment conditions, high construction costs, long production duration, and shortage of skilled labor were the major strength, weakness, opportunity, and threat of tomato cultivation inside a plastic tunnel. The study, therefore, revealed the high possibility and profitability of tunnel-grown tomatoes in view of production and marketing in Lalitpur.

Acknowledgements

We extend our special thanks to Agriculture and Forestry University, Chitwan for their funds support and Vegetables Crop Development Centre, Khumaltar for their continuous supervision and guidance during the study period. We are equally grateful to every farmer, farmer's groups, co-operatives, and Agriculture Knowledge Centre, Lagankhel, for providing valuable information on various aspects of tomato cultivation inside plastic tunnels in Lalitpur.

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