

RESEARCH ARTICLE

COMPARATIVE ANALYSIS OF PRODUCTION ECONOMICS OF TOMATO (*Solanum lycopersicum* L.) IN TUNNEL HOUSE AND OPEN FIELD CONDITIONS IN PANCHKHAL, KAVREPALANCHOK

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ABSTRACT

The survey was conducted in June 2024 in the Kavrepalanchok district's Panchkhal municipality (ward number 2 and 3). Survey research method was used to collect data from 86 respondents chosen from a sample frame of tomato farmers obtained from the annual report of Agriculture Development Office, Dhulikhel. Each 43-tunnel house and open field tomato growers were selected randomly and semi-structured questionnaire was used to collect primary information. The study revealed that out of total respondents selected in the study site, 53.49% of the household heads were female and 88.37% of them were Hindu. Majority of the tunnel house growers (51.16%) had the farming experience of "5 to 10 years" while open field growers had more than "10 years" of tomato farming experience with agriculture as main income source. Similarly, the average land coverage under tunnel house and open field tomato cultivation was 4.11 Ropani and 3.55 Ropani respectively (1 hectare is equivalent to 19.65 Ropani). Furthermore, Srijana was the most preferred variety by tunnel house tomato growers while majority of open field tomato growers adopted Dalila variety in the study area. Only 32.56% and 27.91% of the open field tomato growers had access to training and subsidy respectively which is significantly lower than that of tunnel house tomato farming system. The study results also showed that the total cost of growing tomato per Ropani (NRs. 48104.66) in tunnel house which was 51.12% higher than that incurred in the open field system (NRs. 23359.75). The gross return and gross revenue from tunnel house system were respectively 56.29% and 66.02% higher than that from open field tomato farming system. Similarly, the average selling price of tomato received by tunnel house farmer is also 40.34% higher than that received by open field tomato growers. Cobb-Douglas production function analysis was used to analyze, factor productivity and particularly seed, chemical fertilizer, farm yard manure, tillage, labor, pesticide and plant protection equipment were used as independent variables. Among the factor cost, chemical fertilizer, plant protection equipment cost and pesticide cost were found to be the significant contributor total revenue in tunnel house farming system while pesticide cost, chemical fertilizer cost and tillage cost were the major contributor of total revenue from open field farming system. Incidence of disease and insect/pests were found to be a major problem under both farming systems.

KEYWORDS

Tomato, survey, Open field, tunnel, production economics, Cobb-Douglas

1. INTRODUCTION

Cultivation of vegetable helps to ensure food security and ensures poverty reduction (Ishaq et al., 2003). Vegetable output and area are on the rise globally, as their yield is five to ten times higher than that of cereals and millets, and they grow quickly with shorter cropping times (Shende and Meshram, 2015). Agriculture is the primary sub-sector of the Nepalese economy for livelihood, employment, and socioeconomic reform, accounting for 24.1% of total national GDP (IBN, 2024). The production of vegetables in Nepal is greatly influenced by the country's many agro-ecological zones as well as seasonal variations in temperature and climate (Malla, 2021). 302,135 ha of cultivable land of Nepal is utilized for vegetable farming with the production of 4,376,077 mt and yield of 14.48 mt/ha (MoALD, 2024)

Among different vegetables, Tomato is the one of the major commercial crops for the income generation for Nepalese farmer residing in rural to

urban areas (Pandey et al., 2006). Tomatoes are a warm-season crop belonging to Solanaceae family and requires a lengthy growing season to provide a satisfactory production and the minimum, optimal, and maximum soil temperatures for tomatoes are 10°C, 25°C, and 30°C respectively (Gaikwad et al., 2020). It is regarded as a protective food because of its high nutritional value and large-scale production. Tomato is used in preserved foods, including paste, soup, chutney, sauce, and ketchup and can also be added to salads (Mohiuddin et al., 2007). Tomato is the third most important vegetable in Nepal after cauliflower and cabbage (MoALD, 2023). It thrives in the low and mid-hill regions of the Terai and is also gaining popularity in the high-hill regions as a means of earning revenue (Pandey, 2006). In the Terai, inner Terai, and foothills, open field cultivation is typical throughout the autumn-winter season. However, growing crops in plastic tunnels during the summer-rainy season is gaining popularity and earning higher prices in Nepal and surrounding Indian markets as it is sold as the off-season crop (Ghimire et

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al., 2018). Each year the production trend of tomato is found to be in increasing status due to its health benefits (Vitamins, antioxidants, minerals, dietary fiber) and for fresh consumption which led to the adoption of technology like tunnel farming for off season cultivation (Kafle and Shrestha, 2017). Kavrepalanchok is one of the largest tomatoes producing district in Nepal occupying a land area of 2,670 ha with production of 65,053 mt yielding 24.36 mt/ha (MoALD, 2024). Open field cultivation of tomato is nearly impossible during rainy and summer season because of extreme temperature and heavy rainfall so farmers has started to grow vegetables under tunnel house condition specially to protect crop from heavy rainfall during wet season (June to October) and provide a sheltered environment for production of better-quality crop over rainy season (Pandey, 2006). Nepal has lower tomato productivity than other developing countries because of absence of high-yielding, disease-resistant, or insect-pest-resistant types (Shrestha, 2022). In order to increase tomato productivity at both the national and district levels, it is necessary to establish enhanced and sustainable production systems that are not only inexpensive, but also flexible to changing climatic

situations (Wachira et al., 2014).

Hence, the findings of this study will enable farmers to choose a tomato production method which could result in higher on-farm employment, higher yields, higher farm earnings, better food nutrition, and higher living standards.

2. METHODOLOGY

2.1 Study Area

Kavrepalanchok is the one of the major vegetables producing district of Nepal with the production of 65,053 metric ton yielding 24.36 mt/ha in a land area of 2,670 ha (MoALD, 2024). It is the part of Bagmati province of Nepal which lies at latitude 27°32'44.52" North and longitude 85°38'00.96" East and the Panchkhal municipality was purposively selected for study due to the availability of tunnel house and open field tomato growers and also is the major contributor of vegetable production in this district.

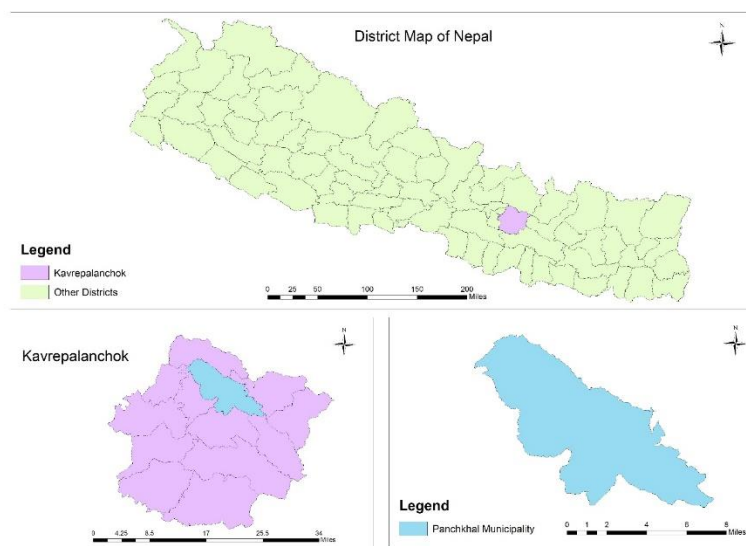


Figure 1: Map showing the study site in Kavrepalanchok district

2.2 Sampling Method

A list of tomato producer was obtained from the annual report of Agriculture Development Office, Dhulikhel, Kavrepalanchok which recorded at least 650 farmers involved in commercial production of vegetables. Therefore, a specific number of respondents were chosen as a representative sample of the entire population, mostly because of the obstacles. The sample size is obtained from the sampling frame using Yamane's formulae as follows with 10% margin of error. Thus, a total of 86 tomato growing households were selected, 43 each of open field growers and tunnel house growers by simple random sampling method. Primary data was collected using the pre-tested questionnaires and face-to-face interview schedule with the respondents and secondary data were collected from various sources like articles, journals, annual reports and so on. The collected data were first coded and entered in MS-EXCEL and analyzed using STATA version 64.

Yamane's Formula for Sample Size Calculation,

$$\text{Sample size (n)} = \frac{N}{1+N(e^2)}$$

Where, **n** represents size of sample, **N** represents population size and **e** represents error margin

2.3 Data collection

Preliminary field visit was carried out to learn more about the population structure, geographic location, socio-cultural context, current economic situation and the problem of the farmer regarding tomato cultivation under tunnel house and open field conditions which aided us to prepare the questionnaire. The prepared questionnaire was pre-tested for the validity of the interview schedule in the Dhulikhel municipality by randomly selecting 5 tomato growers. The final questionnaire was then prepared by taking due consideration of the suggestions obtained during pretesting to make the questionnaire more effective. Finally, household survey was conducted by randomly selecting the respondents of the Panchkhal municipality from any time April to June 2024 to get both quantitative and qualitative data. Secondary information was gathered from the multiple sites relevant to the study like official websites of

MoALD, ADO, journals, and other national and worldwide publications.

2.4 Data analysis techniques

All the data obtained from the field was coded, entered and tabulated in Software programs such as Microsoft Excel and the analysis were done using STATA version 64. A Cobb-Douglas Production Function (CDPF) regression model was used to determine the technological link between the factors used and the gross revenue from tomato production under both production systems. Descriptive statistics like average, percentage, standard deviation was estimated from the sociodemographic and economic data and represented in the form of pie-chart and diagrams. Following analyses were performed to compare the production economics of tunnel house and open field farming systems.

2.5 Cost of Production

The sum of all variable and fixed costs is total cost of production (Sinambela and Darmawan, 2022). It is calculated as given below:

$$\text{Total cost} = \sum \text{variable inputs} + \text{fixed inputs}$$

Where, Total Variable Cost which included all the running costs such as costs of input materials, fertilizers and manures, pesticides, human labor, machineries and transportation cost

TFC = Total Fixed Cost which includes the land lease, depreciation of tunnel and irrigation equipments

2.6 Gross Margin Analysis

Gross margin is calculated by subtracting the whole cost of production from the gross return (Bwala and John, 2018) and is calculated as:

$$\text{Gross Margin} = \text{Gross return} - \text{Total Variable Cost}$$

Where, Gross Return = Price of tomato per kg × Total tomato production(kg)

2.7 Benefit-Cost Ratio

The proportion of gross return to the total cost of any enterprises is

Benefit-Cost Ratio and it is calculated as given below:

B/C ratio= Gross Return / Total cost (Subedi et al., 2020)

2.8 Production function analysis

The Cobb-Douglas model is frequently utilized to illustrate how input levels influence production output and is known for closely reflecting real-world production patterns. In this research, the analysis aimed to examine how different elements contributed to differences in overall revenue between two contrasting farming systems.

$$Y = aX_1^{b_1} X_2^{b_2} X_3^{b_3} X_4^{b_4} X_5^{b_5} X_6^{b_6} X_7^{b_7} e^{\mu}$$

The above equation was transformed into log-linear form as follows:

$$\ln Y = \ln a + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + \dots + b_7 \ln X_7 + \mu \quad (\text{Dahal and Rijal, 2019})$$

Where, Y = Gross returns from tomato cultivation

X1 = cost of seed

X5 = cost of pesticides

X2 = Labor cost

X6 = tillage operation cost

X3 = Chemical fertilizer cost cost

X7 = Plant Protection equipment cost

X4 = Farm Yard Manure cost

μ = Random disturbance term or error term

a = Intercept or constant term

e = Base of natural logarithm

ln = Natural logarithm

b1, b2, b3, ..., b7 = Coefficient of respective variables

Ranking of production problems under both farming systems

The problems were ranked by calculating weighted indices of importance based on farmers' responses regarding production challenges.

The intensity of problem was computed by using the formula as used by (Subedi et al., 2019):

$$I_{imp} = \sum \frac{S_i f_i}{N}$$

Where, I_{imp} = index of importance

$\sum$ = summation

S_i = i^{th} scale value

F_i = frequency of i^{th} given by respondents

N = total no. of respondent

3. RESULTS AND DISCUSSION

3.1 Socio-demographic Characteristics of the Respondents

Table 1 presents a comparison of the sociodemographic attributes of the participants who adopted the two contrasting farming systems in the study area. The table shows that among the total respondents, 46(53.49%) of the household heads were female and only 40(46.51%) of them were male. Out of which among tunnel house tomato growers 22(51.16%) of household heads were male while for open field growers 25(58.14%) of the household heads were female.

Similarly, Household type varies significantly among two farming systems. In an overall, joint family type was dominant in the study site covering 49(56.98%) of the total respondents and 37(43.02%) had nuclear family which was significant at 5% level of significance. Among which, tunnel house adopters had higher proportion of joint families 30(69.77%) as compared to open field system of farming 19(44.19%). While, farmers farming in open field system, on the other hand had large representation of nuclear families covering 24(55.81%) in contrast to 13(30.23%) of tunnel house adopters.

Result shows that the majority of the farmers follow Hindu that is 76(88.37%) of the total respondents. Comparatively, 39(90.70%) of the tunnel house tomato growers' practices Hinduism while 37(86.05%) of the farmers farming in open field system followed Hinduism. Conversely, Farmers farming in open field system had higher percentage of Buddhist residents which is 6(13.95%) compared to the tunnel house adopters 4(9.30%). The results of household head, household type and religion align with the finding published by (NSO, 2021).

The educational status of the respondent in the study site was classified into five categories i.e. Illiterate, Primary Education, Secondary Education, Higher Secondary Education and Bachelor or above degree similar as in the study done by (Bhattarai et al., 2024). Result shows that 39(45.35%) of the total respondents have gained at least primary level of education, with 19(44.19%) tunnel house adopter and 20(46.51%) among open field tomato growers. Only 3(6.98%) of the tunnel house tomato cultivators were illiterate significantly lower than that of 10(23.26%) of open field tomato growers which aligns with the finding given by (Khan and Khan, 2020) depicting that education is crucial for adoption of any new technology.

Table 1 shows that the main source of income for both farming systems adopters in agriculture where majority i.e. 100% of the tunnel house system adopting farmers solely depends on agriculture for their income while 40(93.02%) of the open field growers are involved in agriculture and only small portion 3(6.98%) derived their primary income from the foreign source plus agriculture.

Table 1: Socio-demographic Characteristics of the Study Site

	Variables	System of Farming			Chi-square value	P-value
		Tunnel house(n=43)	Open field(n=43)	Over all(n=86)		
Household head	Male	22(51.16)	18(41.86)	40(46.51)	0.747	0.387
	Female	21(48.84)	25(58.14)	46(53.49)		
Household size	Nuclear	13(30.23)	24(55.81)	37(43.02)	5.74	0.017**
	Joint	30(69.77)	19(44.19)	49(56.98)		
Religion	Hindu	39(90.70)	37(86.05)	76(88.37)	0.45	0.501
	Buddhist	4(9.30)	6(13.95)	10(11.63)		
Educational Status	Illiterate	3(6.98)	10(23.26)	13(15.12)	5.73	0.22
	Primary	19(44.19)	20(46.51)	39(45.35)		
	Secondary	9(20.93)	5(11.63)	14(16.28)		
	Higher Secondary	6(13.95)	6(13.95)	10(11.63)		
	Bachelor Degree or above	4(9.30)	4(9.30)	10(11.63)		
Income Source	Agriculture	43(100)	40(93.02)	83(96.51)	3.108	0.078*
	Foreign Income plus agriculture	0	3(6.98)	3(3.49)		

Note: Figure in Parenthesis indicate percentage; *, ** indicates significance at 10%, 5% level of significance respectively

3.2 Farming Experience of the Respondents

The result shows that among the tunnel house farmers 48.84% of individuals had "<5 years of experience, while 51.16% of individual had

"5-10 years" of experience indicating a mix of novice and experienced farmers. Likewise, open field tomato growers also showed the mixed distribution of farming experience. Among all the categories, 16.28% of the individuals had "<5 years" of experience, 13.95% of the individuals had

"5-10 years" of experience, while 69.77% had "20 years" of experience demonstrating a significant presence of conventional tomato growers.

Also reported the similar findings in their study in Lamjung district which was significant at 1% level of significance (Chalise and Bhandari, 2014).

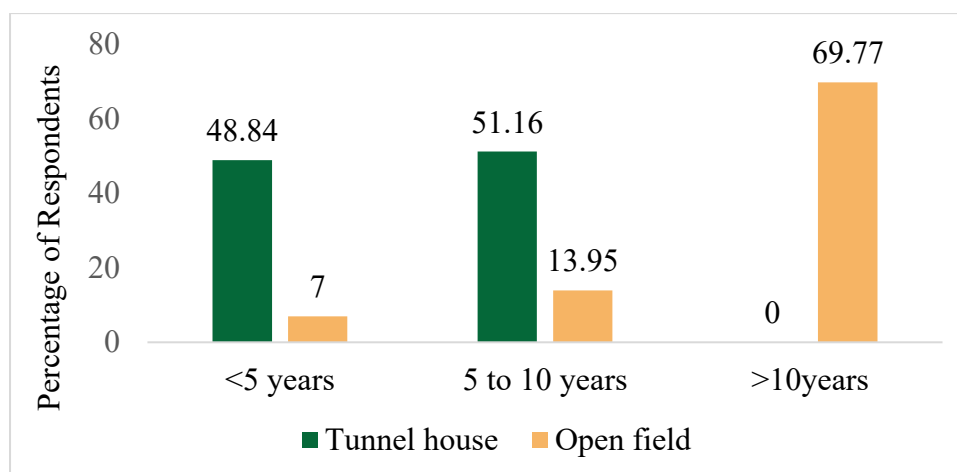


Figure 2: Farming experience of the respondents in the study site

3.3 Landholding Status of the Respondents

The average landholding size in the study area was found to be 8.47 Ropani. The average land holding among tunnel house tomato growers was approximately 9.88 Ropani, surpassing the landholding of open field tomato growers with average of 7.06 Ropani. The calculated p-value of 0.014 indicated statistical significance at 5% level of significance,

underscoring a significant discrepancy in land ownership between the two systems of tomato farming. Furthermore, tunnel house adopting farmers maintained an average of approximately 4.11 Ropani of land dedicated to tomato farming, whereas farmers adopting open field system reported a lower average of 3.55 Ropani. The p-value of 0.224 indicates that this difference does not reach statistical significance at the 5% level.

Table 2: Landholding Status of the Respondents

Landholding Categories	Farming System		Mean difference	T-value	P-value
	Tunnel house	Open field			
Total Land Owned Area	9.88(3.91)	7.069(6.20)	2.81	2.514	0.013**
Total Area Under Tomato Cultivation	4.11(1.78)	3.55(2.39)	0.55	1.224	0.224

Note: Figure in parenthesis indicates Standard Deviation; 1hectare equivalent to 19.66 Ropani

** indicates significant at 5% level of significance

3.4 Varieties Adopted

Proper varietal selection plays significant role in tomato production and income generation. Result revealed that Srijana, Dalila and Kabita are the major varieties adopted by the farmers in the study site. Srijana variety was mostly preferred by the tunnel house tomato growers (76.84%) which is in line with the finding given by (Chapagain et al., 2012) because

of its extreme flexibility, great flexibility and disease resistance capacity. Only 23.25% of them preferred Dalila and the mixture of Srijana and Kabita variety was not popular in this farming system. In contrast to this condition, only 9.30% of the open field tomato growers preferred Srijana variety and 23.23% of them adopted the mixture of Srijana and Kabita variety. Dalila was the most preferred variety among the open field tomato growers as 67.54% of them uses this variety.

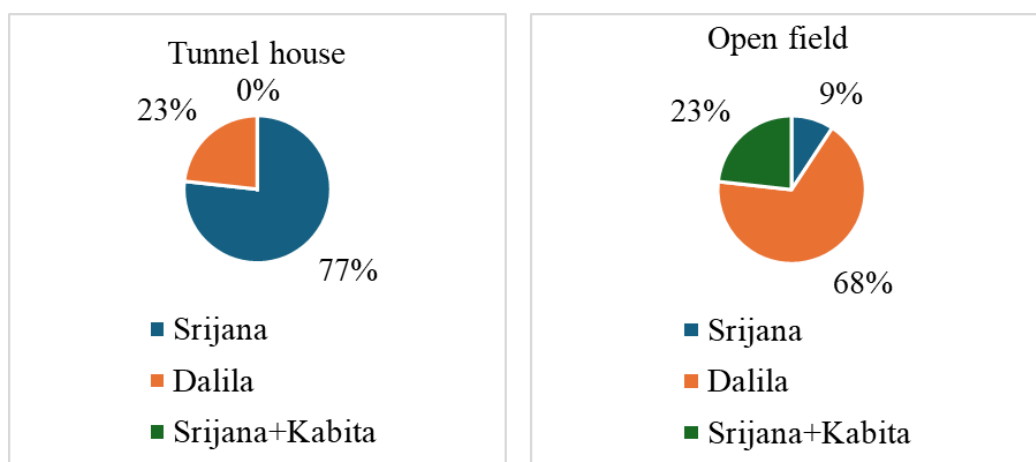


Figure 3: Varietal preference among the farmers adopting two farming systems

3.5 Access to Subsidy and Training by the Respondents

In the examined study area, a stark contrast in access to subsidies existed between the tunnel house and open field tomato growers. The study revealed that 79.07% of the respondents among the tunnel house adopters had the access to subsidies compared to only 27.91% among the open field farmers.

Similarly, the study revealed that 62.79% of the tunnel house tomato growers participated in the training while only 32.56% of the open field tomato producers had access to training provided by different non-governmental organization like Love Green Nepal, Agriculture Development Office (ADO) etc. demonstrating a highly significant difference in access to training and subsidies among the two farming systems adopters and these results aligns with the finding given by (Bhattarai et al., 2024).

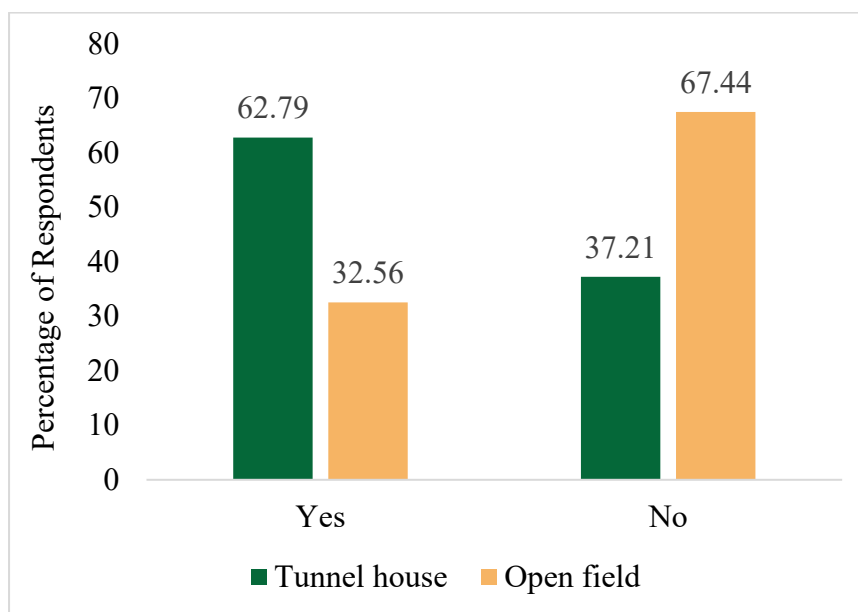


Figure 4: Access to Training

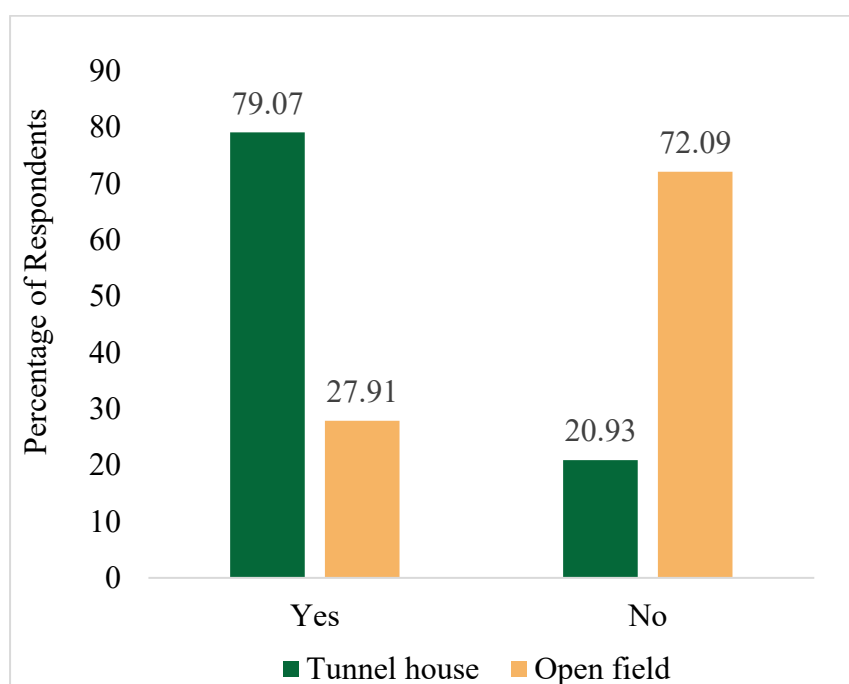


Figure 5: Access to subsidy

3.6 Economics of Production

3.6.1 Average Cost of Production

Table 3 demonstrates the comparison of cost parameters associated with tomato production between tunnel house farming system and open field farming system, several key observations emerge.

Seed is the key element that affects the crop's overall production. The average cost of the seed used in tunnel house was Nrs.829.82 while in open field system was Nrs.931.22 and no significant difference was found between seed cost among two farming system. Tillage operations significantly improve gross return because they change the physio-chemical characteristics of the soil, promoting chemical reactions and increasing the soil's physio-chemical condition, which leads to improved growth and yield (Wasaya et al., 2019).

The study revealed that tunnel house farming system exhibited a higher average tillage cost of NRs. 1181.72, in contrast to open field farming system NRs. 1040.46 which was statistically significant at 5% significance level. Similarly, open field farming system costs NRs. 589.54 for the use of farm yard manure (FYM), while the tunnel house farming method had a higher average cost of NRs. 852.24 which was significant at 1% level of significance.

Likewise, Pesticides cost in one of the major input costs involved in the

production of vegetables especially tomato in Kavrepalanchok district of Nepal (Thapa et al., 2015). On comparison, tunnel house farming system showed comparatively lower pesticide cost NRs. 9029.9 than that in open field farming system NRs. 9866.55 indicating that open field farmers heavily depend on the pesticides for higher yield. Furthermore, Urea, DAP and Potash were the major chemicals used as fertilizer under both farming systems. Tunnel house farming system used the higher average cost of chemical fertilizer NRs. 1188.19 which was significantly higher than used in open field farming system NRs. 645.91 which is significant at 1% level of significance.

Human labor is another major input used during the cultivation of tomato which is calculated in man-days and later converted to monetary value making tomato farming more expensive especially in tunnel house system (Galinato and Miles, 2013). It was required to perform different activities from preparation of nursery bed to harvesting and transplanting of tomato. Result shows that the labor expenses were statistically higher in the tunnel house farming system NRs.10382.94 as compared to the open field farming system NRs.5327.298 which was also statistically significant at 1% level of significant.

Similarly, Transportation cost and plant protection equipment cost NRs.8563.67, NRs.2177.27 incurred respectively in poly house system was higher as compared to open field farming system NRs.2922.48, NRs.484.60 respectively which is statistically significant at 1% level of significant.

Table 3: Average cost of production (NRs.) per Ropani in the study area

Cost Parameters	Farming System		Mean difference	T-value	P-value
	Tunnel house	Open field			
Seed	829.82(502.97)	931.22(344.85)	-101.39	-1.09	0.278
Tillage Operation	1181.72(370.33)	1040.46(201.73)	141.26	4.27	0.03**
FYM	852.24(346.44)	589.54(270.35)	262.704	9.06	0.01***
Chemical Fertilizer	1188.19(116.73)	645.91(131.17)	542.28	20.25	0.001***
Pesticide	9029.9(5877.98)	9866.55(6928.48)	-836.65	-0.601	0.549
Mulching Plastic	5062.5(1125.0)	4792.46(1439.42)	270.03	0.367	0.716
Labor	10382.94(2865.27)	5327.29(2298.36)	5055.64	9.02	0.001***
Transportation	8563.67(2197.26)	2922.48(523.67)	5641.19	16.37	0.001***
PPE	2177.27(1580.48)	484.60(373.58)	1692.66	5.62	0.001***

Note: Figures in parenthesis indicates standard deviation; **, *** indicates significance at 5% and 1% level of significance; 1hectare equivalent to 19.66 Ropani

3.7 Cost and Return analysis

Overall, the total cost of production of tomato per Ropani in open field farming was Rs. 23359.75 which was significantly lower than that of the tunnel house farming Rs. 48104.66 which is statistically significant at 1% level of significance. The variable cost per Ropani was Rs. 22899.03 in open field farming which was significantly less than tunnel house farming Rs. 33171.79. Total fixed cost per Ropani in tunnel house farming was Rs 14932.87 which was significantly higher than in open field farming Rs. 1497.09. The cost analysis shows that the major cost incurred in tunnel house system is fixed cost which is consistent with the finding given by (Janke et al., 2017). The analysis of the total costs of production revealed that the main cost items in open field were pesticides cost followed by fixed cost, labor cost, mulching cost, transportation cost, tillage cost, chemical fertilizer cost, FYM cost and PPE cost while in case of tunnel house cultivation the main cost items were fixed cost, followed by labor costs, pesticide costs, transportation cost, mulching cost, PPE cost, chemical fertilizer cost, FYM cost and seed cost respectively.

The gross return and gross margin from the open field farming was Rs 46127.91, Rs. 23228.88 which was respectively 56.29% and 66.02% lower than that of poly house which was Rs 105548.9 and NRs 72502 which was due to lower average price received by the open field tomato growers. These findings are statistically significant at 1% level of significance and aligns with the finding given by (Chalise and Bhandari, 2014). The yield of tomato in tunnel house system was 2144.24 kilograms per Ropani with a standard deviation of 563.86 which is higher than an open field farming system with yield of 1983.35 kg per Ropani and standard deviation of 529.87. The mean difference between two systems is 161.89 which was not significant. The highest average price per kilogram of tomato received by tunnel house farmer is NRs. 50.49 while open field tomato growers receive NRs. 30.11. The p- value for average selling price is also 0.000 which indicates that the value is significant at 1% level of significance. Although not statistically significant, the BCR was greater in tunnel house farming (2.27), as opposed to open field farming (2.09). Also showed the similar findings for average selling price and BC ratio while conducting the comparative study of tomato production in tunnel and open field conditions in Dhading, Nepal (Khadka and Adhikari, 2021).

Table 4: Return and Revenue analysis among tunnel house and open field

Parameters	Farming System		Mean difference	T-value	P-value
	Tunnel house	Open field			
Total Variable Cost (Rs/Ropani)	33171.79(9509.41)	22899.03(8107.87)	10272.76	5.39	<0.01***
Total Fixed Cost (Rs/Ropani)	14932.87(3863.09)	6437.5(2244.78)	8495.37	6.66	<0.01***
Total Production Cost (Rs/Ropani)	48104.66(11300.44)	23359.75(8093.23)	24744.91	11.67	<0.01***
Total Production(kg/Ropani)	2144.24(563.86)	1982.35(529.87)	161.89	1.37	0.17
Average SP(Rs/kg)	50.48(10.59)	26.44(8.41)	24.04	13.71	<0.01***
Gross Return (Rs/Ropani)	105548.9(23459.43)	46127.91(17516.98)	59420.96	13.30	<0.01***
Gross Margin (Rs/Ropani)	72502(23062.55)	23228.55(15552.22)	47865.77	11.61	<0.01***
BC Ratio	2.27(0.56)	2.09(0.98)	0.175	1.01	0.243

Note: Figure in parenthesis indicate standard deviation; *** indicates significance at 1% level; 1hectare equivalent to 19.66 Ropani

3.8 Cobb-Douglas Production function for Tunnel house farming system

In case of the tunnel house farming system, the model's R^2 value of 0.8811 indicated that it has robust explanatory power, with 88.1% of the variations in total income from tomato production explained by the included explanatory variables. Examining individual explanatory variables, chemical fertilizer, pesticide cost and plant protection equipments had statistically significant impacts on total income from tomato production. Result shows that a 100% increase in chemical fertilizer cost resulted to 65.9% increase in total income which was statistically significant at 1% level of significant. Similarly, 100% increase

in Plant protection equipments cost lead to 9.1% increase in total income which was found to be significant at 1% level. Seed, FYM and tillage cost was found not to have significant impact on the total income to the tomato i.e.100% increase in the seed cost resulted 5.1% increase in the total income which was not statistically significant. Similarly, 100% increase in the tillage cost lead to 12.6% and 0.94% increase in the total income which was not statistically significant. In contrast, an increase in pesticide cost by 100% was associated with only a 9.2% decrement in total income, with statistical significance at 5% level. Our results are consistent with those who noted that the least squares approach is frequently used after the models have been linearized using a logarithmic transformation in order to fit the collection of Cobb-Douglas production functions (Prajneshu, 2008).

Table 5: Cobb-Douglas Production Function of Tomato Production in Tunnel house

Explanatory Variables	Coefficient	Standard Error	T-value	P-value
Constant	5.896	0.716	8.23	0.452
Seed Cost	0.051	0.068	0.76	0.156
FYM Cost	0.126	0.087	1.45	0.156
Chemical Fertilizer	0.659	0.179	3.68***	0.001
Pesticide Cost	-0.092	0.044	-2.09**	0.044
Labor Cost	0.0091	0.106	0.09	0.932
Till Cost	0.0094	0.073	0.13	0.898
PPE	0.091	0.027	3.33***	0.002
No. of Observation	43			
F-value	37.07			
R ²	0.8811			
Adjusted R ²	0.8574			

Note: *, **, *** indicates significant at 10%, 5% and 1% level of significance

3.9 Cobb-Douglas production function in open field system

In case of the open field farming system, the model's R² value of 0.863 indicated that it had robust explanatory power, with 86.3% of the variations in total income from tomato production explained by the included explanatory variables. Of the seven independent factors, the costs of seed, FYM, chemical fertilizer, pesticides, and tillage had the biggest effects on the production's overall revenue. Firstly, 100% increase in the chemical fertilizer cost lead to 59% increase in the total income from tomato production which was statistically significant at 5% level, while 100% increase in the pesticide cost lead to 19.5% increase in the total income which was significant at 5% level. Similarly, 100% increase in the

tillage cost lead to 70.2% increase in the total income which was significant at 1% level of significant. While the labor cost and the plant protection equipment cost did not have significant impact on the total income from the tomato production. While in contrast, 100% increase in the seed cost lead to 28% decrement to the total income which was statistically significant at 10% level. Similarly, 100% increase in the FYM cost lead to 34.1% decrement to the total cost which statistically significant at 10% level of significant. Our results are consistent with those, who noted that the least squares approach is frequently used after the models have been linearized using a logarithmic transformation in order to fit the collection of Cobb-Douglas production functions (Prajneshu, 2008).

Table 6: Cobb-Douglas Production Function of Tomato Production in Open field

Explanatory Variables	Coefficient	Standard Error	T-value	P-value
Constant	3.967	0.98	4.03	0.000
Seed Cost	-0.28	0.146	-1.96*	0.058
FYM Cost	-0.341	0.193	-1.77*	0.086
Chemical Fertilizer	0.59	0.236	2.49**	0.018
Pesticide Cost	0.195	0.073	2.66**	0.012
Labor Cost	0.027	0.096	0.28	0.778
Till Cost	0.702	0.236	2.97***	0.005
PPE	0.022	0.087	0.26	0.797
No. of Observation	43			
F-value	31.73			
R ²	0.8639			
Adjusted R ²	0.8366			

Note: *, **, *** indicates significant at 10%, 5% and 1% level of significance

3.10 Production Problem Ranking among two different farming systems

Both the farming system faced the similar production problems, with the top problem being the incidence of disease and insect/pest. Tunnel house farming system had an index score of 0.98, while open field farming system had an index score of 1, both ranking as the highest problem in their respective regions. The second most significant problem was the lack of availability of quality seed, with open field scoring 0.74(II) and tunnel house scoring 0.68(II). The third most prevalent problem for the tunnel

house farming system was lack of irrigation facilities scoring 0.66(III) while for open field farming system was lack of timely availability of fertilizer, scoring 0.60(III). Similarly, the fourth most important problem was lack of irrigation facilities for open field farming system scoring 0.46(IV), while for tunnel house farming system was lack of timely availability of fertilizer, scoring 0.46(IV). Lastly, the lack of availability of labor was noted as the fifth major problem where both the farming system had an index score of 0.20(V). The most prominent production challenge was the incidence of disease and insect/pest faced by both the farming systems.

Table 7: Production Problems in two Different tomato Farming Systems

Production Problems	System of Farming			
	Tunnel house		Open field	
	Index	Rank	Index	Rank
Incidence of disease and insect/pest	0.98	I	1	I
Lack of irrigation facilities	0.66	III	0.46	IV
Lack of availability of quality seed	0.68	II	0.74	II
Lack of timely availability of fertilizer	0.46	IV	0.60	III
lack of availability of labor	0.20	V	0.20	V

4. CONCLUSION

The comparative production economics of tomato farming in two farming systems revealed that tomato farming was practiced predominantly by females and Hindu farmers. The results of the study indicated that both farming strategies were lucrative at the study location. On comparison, the total cost of production of tomato per Ropani in tunnel house system was more than double (51.12% higher) than that of open field farming system which was mainly about by the expense of tunnel housing building. However, despite of having higher total cost, the gross return, gross margin from tunnel house system were 56.29%, 66.02% respectively higher than that of the open field system. Similarly, the average selling price of per kilogram of tomato received by tunnel house farmer was also 40.34% higher than received by open field tomato growers despite having similar yield in both systems. The Cobb Douglas Production function analysis highlighted the significant influence of chemical fertilizer, pesticide, and PPE costs on income variations in tunnel house systems while seed, FYM, pesticide, chemical fertilizer, and tillage costs in open field farming systems. Incidence of disease and insect/pests were found to be a major problem in both farming systems therefore, integrated pest management can be adopted.

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