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Comparative Profitability and Yield Determinants of Hybrid and Local Tomato Production in Parachinar, Pakistan: Evidence from Farm-Level Data

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	Abstract
<p>Dr. Mohammad Fayaz Institute of Business and Management Sciences (IBMS), The University of Agriculture Peshawar, Pakistan Email: mfayaz@aup.edu.pk</p> <p>Dr. Farhana Gul Department of Economics, The University of Swabi, Pakistan. Email: farhana@uoswabi.edu.pk</p> <p>Muhammad Ali Nadeem M.Sc (Hons), Department of Agricultural & Applied Economics, The University of Agriculture Peshawar, Pakistan</p>	<p>This study compares the profitability of hybrid and local tomato production in Parachinar, Pakistan, and identifies the factors influencing tomato yield. Data from 112 tomato growers were analyzed using enterprise budgeting, t-tests, and OLS regression. Hybrid tomatoes produced significantly higher yields (2,955.5 kg acre⁻¹) and net returns (Rs. 106,095 acre⁻¹) than local varieties, despite slightly higher production costs. The benefit-cost ratio was also higher for hybrid production (2.04) than for local production (1.92). Regression results revealed that labor use and the application of nitrogen and phosphorus fertilizers significantly increased yield, while tractor use had no significant effect. The findings suggest that hybrid tomato cultivation offers a more profitable and productive option for farmers. Promoting access to quality hybrid seed and improved nutrient management can further enhance tomato productivity and farm income.</p>
Keywords	Hybrid tomato, profitability, productivity, yield determinants, Pakistan



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Introduction

Tomato (*Solanum lycopersicum* L.) is among the most important vegetable crops cultivated worldwide and plays a crucial role in ensuring food security, improving nutrition, and generating income for farming households (FAO, 2022; Heuvelink, 2018). The crop is valued for its high nutritional content, including vitamins A and C, minerals, antioxidants, and lycopene, which contribute significantly to human health and disease prevention (Willcox et al., 2003; Raiola et al., 2014). Globally, tomato production has expanded considerably over the past two decades due to increasing consumer demand and the development of improved production technologies (FAO, 2022; Heuvelink, 2018).

In Pakistan, tomato is a major vegetable crop grown across diverse agro ecological zones. The vegetable sector contributes substantially to agricultural gross domestic product (GDP) and rural employment (Government of Pakistan, 2024). Despite favorable climatic conditions, tomato productivity in Pakistan remains relatively low compared with international standards. This productivity gap is largely attributed to poor-quality seed, inadequate nutrient management, pest and disease pressure, and limited access to modern production technologies (Government of Pakistan, 2014; FAO, 2022; PARC, 2021; Malik et al., 2018; and Hassan et al., 2021).

Hybrid tomato varieties have been increasingly promoted as a means of improving productivity and farm profitability. Compared with traditional local varieties, hybrids generally possess higher yield potential, better resistance to biotic and abiotic stresses, improved fruit quality, and superior market acceptance (Kalloo, 1991; Engindeniz, 2007; Chandanshive et al., 2016; Heuvelink, 2018; Singh et al., 2020). Several studies have reported that adoption of hybrid seed technology can significantly increase vegetable yields and farm income (Birthal et al., 2001; Engindeniz, 2007; Bayramoglu et al., 2010; Tambo et al., 2010). However, hybrid cultivation often requires higher investment in quality seed and complementary inputs, raising questions regarding its economic feasibility for smallholder farmers (Birthal et al., 2001; FAO, 2022). Parachinar, located in Kurram District of Khyber Pakhtunkhwa, is recognized as an important vegetable-producing region due to its favorable climate and abundant irrigation water supplied through natural streams. Agriculture, particularly vegetable cultivation, constitutes an important source of livelihood for farming households in the area (Government of Khyber Pakhtunkhwa, 2020; Muhammad et al., 2024). Tomato production is among the major vegetable enterprises contributing to household income and local agricultural development (FAO, 2022). Nevertheless, empirical evidence comparing the economic performance of hybrid and local tomato varieties in the district remains limited. Therefore, this study was designed to compare the profitability of hybrid and local tomato production systems and identify the major factors influencing tomato yield.

The specific objectives were:

1. To estimate and compare production costs and returns of hybrid and local tomato varieties.
2. To assess differences in yield and profitability between hybrid and local tomato growers.
3. To identify key determinants affecting tomato productivity in the study area.

Data and Methodology

Study Area

The study was conducted in Parachinar, the administrative headquarters of Kurram District, Khyber Pakhtunkhwa, Pakistan. The region is situated in the northwestern mountainous zone of the country and is characterized by fertile valleys, moderate summer temperatures, and sufficient water resources that favor vegetable production (Government of Khyber Pakhtunkhwa, 2020; Pakistan Meteorological Department, 2023). Agriculture is the primary source of livelihood for the majority of rural households, and tomato cultivation represents one of the most important commercial vegetable enterprises in the area (Pakistan Bureau of Statistics, 2023; Government of Pakistan, 2024). The climate of Parachinar is suitable for tomato cultivation due to its relatively cool summer temperatures and availability of irrigation water from natural streams (Pakistan Meteorological Department, 2023). These favorable agro ecological conditions enable farmers to cultivate both local and hybrid tomato varieties for commercial purposes (Government of Khyber Pakhtunkhwa, 2020).

Sampling Design and Sample Selection

A multistage sampling technique was employed to select respondents. Multistage sampling is widely used in agricultural socioeconomic studies because it facilitates representative selection from geographically dispersed populations (Kothari, 2004).

In the first stage, Kurram District was purposively selected because of its importance in vegetable production. In the second stage, two major tomato-producing villages, namely Kirman and Sragalla, were selected based on the concentration of tomato growers. In the third stage, a list of tomato-producing households was obtained from local agricultural extension personnel and village representatives.



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Using proportional allocation sampling, a total of 112 tomato growers were selected. The sample comprised 56 hybrid tomato growers and 56 local tomato growers. Equal representation of both groups facilitated meaningful comparison between production systems.

Data Collection

Primary data were collected through a structured and pre-tested questionnaire administered through face-to-face interviews. The questionnaire was designed to collect information on:

- Socioeconomic characteristics of farmers
- Farm size and resource endowment
- Input utilization
- Labor use
- Fertilizer application
- Production costs
- Yield levels
- Marketing practices
- Revenue generation

Prior to the survey, the questionnaire was pre-tested on a small group of tomato growers outside the sampled villages. Necessary modifications were incorporated to improve clarity and reliability of the instrument.

Both quantitative and qualitative information were collected. Secondary information regarding tomato production and agricultural development was obtained from government publications, research reports, and scientific literature.

Analytical Framework

Data were coded and entered into SPSS and STATA software for statistical analysis. Descriptive statistics, enterprise budgeting techniques, independent-sample t-tests, and Ordinary Least Squares (OLS) regression analysis were employed.

Descriptive Statistics

Descriptive statistical measures such as frequencies, percentages, means, and standard deviations were used to summarize the socioeconomic characteristics of respondents and production practices.

According to Gujarati and Porter (2009), descriptive statistics provide an essential foundation for understanding the structure and characteristics of survey data before conducting inferential analyses.

Cost and Return Analysis

Enterprise budgeting was used to estimate production costs and profitability of tomato cultivation. Enterprise budgeting is a standard approach in farm management studies for evaluating economic performance of agricultural enterprises (Debertin, 2012).

Total production cost included:

- Nursery raising cost
- Land preparation cost
- Labor cost
- Fertilizer cost
- Pesticide cost
- Irrigation cost
- Land rent
- Marketing cost



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The following equations were used:

Gross Revenue

$$GR=Q \times P$$

where:

GR = Gross Revenue (Rs. acre⁻¹)

Q = Quantity of tomato produced (kg acre⁻¹)

P = Selling price (Rs. kg⁻¹)

Net Revenue

$$NR=GR-TC$$

where:

NR = Net Revenue

GR = Gross Revenue

TC = Total Cost of Production

Benefit-Cost Ratio

For additional profitability assessment, the Benefit-Cost Ratio (BCR) may be expressed as:

BCR=GR/TC where a value greater than one indicates economic profitability (Olukosi & Erhabor, 2008).

Comparative Analysis

Independent-sample t-tests were employed to compare mean differences between hybrid and local tomato growers.

The t-statistic was calculated as:

$$t = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{Sp \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

Where

\bar{X}_1 = the mean of first sample

\bar{X}_2 = the mean of second sample.

Sp Represents the pooled standard deviation and can be measures as follows.

$$Sp = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{(n_1 + n_2 - 2)}}$$

Similarly s_1^2 shows the variance of the first sample and s_2^2 shows the variance of the second sample.

This technique is commonly used in agricultural economics research to compare performance indicators across groups (Field, 2018).

The following variables were compared:

- Yield per acre
- Production cost per acre
- Net revenue per acre

Econometric Analysis

3.6.1 Specification of the Production Function

To identify determinants of tomato yield, a Cobb-Douglas like production function was estimated using Ordinary Least Squares (OLS).

The Cobb-Douglas like functional form is widely applied in agricultural production economics because estimated coefficients directly represent output elasticities (Debertin, 2012).

The empirical model was specified as:

$$\ln Y = \beta_0 + \beta_1 \ln Tr + \beta_2 \ln Lab + \beta_3 \ln N + \beta_4 \ln P + \epsilon$$

where:

LnY = Natural log of tomato yield per acre

LnTr = Natural log of Tractor hours per acre

LnLD = Natural log of labour days per acre

LnLN = Natural log of nitrogenous fertilizer applied per acre in Kgs.

LnP = Natural log of phosphorus fertilizer applied per acre in Kgs.

ϵ = Error term

Diagnostic Tests

After estimating the regression model, the following diagnostic tests were conducted to verify the validity of model assumptions.

Multicollinearity

Variance Inflation Factor (VIF) analysis was used to assess multicollinearity among explanatory variables. According to Hair et al. (2019), VIF values exceeding 10 indicate serious multicollinearity problems. In this study, all VIF values were below the critical threshold, indicating the absence of severe multicollinearity.

Heteroscedasticity

Robust standard errors were used to correct potential heteroscedasticity. Robust estimation improves reliability of statistical inference when variance of residuals is not constant (Wooldridge, 2020).

Hypotheses

The study tested the following hypotheses:

H0₁: There is no significant difference in yield between hybrid and local tomato varieties.

H0₂: There is no significant difference in production costs between hybrid and local tomato varieties.

H0₃: There is no significant difference in net revenue between hybrid and local tomato varieties.

H0₄: Labor, fertilizer use, and tractor hours do not significantly affect tomato yield.

Results and Discussion

Socioeconomic Characteristics of Tomato Growers

The survey results revealed (see Table-1) that tomato production in the study area was primarily undertaken by middle-aged farmers possessing considerable farming experience. Most respondents belonged to large household structures, reflecting the prevalence of joint family systems in the region. The majority of farmers relied on agriculture as their principal source of income and had access to stream irrigation, which reduced irrigation costs and supported intensive vegetable production. These findings are consistent with previous studies reporting that farming experience, family labor availability, and reliable irrigation positively influence vegetable production and farm productivity (Abdulai & Huffman, 2014; Government of Pakistan, 2024).

More than two-thirds of the respondents reported easy access to hybrid tomato seed, indicating increasing diffusion of improved seed technologies in the study area. However, marketing remained largely dependent on intermediaries (Beoparis), suggesting limited direct market access for producers. Similar observations regarding the role of middlemen and marketing constraints in Pakistan's vegetable sector have been reported by Hassan et al. (2012) and Ali et al. (2020).

Comparative Cost Structure of Tomato Production

The average production cost of hybrid tomato was estimated at Rs. 102,381 per acre, slightly higher than the Rs. 99,012 per acre incurred by local tomato growers (see Table-2). Although hybrid cultivation required greater expenditure on nursery raising and seed acquisition, differences in total production cost were statistically insignificant. Similar

observations have been reported by Engindeniz, Selçuk (2007) and Birthal, Pratap S. et al. (2001), who found that hybrid vegetable production generally involves higher input costs, particularly for seed and nursery management.

Land rent represented the largest cost component, accounting for approximately 21% of total production expenses for both varieties. Fertilizer expenditure constituted another major component, contributing approximately 22% of total costs. Labor expenses represented nearly 30% and 27% of total production costs for hybrid and local tomatoes, respectively. These findings indicate that labor and fertilizer management are critical determinants of production efficiency, which is consistent with previous studies identifying labor, fertilizer, and land costs as the major contributors to vegetable production costs (Heuvelink, 2018; Engindeniz, 2007; FAO, 2022).

Marketing expenses accounted for approximately 16% and 15% of total costs for hybrid and local tomatoes, respectively. Transportation and packaging materials represented the largest marketing cost components, highlighting the importance of post-harvest handling and market infrastructure in determining profitability. Similar conclusions have been reported by Kitinoja, Lisa and Kader, Adel A. (2015) and the Food and Agriculture Organization (FAO, 2019), who emphasized that transportation, packaging, and post-harvest handling substantially influence producers' net returns.

Yield Performance of Hybrid and Local Tomatoes

The results demonstrated a clear productivity advantage of hybrid tomato varieties. Average yield of hybrid tomatoes was 2,955.5 kg per acre compared with 2,709.4 kg per acre for local varieties. The mean yield difference of 246.1 kg per acre was statistically significant ($t = 2.72$, $p = 0.008$), indicating superior performance of hybrid varieties under local production conditions (see Table-3).

The higher yield achieved by hybrid growers may be attributed to improved genetic potential, greater responsiveness to fertilizer application, and enhanced resistance to environmental stresses (Chandanshive et al., 2016; Singh et al., 2020). These findings support the growing body of evidence suggesting that hybrid technologies can substantially improve vegetable productivity among smallholder farmers.

Profitability Analysis

Hybrid tomato cultivation generated substantially greater economic returns than local tomato production. Average gross revenue from hybrid tomatoes was Rs. 208,954 per acre compared with Rs. 190,524 per acre from local varieties (see Table-4).

Similarly, average net revenue from hybrid tomato production was estimated at Rs. 106,095 per acre, significantly exceeding the Rs. 91,542 per acre earned (see Table-4) by local tomato growers. The mean difference of Rs. 14,553 per acre was statistically significant ($t = 3.02$, $p = 0.003$). These results indicate that although hybrid tomato production involves slightly higher production costs, the additional expenditure is more than compensated by increased yield and revenue. Consequently, hybrid tomato cultivation offers a superior return on investment and represents a more profitable production strategy for farmers in the study area. Similar findings have been reported by Engindeniz (2007), Heuvelink (2018), and Birthal et al. (2001), who observed that hybrid vegetable production generally generates higher yields, greater market returns, and improved farm profitability despite increased input costs.

Benefit-Cost Ratio (BCR) Analysis

The Benefit–Cost Ratio (BCR) was calculated to assess the economic efficiency of hybrid and local tomato production systems, as it is one of the most widely used indicators for evaluating the profitability of agricultural enterprises (Gittinger, 1982; Dillon & Hardaker, 1993).

The results indicate (see Table-7) that both hybrid and local tomato production were profitable, as their BCR values exceeded one. However, hybrid tomato production achieved a higher BCR (2.04) compared with local tomato production (1.92). This implies that for every rupee invested in hybrid tomato cultivation, farmers earned approximately Rs. 2.04 in gross returns, whereas local tomato growers earned about Rs. 1.92.

The higher BCR of hybrid tomatoes demonstrates their superior economic efficiency and profitability. Although hybrid cultivation involved slightly higher production costs, the additional investment was compensated by significantly higher yields and revenues. Therefore, hybrid tomato production offers greater returns on investment and represents a more attractive production option for farmers in the study area. Similar findings have been reported by Engindeniz (2007), Heuvelink (2018), and Birthal et al. (2001), who concluded that hybrid vegetable production generally provides higher economic returns despite requiring greater investment in quality seed and crop management.

Determinants of Tomato Yield

The regression analysis revealed that labor use, nitrogen fertilizer, and phosphorus fertilizer significantly influenced tomato productivity. The overall model was statistically significant and explained approximately 72% of the variation in yield ($R^2 = 0.723$), indicating strong explanatory power (see Table-6).



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The coefficient estimates indicate that labor use, nitrogen fertilizer, and phosphorus fertilizer significantly increase tomato productivity. A 1% increase in labor input increases tomato yield by approximately 0.10%, while nitrogen and phosphorus fertilizers increase yield by 0.18% and 0.16%, respectively. Tractor hours were positive but statistically insignificant, suggesting that mechanization alone does not substantially enhance tomato productivity in the study area.

Nitrogen fertilizer also had a positive and significant effect on yield. Increased nitrogen application enhanced vegetative growth and fruit development, leading to improved productivity. Similarly, phosphorus fertilizer exerted a significant positive influence on yield, reflecting its critical role in root development, flowering, and fruit formation (Khattak et al., 2021; Javaria & Khan, 2011; Khan et al., 2022).

In contrast, tractor hours showed a positive but statistically insignificant effect, suggesting that mechanized land preparation alone may not substantially increase tomato productivity once other management factors are considered (Khattak et al., 2016). Overall, the regression results emphasize that improved nutrient management and adequate labor allocation are key drivers of tomato productivity and should receive priority attention in extension programs aimed at increasing vegetable production (Khattak et al., 2021). These findings are consistent with previous studies demonstrating that balanced fertilizer application, efficient labor utilization, and improved crop management practices significantly enhance tomato productivity and farm efficiency (Heuvelink, Ep, 2018; Gebremedhin, Berhanu & Swinton, Scott M., 2003; Food and Agriculture Organization of the United Nations, 2022).

Variance Inflation Factor (VIF) Analysis

Table 5 shows that all VIF values range from 1.11 to 1.38, with a mean VIF of 1.23. Since all values are well below the commonly accepted threshold of 10, there is no evidence of serious Multicollinearity among the explanatory variables. Therefore, the independent variables can be included in the regression model without causing instability in the coefficient estimates, and the estimated results are considered reliable (Gujarati & Porter, 2009; Hair et al., 2019; LV et al., 2025; Alyousaf et al., 2026).

Conclusion

This study compared the profitability and yield performance of hybrid and local tomato varieties in Parachinar, Pakistan. The results showed that hybrid tomato production generated significantly higher yields and net returns than local varieties, despite slightly higher production costs. The regression analysis revealed that labor use, nitrogen fertilizer, and phosphorus fertilizer significantly influenced tomato yield, whereas tractor hours had no significant effect. Overall, hybrid tomato cultivation proved to be a more profitable and productive option for farmers in the study area.

Recommendations

1. Farmers should be encouraged to adopt certified hybrid tomato varieties due to their higher profitability and yield potential.
2. Agricultural extension services should provide training on improved tomato production and nutrient management practices.
3. Timely availability of quality hybrid seed and fertilizers should be ensured through effective input supply systems.
4. Access to agricultural credit should be improved to enable farmers to invest in modern production technologies.
5. Market infrastructure and transportation facilities should be strengthened to reduce marketing costs and increase farmers' returns.

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Table-1: *Socioeconomic Characteristics of Tomato Growers (n = 112)*

Variable	Category	Frequency	Percentage (%)
Education	Illiterate	46	41.1
	Primary–Middle	38	33.9
	Secondary and Above	28	25.0
Family Size	≤10 Members	40	35.7
	11–15 Members	52	46.4
	>15 Members	20	17.9
Farm Size	Small (<2.5 acre)	54	48.2
	Medium (2.6–5 acre)	55	49.1
	Large (>5 acre)	3	2.7
Profession	Government Employee	35	31.3
	Self-employed	60	53.6
	Private Employee	17	15.1

Note. Source: Field Survey

Table-2: *Production Cost Structure of Hybrid and Local Tomato Production (Rs. Acre⁻¹)*

Cost Component	Hybrid Tomato	Local Tomato
Nursery Raising	10,837	5,033
Land Preparation	4,607	4,827
Labor Cost	30,496	26,526
Fertilizer Cost	22,144	21,996
Pesticide Cost	889	813
Land Rent	21,607	21,077
Marketing Cost	16,415	14,937
Total Cost	102,381	99,012

Note. Values are averages per acre.

Table 3: *Comparative Economic Performance of Hybrid and Local Tomato Production*

Indicator	Hybrid Tomato	Local Tomato
Yield (kg acre ⁻¹)	2,955.5	2,709.4
Gross Revenue (Rs. acre ⁻¹)	208,954	190,524
Total Cost (Rs. acre ⁻¹)	102,381	99,012
Net Revenue (Rs. acre ⁻¹)	106,573	91,512

Note. Net Revenue = Gross Revenue – Total Cost.

Table 4: *Comparison of Yield, Production Cost and Net Revenue Between Hybrid and Local Tomatoes*

Variable	Hybrid Mean	Local Mean	Mean Difference	t-value	p-value
Yield (kg acre ⁻¹)	2,955.50	2,709.41	246.09	2.72	0.008***
Production Cost (Rs. acre ⁻¹)	102,802.21	99,012.19	3,790.01	1.20	0.234
Net Revenue (Rs. acre ⁻¹)	106,095.29	91,542.45	14,552.88	3.02	0.003***



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Note. ***p < .01.

Table 5: Variance Inflation Factor (VIF) Analysis

Variable	VIF
Nitrogen Fertilizer	1.38
Phosphorus Fertilizer	1.28
Labor Days	1.14
Tractor Hours	1.11
Mean VIF	1.23

Note. VIF values below 10 indicate absence of serious multicollinearity.

Table 6: Determinants of Tomato Yield: OLS Regression Results

Variable	Coefficient	Std. Error	t-value	p-value
Tractor Hours	0.04	0.03	1.26	0.211
Labor Days	0.10**	0.04	2.23	0.028
Nitrogen Fertilizer	0.18**	0.08	2.22	0.027
Phosphorus Fertilizer	0.16***	0.01	9.79	0.000
Constant	3.89***	0.44	8.66	0.000
Model Statistics	Value			
R ²	0.723			
F-statistic	41.79			
Observations	112			

Note. Dependent variable = Tomato yield (kg acre⁻¹).

p < .05, *p < .01.

Table 7: Benefit-Cost Ratio of Hybrid and Local Tomato Production

Indicator	Hybrid Tomato	Local Tomato
Gross Revenue (Rs. acre ⁻¹)	208,954	190,524
Total Cost (Rs. acre ⁻¹)	102,381	99,012
Benefit-Cost Ratio (BCR)	2.04	1.92