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Productivity Determinants and Production Constraints of Apple (*Malus* Spp.) in Jumla District of Nepal

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Abstract A study was conducted to determine the factors affecting apple productivity and production constraints in the Jumla district of Nepal from February to June 2023. A total of 70 respondents were selected by using a simple random sampling technique. Semi-structured questionnaires and focus group discussions were used to collect the primary data. Secondary data were collected from ADO reports, Apple super zone and, CBS. SPSS was used to analyze the collected data and descriptive statistics were used to describe socio-demographic characteristics using frequency and percentage. A multiple regression model was used to determine factors affecting Apple's productivity. It showed that 61.7% of the productivity was explained by independent variables used in the model. The result of the regression model showed that years of farming experience and tree density were found positively significant at 10% and 1% level of significance. Intercropping was found negatively significant at 10% level of significance. The relative importance index method was used for ranking the production constraints of Apple. Insect disease damage was found to be the most important constraint to apple production with a high index value (0.911) followed by problem of irrigation (0.703), ineffective extension services (0.497), unavailability of inputs (0.451) and labor costs (0.437). Therefore the study suggests increased tree density, years of farming experience, and the introduction of effective bio pesticides are needed for improving the apple sector in the study area. For the better production and productivity of apple, further study on effective biopesticides, promising resistant varieties and sustainable orchard management practices are needed.
Keywords Apple productivity; Multiple regression; Production constraints

Introduction

Agriculture development is crucial for boosting the overall economy of Nepal, as 60% of its population relies heavily on its agricultural sector due to its status as an agrarian economy (Lamichhane, 2022). Apple farming and production contributes around 0.3470% of Nepal's agricultural GDP (MOALD, 2023). Apple production is a significant agricultural activity for farmers residing in the high hills and mountainous regions of Nepal (Devkota et al., 2017). Although the productive area for apple farming in Jumla and Mustang districts is limited, Jumla has the highest area dedicated to apple production (MOALD, 2023). A range of factors can influence Apple's productivity including both climatic conditions and production practices. While climatic factors are beyond the control of humans, production practices can be adjusted to improve apple productivity. Although the productivity of the Jumla district is decent nationally, it is very far less than in advanced countries like China.

Apple (*Malus spp.)* is the most significant temperate fruit commercially and is part of the Rosaceae family (Potter et al., 2002). It is a vital and profitable agricultural commodity with the potential to contribute to income generation and employment opportunities in the high hills of Nepal (Amgai et al., 2015). Apple production is a main source of income in the Jumla district of Nepal, playing a crucial role in food security (Atreya and Kafle, 2016). The climatic condition of the district, marked by high altitude, low humidity, and plenty of sunshine creates a favorable condition for apple cultivation (Thapa et al., 2024) and due to less precipitation and ample cold days, the growing season for crops are shorter (Krap, 2012). Farming Apple proves to be a gift to the farmers of the Jumla district because of its economic, social, and environmental benefits (Subedi et al., 2016). In 2008, Jumla was designated an organic district by the government of Nepal (Lewison, 2019). As a result, consumer demand is increasing but due to the lack of transport facilities, lack of irrigation, and cold storage, apple growers are facing

constraints in apple production and marketing. The primary factors that hinder apple production in Jumla district are various diseases and pests that affect both the trees and fruit. Pests and diseases of Apple trees not only reduce the productivity of the tree but also hurt the quality of fruits (Beigh et al., 2015).

This study is designed to find the determinants of apple productivity and identify the existing production problems that can contribute to filling the existing gaps and for better implementation of future programs for the development of apple fruit enterprise in the Jumla district of Nepal.

1 Materials and Methods

1.1 Experimental site

The study was carried out in the Jumla district of Karnali province which lies at 25˚58' to 29˚ North latitude and 81˚51' to 82˚35' East longitude. It covered the areas assigned under the PMAMP Apple Super zone: Chandannath, Tatopani, and Guthichaur of Jumla district. Jumla lies from 915 m to 4,579 m from mean sea level. The high elevation and cold days providing sufficient temperature for chilling and vernalization make the Jumla district a favorable region for Apple production.

1.2 Sampling frame and sampling techniques

Apple growers of the Jumla district were the population of the study. Apple growers associated with PMAMP, PIU, Apple Superzone Jumla were the sampling frame. Seventy apple growers were selected by using simple random sampling techniques for the primary data collection (Sample size was determined by using a Raosoft sample size calculator with a margin of error being 10% and a level of confidence being 90%).

1.3 Sources of data collection

Both the primary and secondary data were used. Primary data were collected from apple growers through household surveys and focus group discussions (FGD). The sources of secondary data were annual reports, data from NGO's and INGO's. Publications and websites of FAO and MOALD were made accessible for the withdrawal of data. The secondary information was also obtained through reviewing different publications mainly produced by, the Department of Agriculture, Ministry of Agriculture Development (MOALD), Central Bureau of Statistics (CBS), Nepal Agricultural Research Council (NARC), Apple super zone, Jumla and various relevant and related published journals and research articles.

1.4 Research instruments

1.4.1 Household survey

Individual households were approached in person and questioned using a semi-structured questionnaire. A simple interview schedule was developed, which included information on the target group's socioeconomic characteristics, existing production practices, factors affecting apple production, production status, and various constraints associated with apple production. The 70 households were interviewed to gather primary data.

1.4.2 Focus group discussion

Farmers' groups were formed in an accessible location of the site and focus group discussion were carried out by the use of open-ended questionnaires. The responses received from them were useful to validate the first-hand results of individual contact.

1.5 Explanation of variables

1.5.1 Socio-demographic variables

Socio-demographic variables including gender, family type, education level of respondents, active members of family involved in agriculture, land holding status, etc. were analyzed using descriptive statistics.

1.5.2 Area, production and productivity

The area under apple production was analyzed on hectare and the production was analyzed on tons. The productivity of apples per household farm was calculated by:

Productivity = P/A

Where, P= Production of apples in tons; A= Area under apple production in hectares

2 Results and Analysis

2.1 Data analysis

The information collected from the field was first coded and entered into the computer. Data entry and analysis were done by using computer software packages like the Statistical Package for Social Science (SPSS) and Microsoft EXCEL based on the need was used for further data analysis.

2.1.1 The model for the study

Multiple linear regression analysis was done to determine the factors influencing Apple's productivity, assuming that there is a relationship between the many independent variables used and the dependent variable. The proposed equation of the multiple regression model was as follows:

Ln (Y productivity) = α+β1 lnX1+ β2 lnX2+ β3 lnX3+ β4 lnX4+ β5X5

Where, lnY= natural log of the productivity which was the dependent variable; X1 to X4 were the independent variables and X5 was the dummy independent variable; α = intercept made on the regression line; β1 to β5 are the coefficients of variables

2.1.2 Indexing

Problems for the production of the apple were ranked with the help of the relative importance index / forced ranking technique using a five-point scaling technique. The problems were ranked from I to V (I being major constraint and V being minor constraints). The formula given below was used to find the index for the intensity of production problems faced by producers.

$$\text{Iimp} = \sum \frac{SiFi}{N}$$

Where, Iimp = Index of importance; ∑ = Summation; Si = I^{th} scale value; Fi = Frequency of i^{th} importance given by the respondents; N = Total number of respondents

2.2 Results

The results of the socio-demographic characteristics of the continuous variable of the sampled respondents (Table 1) showed that the average household size was found to be 6.66 with a standard deviation of 2.277, which was higher than that of the national average family size of 4.27 (NPHC, 2021). The average male and female members of the household were found to be 3.30 and 3.36, respectively. The average area of apples in hectares was found to be 0.519 hectares with the minimum and maximum area of 0.13 and 1.8 hectares, respectively.

Table 1 Socio-demographic characteristics (continuous variable) of sampled respondents

Variables	Minimum	Maximum	Mean	Standard deviation
Household size	3	14	6.66	2.277
Male members of Household	1	8	3.30	1.289
Female members of Household	1	8	3.36	1.465
Economically active members	2	13	4.76	1.884
Dependent members	0	7	1.90	1.385
Total apple cultivated land (ha)	0.13	1.8	0.519	0.352

The results of the socio-demographic characteristics of the categorical variable of the sampled respondents (Table 2) showed that out of 70 respondents, 47 (67.1%) were males and 23 (32.9%) were females. The reason may be due to the more active involvement of males in apple farming while females are involved in household activities. Most of the respondents (38.6%) had a secondary level of education. 14.3% were illiterate, 21.4% were educated to the primary level and 25.7% were educated to the higher secondary level. The average literacy rate of the study area was 85.7%. Most of the respondents have access to irrigation facilities and extension services. Soil testing is done by only 35.7% of the respondents. Most of the respondents (38.6%) were not involved in any sectors. This

might be due to resources and geographical isolation as well as trust issues with agri institutions. 28.6% of the respondents were involved in the Farmers group followed by 21.4% involved in cooperatives.

Table 2 Socio-demographic characteristics (categorical variable) of sampled respondents

Variables		Frequency	Percentage (%)
Gender	Male	47	67.1
	Female	23	32.9
Education level of the respondent	Illiterate	10	14.3
	Primary level	15	21.4
	Secondary level	27	38.6
	Higher secondary level	18	25.7
Irrigation	Yes	41	58.6
	No	29	41.4
Soil testing	Yes	25	35.7
	No	45	64.3
Extension service	Access	39	55.7
	Otherwise	31	44.3
Involvement in sectors	Cooperatives	15	21.4
	Farmers group	20	28.6
	Agri-institution	8	11.4
	None	27	38.6

2.3 Factors affecting apple productivity

The model was found to be significant at a 1% level of significance with an F value of 23.189 (Table 3). The F-test was used to test the significance of the model predictors in explaining the dependent variable. The adjusted R-squared was found to be 0.617 with 61.7% of the productivity explained by independent variables used in the model and the remaining 38.3% of the productivity is explained by the variables not used in the model and random errors.

Table 3 Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	F value	Sig.
1	0.803[a]	0.644	0.617	3.965041	23.189	0.000[b]

Note: a: Predictors: (Constant), Age, Total number of productive trees, Years of farming experience, Tree density, Intercropping; b: Dependent variable: Productivity (tons per hectare)

The results showed (Table 4) that the years of farming experience and tree density were positively significant to apple productivity at 10% and 1% level of significance. Intercropping was found to be negatively significant to apple productivity at 10% level of significance.

Table 4 Factors affecting apple productivity

Model	Unstandardized B	Coefficients Std. Error	Standardized coefficients Beta	t	Sig.	Collinearity Statistics	
						Tolerance	VIF
(Constant)	3.838	1.883	-	2.038	0.046	-	-
Age	-0.065	0.043	-0.135	-1.515	0.135	0.695	1.439
Total number of productive trees	0.002	0.001	0.142	1.370	0.176	0.517	1.935
Years of farming experience	0.130	0.072	0.164	1.798	0.077*	0.669	1.494
Tree density	0.004	0.001	0.648	6.148	0.000***	0.500	2.000
Intercropping	-2.066	1.078	-0.147	-1.917	0.060*	0.947	1.055

Note: Dependent Variable: Productivity (tons/hectare); *, *** represents significance at 10%, and 1% level of significance

2.4 Model adequacy check

2.4.1 Linearity

A normal probability plot is used to check the relationship between the dependent variable (Apple productivity) and independent variables. The results showed that the p-p plot graph indicates that all observations lie approach to a straight line (Figure 1). This implies that the relationship between Apple's productivity and predictors is approximately linear.

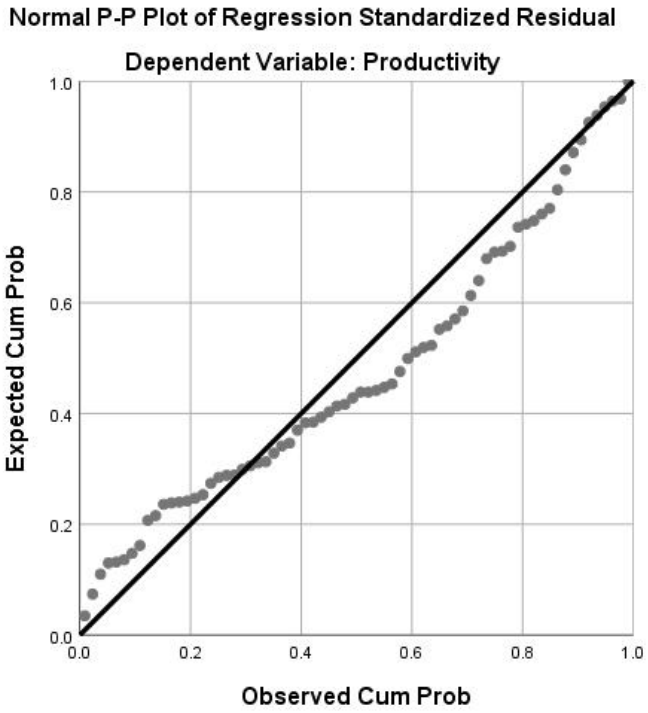

Figure 1 Normal p-p plot of standardized residual of apple productivity

2.4.2 Normality

Normality is checked by a graphical method using a histogram of residuals. The normality assumption is approximately fitted because the histogram of residuals of the apple productivity has a bell shape and is unimodal (Figure 2).

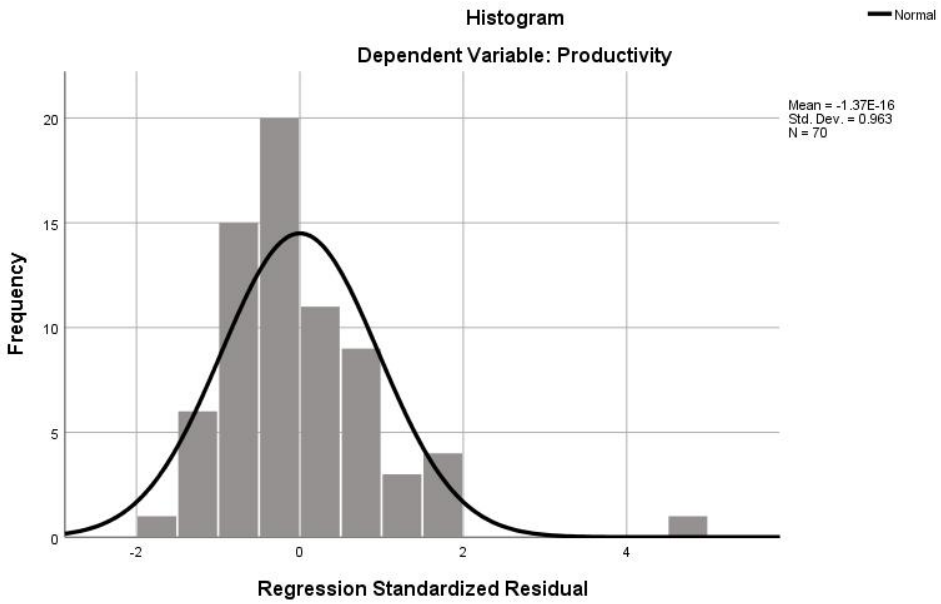

Figure 2 Histogram of residual regression fitted on apple productivity

2.4.3 Homoscedasticity

Homoscedasticity is checked by using the Breusch – Pagan test. The test shows p-value of 0.184 which is greater than the p-value of 0.05 that supports the null hypothesis and proves the data shows homoscedasticity. This indicates that the data has a somewhat constant variance.

2.4.4 Multicollinearity

If the VIF of a variable exceeds 10, the variable is said to be highly collinear. VIF of all independent variables was found to be less than 10, which indicates that absence of strong multicollinearity in all predictors.

2.5 Constraints to apple production

Farmer's perception to problems relating to apple production was surveyed (Table 5). The most problematic and important constraint to apple production was disease pest damage with an index value of 0.911.

Table 5 Production constraints in the study area

Problems	P1	P2	P3	P4	P5	Index	Rank
Unavailability of inputs	3	8	17	18	24	0.451	IV
Labor costs	0	9	19	18	24	0.437	V
Problem of irrigation	19	25	6	13	7	0.703	II
Ineffective extension services	2	10	23	20	15	0.497	III
Disease pest damage	46	18	5	1	0	0.911	I

3 Discussion

A multiple regression model was used (Table 4). Five factors (age, total number of productive trees, years of farming experience, tree density, and intercropping) were used as independent variables for the model. Productivity was used as the dependent variable. The coefficient of years of farming experience is 0.130 indicates that if farming experience is increased by one year, it will lead to an increase of 0.130 tons of apple production per hectare. This finding aligns with the result of (Ahmed et al., 2022) and (Ghulam and Bahadur, 2017) suggesting that the more a person gains experience, they become more open to try new and improved innovations, learning from the benefits and disadvantages of their old practices. The coefficient of tree density is 0.004 indicating that if tree density is increased by a unit (trees per hectare), it will lead to an increase of 0.004 tons of apple production per hectare. The finding is in agreement with (Bhattaa and Paudel, 2022) that the increase in the number of trees per unit area leads to efficient land use and higher yield per unit area but may result in competitive stress during growth. The coefficient of Intercropping is -2.066 indicating that if intercropping is done, it will lead to a decrease of 2.066 tons of apple production per hectare. This finding is in agreement with (Prechsl, 2008) which is a study conducted in Jumla and Mugu district that suggests intercropping has negative effects due to lack of knowledge of farmers on proper intercropping methods.

Woolly apple aphids, Sanjose scale, tent caterpillar, apple scab and nectoria twig blights are the major production constraints of apples in Jumla (Subedi et al., 2019). Problems of irrigation, ineffective extension services, unavailability of inputs, and labor costs were the order of the other problems ranked after disease pest damage. Irrigation is a major input for the improvement of the apple production. Ineffective extension service might be a production constraints as it limits farmers' knowledge of modern agricultural practices, pest and disease management, and other technical training. Our study contributes further evidence of the positive relationship between tree density and farming experience to the productivity of apple amidst the pitfall of production constraints, particularly damage by diseases and pests. The production constraints caused by diseases, pests and lack of irrigation facilities necessitate further study on effective biopesticides and promising resistant or tolerant varieties. Additionally, sustainable orchard management practices with optimal tree density and intercropping methods could help in increasing the productivity of apple.

4 Conclusion

By using effective teaching methods, management of production constraints, and providing knowledge on major factors affecting apple productivity, high possibility exists for the improvement in the apple status of the district.

Years of farming experience and tree density should be increased to ensure profitable apple productivity in the Jumla district of Nepal. The introduction of effective bio pesticides, promising pest-resistant varieties, and efficient irrigation systems are recommended.

Authors' contributions

SG and DPC were involved in conducting the survey, data collection, data analysis and interpretation, and drafting of the manuscript. MD and NA were involved in the revision and final shape of the manuscript. All authors read and approved the final manuscript.

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