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Assessing Factors Influencing the Adoption of Orchard Management Practices among Walnut Growers: A Study of Exotic and Native Jumlish Varieties of Nepal

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HIGHLIGHTS

- Most commercial walnut growers are unaware of good orchard management practice.
- This study aimed to examine the key factors that affect the adoption of orchard management practices.
- Education and area under walnut cultivation substantially impact the adoption rate.
- Locally grafted Jumlish walnut has proven to be more adaptable to Nepal's agro-climatic conditions than several exotic types.

Abstract

Walnut, a high-value crop with significant global demand, plays a vital role in enhancing the agricultural economy of the western high hills of Nepal. Sustainable orchard management practices are crucial to improving plant health and farm productivity. A survey conducted from February to July 2023 assessed the management practices of walnut orchards and evaluated the agro-climatic suitability of exotic walnut varieties in Rukum-East, Nepal. Using a simple random sampling method, 120 commercial walnut farmers participated in the study, with data collected through pre-tested, semi-structured questionnaires. The analysis utilized descriptive statistical tools, t-tests, and logistic regression models. Results revealed that farmers cultivated an average of 6.79 ropani of land with walnuts and had 2.22 years of orchard management experience. Exotic varieties such as Chandler (US origin), Franquette, and Fernette (French origin) were grown by 64.2% of farmers, while 35.8% relied on locally grafted Jumlish varieties. Globally relevant insights emerged, showing that education and cultivated area influenced orchard sanitation, and factors like land direction, road access, irrigation, and the use of Bordeaux paste significantly reduced dieback issues. Locally grafted varieties demonstrated superior growth performance and agro-climatic adaptability compared to the exotic varieties. This study highlights the global importance of integrating modern orchard care, subsidized quality sapling distribution, irrigation infrastructure, and grafting techniques to reduce sapling mortality. These findings contribute to the worldwide discourse on sustainable walnut cultivation in diverse agro-climatic contexts, promoting practices applicable to other regions with similar challenges.

Keywords: *Juglans regia;* Dieback; Hartley and Payne; Subsidy; Training and Extension

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1. Introduction

Horticultural commodities contribute 14% to the total agricultural GDP (AGDP), while fruits alone contribute 7.04% (MoALD 2021). With undulating slopes, the hilly and high-hill topography shows promise for horticultural crops such as apple, walnut, peach, and citrus. *Juglans* is a genus within the Juglandaceae family, and its seeds are commonly recognized as walnuts (Jahanban et al. 2019). The Persian walnut tree, also called English walnut or *Juglans regia* L., is a widespread monoecious species belonging to the order Fagales (Bernard et al. 2018). Walnuts exhibit adaptability to temperate climates worldwide (Mir and Kumar 2011) and have historical significance in traditional medicine and religious practices in Nepal (Aryal et al. 2009). The horticulture sector and private nurseries produce over 335,000 non-grafted walnut saplings and around 30,000 grafted saplings annually (NCFD 2020). Nepal's total walnut cultivation area is 5988 hectares, with a national average production of 10,895 MT and a yield of 4.46 MT/ha (MOALD 2022). Rukum-East, covering 502 hectares, dedicates 355 hectares to walnut cultivation, producing 1398 MT with a productivity of 3.94 MT/ha, below the national average (MOALD 2022).

The walnut species in Nepal is *Juglans regia* L., locally referred to as 'Okhar' (Thapa et al. 2021). It is grown in temperate zones (Dhakal et al. 2003) as well as in the country's mountainous regions at elevations of 1350–3000 meters above sea level (Khanal et al. 2023). The local hard-shelled walnut (*Hade*), abundantly found in the subtropical and temperate forests of Nepal, has thrived for centuries and serves as an excellent rootstock, well-adapted to the agro-ecological, climatic, and soil conditions of the region (Chalise et al. 2021). Some exotic thin-shelled varieties, such as 'Hartley', 'Payne', and 'Ashley', grafted onto these native rootstocks, are gaining popularity in commercial farming due to their significant economic value. They are collectively called the Jumlish varieties, as most of the breeding research related to walnuts is conducted at the Horticultural Research Station in Rajikot, Jumla (Sharma et al. 2022). Recently some exotic varieties such as Chandler, Franquette, Fernor, and Fernett, are been commercially cultivated in Nepal. Traditional rootstocks, *Juglans regia* (English walnut), native to their respective countries, have been used for these exotic varieties, which have been widely cultivated with financial aid and subsidy programs from governmental bodies. This has raised concerns regarding their climatic and soil adaptability in Nepal. The tall Persian walnut tree, with an average height of 25-35 meters and a wide trunk, bears green fruits with semi-fleshy coverings and brown, uneven nuts. Walnut serves as a prime example of the underutilization of available plant genetic resources. Variation plays a vital role in identifying superior seedlings with desirable traits, such as high-quality nuts and adaptability to local climatic and soil conditions, to support the potential expansion of walnut cultivation in the country. A heterogeneous population enables us to choose the best walnut genotypes, which is an easy and rapid way to improve the variety because breeding takes a long time for fruit crops, particularly walnuts with lengthy juvenile periods.

Walnuts are one of the main fruits that can bring in money and create jobs in the mountain districts of western Nepal. Regarding climate appropriateness, walnut cultivation has a comparative and competitive advantage and a lot of potential for export. Nepal is obliged to import more and more walnuts from foreign countries for commercial cultivation. Farmers cannot provide the best management practices to ensure walnut saplings' higher survival after establishing orchards. There are no regular orchards of walnuts in the country because the existing plants are of seedling origin. Lack of quality planting materials and mineral fertilizers are the main constraints to walnut cultivation in Nepal. Till now, there was no registered variety of walnuts in the country, and no walnut breeding program was performed in the past. Nepal Agriculture Research Council (NARC) is the sole agent responsible for fruit research. Several studies have been done in foreign countries to identify and introduce the superior walnut genotypes. Still, in Nepal, the first initiation of walnut research was to identify potential genotypes. In the Rukum-East district, farmers encounter challenges such as a low walnut sapling survival rate, heightened disease and pest prevalence, and a lack of practical information and technological knowledge in production (Thapa and Dhimal 2017). Additionally, nursery farmers face issues like land fragmentation, subsistence farming, inadequate fencing around orchards, scarcity of scion, transportation challenges, traditional cultivation methods, negligence in nursery management, and limited availability of disease-free saplings (Asiedu et al. 2012).

The walnut zone, Prime Minister Agriculture Modernization Project (PMAMP) of Rukum-East district, has been focusing on walnut cultivation and now has a production area of 355 ha (MoALD 2022). In Nepal, some agricultural innovation is already taking place. Enhanced agroforestry has improved livelihoods on the hillsides of Nepal as part of intricate farming systems (Pandit, 2014). According to Barrueto et al. (2018), women, poor people, and farmers without land lack the resources, risk-taking ability, land, or expertise necessary to weigh the advantages and disadvantages of this crop. Land size was one apparent determinant for whether a farmer grows trees, as stated by Alan Oli et al. (2015), and farm size influences the agricultural innovation (Aase et al. 2013). However, until now, no study or research has been conducted to find the condition of walnut-growing orchards, along with the potential and constraints regarding their establishments. In addition, there hasn't been adequate research regarding the suitability of grafted varieties of walnuts in Rukum-East. So, a study is required to assess the factors responsible for inhibiting dieback incidents in the walnut orchard, along with factors influencing the adoption of good orchard management practices. This study will sort out the various factors prevailing in the area, leading to hindrances in production. This study aims to determine the actual cause of the problems concerning walnut cultivation and management practices.

We conducted a semi-structured household survey in walnut orchards to identify factors influencing dieback and the adoption of good orchard management practices (GAPs). Quantitative data from closed questions were analyzed using statistical and logistic regression methods to determine drivers of GAP adoption. Insights from open-ended responses provided additional context on the agro-climatic suitability and growth performance of two walnut types. We developed recommendations for future cultivators, development partners, and policymakers based on these findings.

Adoption is defined as integrating new technology into existing practices, typically involving a phase of "trying" and varying degrees of acceptance (Loevinsohn et al. 2013). The two primary dimensions of adoption are adoption intensity, measuring how swiftly farmers embrace innovations, and adoption rate, indicating the extent to which a specific technology is used over time (Mwangi and Kariuki 2015). Various economic, social, and technical factors, coupled with the risk-taking mindset of farmers, significantly influence the adoption of agricultural production technologies and orchard management methods in countries like Nepal. Age is considered a factor in determining acceptance of modern technology and adoption of improved practices (Dhraief et al. 2019). One of the key factors influencing the adoption of new technology is gender. Men who head households are likelier to adopt and apply modern technologies, whereas women are likelier to use indigenous knowledge (Markovic 2021). Male-headed households are more equipped to use innovation because they have access to more knowledge than female-headed households, which are more susceptible to cultural norms and freedom (Melesse 2018). Higher education impacts respondents' attitudes and ideas, making them more open-minded, rational, and able to recognize the benefits of new technologies (Mwangi and Kariuki 2015). Larger households can relax the labor constraints necessary when introducing new technologies, which determines the adoption process Alan (Mwangi and Kariuki 2015). The size of a farm is a sign of affluence and possibly a proxy for social standing and communal influence (Zewdie 2021). A critical factor in adopting new technology is the availability and accessibility of extension services (Mwangi and Kariuki 2015). Information obtained through extension services makes a new technology's performance less uncertain, influencing how an individual embraces it.

2. Materials and Methods

2.1. Study Site

Rukum-East stands out as a prominent tourist destination in Nepal's mountainous region, celebrated for its 52 lakes and 53 peaks, covering an area of 1161.13 km^2 and housing a population of 57,962 as per the 2021 Nepal census. The region comprises three rural municipalities: Putha Uttarganga, Sisne, and Bhume. The research focused on the rural municipalities of Bhume (wards no. 2, 6, 7), Putha Uttarganga (wards no. 2, 5, 6, 10, 11), and Sisne (wards no. 2, 3, 4) due to their inclusion in the commercial walnut zone under PMAMP, Rukum-East. The selection of this study area was purposeful, considering factors such as the extent of walnut

production, the number of walnut-cultivating farmers, the production of walnut seedlings and saplings, accessibility, and suitability.

The survey encompassed a diverse range of orchards, including newly established and old orchards, both registered and unregistered, and small—and large-scale orchards. It also included insights from new farmers interested in walnut cultivation. The study delved into farmers' perspectives regarding knowledge, adoption rates, and the performance of exotic walnuts within the command zone of the walnut orchard.

2.2. Research Design and Field Survey

A preliminary field visit was conducted to gather data on the research survey's socioeconomic, institutional, and geographic aspects. Following identifying issues and assessing their impact on knowledge levels and sapling growth, a thorough review of literature, methods, and methodology was undertaken to align the research topic with the study's location and objectives. Both primary and secondary data were collected. A semi-structured questionnaire was pre-tested with ten respondents from a nearby location to ensure the effectiveness of the household survey.

2.3. Sampling Procedure and Determination of Sample Size

Farmers from the study site were selected as respondents. The sample population consisted of farmers in the rural municipalities of Bhume, Putha Uttarganga, and Sisne in Rukum-East who now cultivate walnuts, were new producers, and were already familiar with the crop. The sampling frame was the list of those farmers. Simple random sampling without replacement was followed. For this, a lottery system of sampling procedures was applied. The sample size was estimated using the simplified formula given by Taro Yamane (Naing 2003).

The formula used for sample size determination:

$$n = \frac{N}{1+Ne^2}, \quad (1)$$

Where, n = Sample size

N=Population size

e = Sampling error

The yearly progress report of PMAMP, walnut zone, Rukum-East, provided all the data regarding 180 walnut growers. This sampling frame of 180 commercial walnut farmers was used to select the respondents with a sample size of 124.13 (rounding it to 120). Using Taro Yamane's formula, the sample size was determined with a 5% margin of error and a 95% confidence level. The walnut farmers were assigned numbers on individual slips of paper that were all the same size, shape, and color. They are folded and mixed up in a small box. The number of slips was chosen using a blindfold selection process to get the appropriate sample size.

2.4. Data Collection and Data Types

The data was gathered through personal interviews, where respondents were asked questions according to a structured interview schedule and checklist to obtain the necessary information. The key informant interview (KII) was carried out primarily to triangulate data and information obtained from scheduled interviews and secondarily to obtain additional qualitative information. Primary data were obtained from a questionnaire survey, focus group discussion (FGD), and field observation. Secondary data were obtained from the annual reports of PMAMP-PIU, Rukum-East, publications of horticultural centers, journal articles, and research publications.

2.5. Data analysis Technique

The collected primary data was coded, entered, and cleaned before being prepared for analysis. Various analytical tools were used for this process. Microsoft Excel (2010) and SPSS (version 25) were utilized to

analyze the data. Descriptive statistics, such as frequency, percentage, and mean, were calculated to determine the distribution of study variables. Inferential statistics, including chi-square (χ^2) tests and independent sample t-tests, were applied to check for statistically significant differences. Additionally, MS Excel was used to create problem indices, pie charts, and bar diagrams.

2.5.1. Force ranking method

Forced rank scaling was used to index the problems faced by the walnut growers in Rukum-East. The ranking of the attitudes of the farmers regarding pull factors for walnut cultivation was also calculated using the same formula (Chaudhary et al. 2023). The intensity of problems and ranking of attitudes were scaled from 1 to 7, and index values of 0.14, 0.28, 0.42, 0.57, 0.71, 0.85, and 1.00 were assigned. The index was computed by the following formula:

$$Iimp = \sum (S_i * F_i/N), \quad (2)$$

Where, Iimp = Index of importance

$\sum$ = Summation S_i = I^{th} value of scale

F_i = frequency of I^{th} importance given by the respondents

N = Respondent's number

2.5.2. Binary logistic regression model

A binary logistic regression model was used to analyze the influencing factors in dieback inhibition and adoption of improved orchard management practices among walnut growers through socio-demographic attributes. Adoption of improved practices was taken as a dependent variable, and gender, age, education, ethnicity, active members, family income, occupation, and area under walnut cultivation were taken as independent or predictor variables.

Adoption of improved orchard management practices among walnut growers = f (gender, age, education, ethnicity, active working members, family income, occupation, area under walnut cultivation).

In this study, the dependent variable was the farmers' decision to adopt or not adopt orchard management practices, coded as 1 for adoption and 0 for non-adoption. The logistic model was used to predict the logit of this dependent variable based on various independent variables.

Also, influencing factors for suppression of dieback incidence in the walnut orchard = f (types of land, years of experience, time spent in walnut orchard, direction of land, distance to office, soil amendments, road access to orchard, irrigation facility, quality saplings, farmer's group, access to inputs, bordeaux paste, orchard sanitation, training and extension services, and subsidies).

The dependent variable for this study was dieback incidents in walnut orchards or not, with a value of 1 (if there is a dieback incident) and 0 (if there is no such incident). The logistic model predicts the logit of the dependent variable (dieback incident) from independent variables. The list of variables used in the model and their description are given in (Table 1) and (Table 2).

The likelihood of farmers being adopted the improved practices is predicted by odds (y=1); that is the ratio of the probability that Y equals to 1 to the probability that Y does not equal to 1 is shown below in Eq. (1):

$$Odd\ Y = P(Y=1)/ (1-P(Y=1), \quad (3)$$

The binary logistic regression model is specified as follow:

The logit (Y) is given by natural log of odds as shown below in Eq. (2):

$$In\ [p\ (Yi=1)/ (1-p\ (Yi=1))] = log\ odds = Logit\ (Y), \quad (4)$$

This can be expanded as the logistic transformation of the probability of the adoption of the practices and dieback incident suppression and is shown in Eq. (3) below:

$$\text{Logit (Y)} = \propto + \sum \beta 1X1 + \sum \beta 2X2 + \ldots + \sum \beta nXn + \varepsilon i, \quad (5)$$

Where Y= dependent variables (Adoption) with 1= adopted and 0 = not adopted;

$\propto$= intercept

εi= error index

$\beta 1, \ldots, \beta n$= coefficient of independent variables

X1… Xn = the independent variables

P (p) = probability of adopting the improved management practices in the walnut orchard

1-P = probability of not adopting the improved management practices in the walnut orchard

Ln = natural log

Table 1. Overview of the variables utilized in the binary logistic regression model to assess the adoption of improved management practices among commercial walnut growers

Variable	Type	Description	Value
Dependent variable			
Adoption of improved POPs (Y)	Dummy	Farmers has adopted the improved POPs or not	1 if adopted, 0 if not adopted
Independent variables			
Age (X_1)	Continuous	Age of the respondent	Years
Gender (X_2)	Dummy	Gender of the respondent	1 if male, 0 if female
Education (X_3)	Dummy	Education status of respondent	1 if educated, 0 if illiterate
Ethnicity (X_4)	Dummy	Ethnicity of the respondent	1 if janajati, 0 if other
Occupation (X_5)	Dummy	Occupation of the respondent	1 if agriculture, 0 if other
Active working members (X_6)	Continuous	Actively working family members of respondent	Person
Annual income (X_7)	Continuous	Annual income of respondent	Amount
Area under walnut cultivation (X_8)	Continuous	Total land size for walnut orchard	Ha

2.5.2. Independent sample t-test and chi-squar

The independent sample t-test was employed to compare the means of two unrelated groups—specifically, the growth performance and agro-climatic suitability of exotic and Jumlish walnut varieties. This test aims to determine whether there is a significant difference between the two samples. A chi-square test was also conducted to assess the significant differences in agro-climatic suitability variables between the exotic and Jumlish walnuts.

$$x^2 = \sum \frac{(Oij - Eij)^2}{Eij}, \quad (6)$$

Where,

χ^2 = chi-square,

O_{ij} = observed frequency of each ijth term,

E_{ij} = indicates the expected frequency of ijth term,

i = 1, 2, 3 . . . r, j = 1, 2, 3 . . . k.

This was evaluated at a probability level of 0.05 across various degrees of freedom.

Table 2. Description of variables used in the binary logistic regression model for possible influencing factors for inhibition of dieback incident in the walnut orchard

Variable	Type	Description	Value
Dependent variable			
Dieback incident (Y)	Dummy	Dieback incident seen or not	1 if seen, 0 if not seen
Independent variables			
Land types (X_1)	Dummy	Land types of orchard	1 if lowland, 0 if not
Years of experience (X_2)	Continuous	No. of year of experience of orchard owner	Years
Time spend in orchard (X_3)	Continuous	Average time spend in orchard per week	Hours
Slope of land (X_4)	Dummy	Types of slope of walnut orchard	1 if steep slope, 0 otherwise
Direction of land(X_5)	Dummy	Orientation of land of walnut orchard	1 if South-West, 0 otherwise
Distance to zone office (X_6)	Continuous	Average distance of orchard owner to zone office	Km
Soil amendments (X_7)	Dummy	Soil testing of orchard	1 if No, 0 otherwise
Road access to orchard (X_8)	Dummy	Access of road to walnut orchard	1 if No, 0 otherwise
Irrigation facility (X_9)	Dummy	Provision of irrigation in orchard	1 if No, 0 otherwise
Quality saplings (X_{10})	Dummy	Access to quality saplings	1 if No, 0 otherwise
Farmer's group (X_{11})	Dummy	Involvement in farmer's group	1 if No, 0 otherwise
Access to inputs (X_{12})	Dummy	Access to inputs and services	1 if No, 0 otherwise
Bordeaux paste (X_{13})	Dummy	Bordeaux paste/spray in walnut orchard	1 if No, 0 otherwise
Orchard sanitation (X_{14})	Dummy	Sanitation maintenance of orchard	1 if No, 0 otherwise
Trainings and extension services (X_{15})	Dummy	Access to trainings and extension services	1 if not received, 0 otherwise
Subsidies (X_{16})	Dummy	Subsidies received by orchard owners	1 if No, 0 otherwise

3. Results and Discussion

3.1. Different Management Practices Adopted by Orchard Owners in Rukum-East, Nepal

Among the sampled respondents, 60% of orchard owners were observed using farmyard manure as a fertilizer source, while 42.5% ensured timely irrigation for their plants. Additionally, 48.3% of farmers practiced intercropping in their orchards, 66.7% implemented mulching, and 26.7% performed pruning on time. Furthermore, 76.5% of walnut orchard owners maintained proper plant spacing, and 37.5% and 70.8% of farmers adopted disease and insect management practices. About 33.3% utilized fencing around their orchards, predominantly employing wired and stone fences. Moreover, 42.5% actively participated in bio-pesticide preparation, and 78.3% had dug pits for planting walnut saplings. About 60% of respondents engaged in weeding in their orchards, and 31.7% conducted soil amendment practices such as testing and treatments.

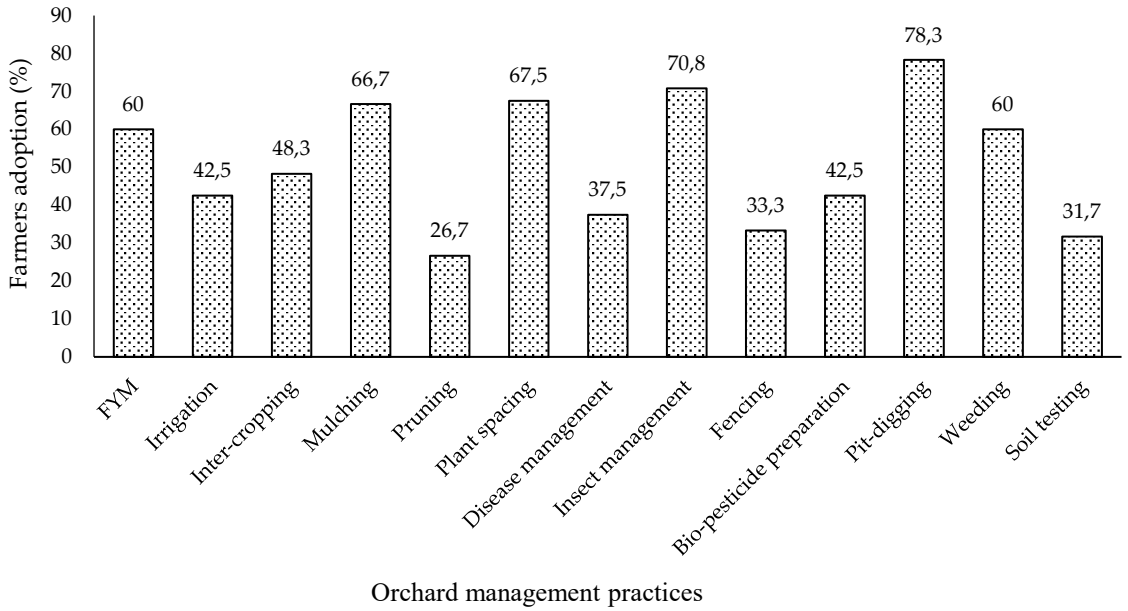

Figure 1. Different management practices adopted by orchard owners in Rukum-East (Source: Field survey, 2023)

3.2. Trainings Received by the Respondents of Rukum-East, Nepal

In the given figure, 25% of respondents from the sampled households had received training on grafting. Similarly, 5% had walnut and pruning training, 4% on bio-pesticide preparation, and 9% on disease and insect/pest management. Additionally, 13% had training on general walnut cultivation practices, 18% on nursery establishments, and 26% had not received any training.

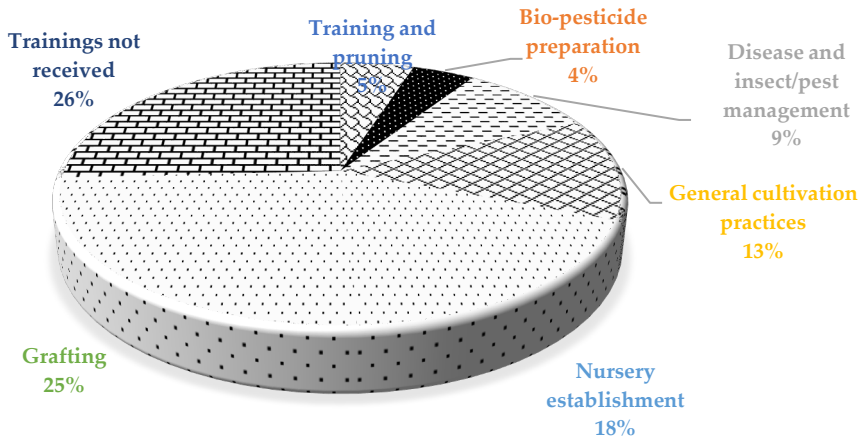

Figure 2. Different trainings received by the respondents (Source: Field survey, 2023)

3.3. Disease/pests and İnsect İncidence in the Walnut Orchard of Rukum-East, Nepal

The results in (Figure 3) showed that the highest % of dieback disease incidents, 32%, were observed in most walnut orchards in the study site, followed by root rot affecting 24% of the walnut orchards. Additionally, 21% of walnut orchards experienced trunk borer infestation, while 16% reported anthracnose incidence. Weevil incidents affected 4% of walnut orchards, and 3% did not report any disease or insect pest incidence.

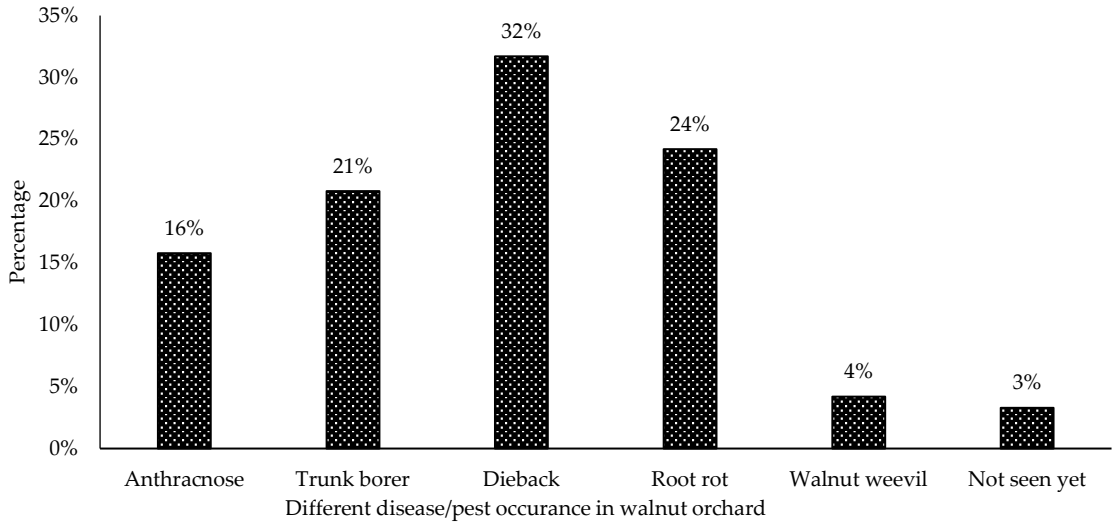

Figure 3. Disease/pests and insect incidence in the study area (Source: Field survey, 2023)

3.4. Influence of Socio-Demographic Characteristics on the Adoption of Orchard Management Practices

The study revealed that the adoption of good orchard management practices was positively influenced by education, ethnicity, and the area under walnut cultivation. Among the independent variables, annual family income had a significant but negative influence at the 5% significance level. Similarly, age was negatively influenced by adopting good orchard management practices at the 1% significance level. For a one-unit increase in gender and age, the log odds of adoption decrease by 0.15 and 0.81, respectively. Gender plays a significant role in technology adoption because the household head, typically a male, holds more access to and control over essential production resources than females, largely due to prevailing socio-cultural values and norms (Mesfin 2005; Omonona et al. 2006). Women are the primary cultivators and caretakers of the home garden, and they are more likely to collaborate with men in cultivating the property adjacent to the home garden (Gebre et al. 2019). Since men head most households in Rukum-East, the adoption of orchard management practices is negatively influenced by gender. Research has shown a negative correlation between age and technology adoption, as explained by Barrera et al. (2005) and Adesina and Zinnah (1993). This phenomenon occurs because older farmers tend to become more risk-averse and less interested in long-term farm investments. In contrast, younger farmers generally exhibit lower risk aversion and are more inclined to experiment with new technologies.

Education and the area under walnut cultivation have a positive influence and a significant effect at 1% and 5%, respectively. Therefore, for a unit increase in education and the area under walnut cultivation, the log odds ratio of adopting management practices increases by 13.16 and 1.30, respectively. The education level of a farmer is considered to have a favorable influence on the decision to adopt new technology. Farmer education enhances the ability to obtain, understand, and apply information about adopting new technology (Lavison 2013; Mignouna et al. 2011; Namara et al. 2003). This is because higher education shapes respondents' attitudes and beliefs, making them more receptive, rational, and capable of evaluating the advantages of adopting new technologies. Ahmed and Bagchi (2004) reported a positive interaction between farm size and agricultural technology adoption. Farmers with larger farm sizes are more likely to accept new technology because they can afford to devote a portion of their land to experimenting with the latest technologies, unlike farmers with smaller farm sizes (Uaiene 2011).

The model's chi-square (χ^2) value of 34.43 and the log-likelihood ratio of -23.945721 suggest that all the variables included in the model have a significant impact on the likelihood of adopting orchard management practices for walnuts. The pseudo-R^2 value of 0.4183 means that about 41.83% of the decision to adopt good orchard management practices is governed by the tabulated variables, i.e., the model fits 41.83% of the given data.

Table 3. Influence of socio-demographic characteristics on the adoption of orchard management practices

Socio-demographic characters	Coefficient	Odds ratio	Std. Err.	Z	p>|z|
Gender (Female=1)	-1.87	0.15	0.12	-2.27	0.02**
Age (Years)	-0.20	0.81	0.60	-2.75	0.006***
Education (Yes=1)	2.57	13.16	12.61	2.69	0.007***
Ethnicity (Janajati=1)	0.09	1.09	0.84	0.12	0.90
Annual income	-0.61	0.54	0.58	-0.57	0.56
Occupation (Agriculture=1)	-0.78	0.45	0.56	-0.63	0.52
Active members	-0.22	0.80	0.161	-1.10	0.27
Area under walnut cultivation (Ha)	0.26	1.30	0.163	2.08	0.03**
Constant	19.63	4.00	13.52	1.45	0.14
Summary statistics					
Number of observations	120				
LR chi^2 (10)	34.43				
Prob>chi^2	0.0000				
Pseudo R^2	0.4183				
Log likelihood	-23.945721				

Note: The symbols *, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.

3.5. Mean Comparison for the Agro-Climatic Suitability and Growth Performance among two Walnut Types in Rukum-East, Nepal

The independent sample t-test was employed to compare two sample means from unrelated groups, specifically focusing on the growth performance and agro-climatic suitability of exotic and Jumlish walnut varieties. This test aimed to discern any differences between the two samples. According to the results presented in (Table 4), the height of both plants, survival percentage, number of branches, and fruiting years exhibited statistical significance at the 1% level. Additionally, for the categorical variables, such as tolerance to diseases and pests, as well as the ability to cope with abiotic stress, a high level of significance at the 1% level was observed. These findings signify that the mean differences between the two varieties in various growth parameters are highly significant. Notably, Jumlish walnut demonstrated superior adaptability compared to various exotic walnut varieties. This implies that Jumlish walnut outperformed exotic varieties regarding key growth parameters. The statistical significance underscores the robustness of these differences, indicating a noteworthy advantage for Jumlish walnut in terms of height, survival percentage, number of branches, fruiting years, and resilience to diseases, pests, and abiotic stress.

3.6. Influencing Factors for Dieback Incident among Walnut Orchard Owners of Rukum-East, Nepal

Various factors, such as the orientation of the land, motor road accessibility, subsidies, and management practices like time spent in orchards, irrigation facilities, and the application of Bordeaux paste, influence the occurrence of dieback in walnut orchards in Rukum-East. The results of a binary logistic regression model, as presented in (Table 5), elucidate the impact of these independent variables on dieback incidence. Sixteen independent variables were utilized for the regression analysis, and six were deemed statistically significant among them. The time dedicated to orchard management exhibited a significant effect at the 5% significance level. Additionally, the orientation of the land, road access to the orchard, availability of irrigation facilities, application of Bordeaux paste, and the presence of subsidies were found to have significant effects at the 5%, 1%, 5%, 5%, and 10% levels of significance, respectively.

The findings suggest that for each additional unit of time spent in the orchard, there is a corresponding 2% reduction in the likelihood of experiencing dieback incidents. The log odds of an increase in dieback incidents decrease by 1.46. This could be attributed to higher adoption and awareness of management practices aimed at mitigating dieback. Notably, ignorance of orchard management and poor practices strongly correlates with a decline in orchard productivity (Poudel et al., 2022). The probability of experiencing a dieback incident decreases by 18.7% with a one-unit increase in the direction of land facing northeast. The log odds of a

reduction in dieback incidence increase by 0.20. Walnuts thrive in well-drained, fertile soils on lower north- and east-facing slopes. They do not fare well on steep slopes facing south or west due to the excessive heat and dry conditions. Midday water potentials were similarly higher on south-facing slopes, but plant frequency and groundcover were more abundant on north-facing slopes (Ulrich et al. 2008). A similar outcome was observed by Poudel et al. (2022) in a citrus orchard, where they noted that south and east-facing slopes receive more sunlight than north-facing slopes, leading to increased moisture loss and hindered growth.

Table 4. Independent sample t-test for mean comparison between two walnut types

Continuous variables	Mean value	S.D	S.E	t-value	p-value
Height of Plant					
• Jumla	97.21	31.67	4.23	5.574***	0.0000
• Exotic	61.78	35.37	4.42		
Survival % of plant					
• Jumla	75	17.74	2.37	6.936***	0.0000
• Exotic	49.37	22.10	2.76		
No. of branches					
• Jumla	3.01	0.94	0.126	6.671***	0.0000
• Exotic	1.82	1.00	0.125		
Fruiting year					
• Jumla	0.821	0.38	0.051	6.198***	0.0000
• Exotic	0.328	0.47	0.059		

Categorical variables	Overall (120)	Farmers category		Chi-square value	p-value
Tolerant to Pest/Diseases		Yes	No		
• Jumla	56	51	5	62.642***	0.000
• Exotic	64	12	52		
Ability to cope abiotic stress					
• Jumla	56	50	6	67.619***	0.000
• Exotic	64	9	55		

Note: The symbols *, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.

Through the marginal effect after logistic regression, it is predicted that with a one-unit increase in road access to orchards and irrigation facilities, the probability of experiencing dieback incidents decreases by 2.3% and 2.1%, respectively. Similarly, the log odds of suppressing dieback incidence increase by 0.14 and 0.16. The absence of irrigation and erratic rainfall can adversely impact orchard yield and production, creating opportunities for various diseases and pests (Dorji et al. 2016). Irrigation is vital in promoting more significant root growth, canopy development, fruit yield, and quality, making it a crucial tool in the battle against diseases and pests (Levy 1998). Similarly, easy road access to orchards enables farmers to efficiently implement improved management practices against diseases and pests in a shorter time. Infrastructure enhancements, including roads, canals, and transportation systems, should be prioritized to mitigate orchard losses (Hussen and Yimer 2013). Dieback incidents were negatively influenced by the application of Bordeaux paste at the 5% significance level. The results demonstrate that with a one-unit increase in the application of Bordeaux paste, the probability of experiencing a dieback incident decreases by 8.7%. The log odds of dieback incidence decrease by 0.48. Applying the Bordeaux mixture significantly and positively impacts disease suppression and orchard productivity. The components of the Bordeaux mixture act as fungicides and bactericides, effectively managing various walnut diseases such as stem cankers and dieback (Sharma et al., 2012).

In this context, the provision of subsidies negatively influences the incidence of dieback. According to the marginal effect after logistic regression, it is predicted that subsidies for quality saplings are 0.2% less likely to contribute to dieback incidents in walnut orchards, a significance observed at the 10% level. Adopting recently released agricultural technologies is promoted through subsidies (Kattel et al. 2020; Subedi et al. 2019). Subsidies on products and services enable farmers to acquire quality-grafted saplings at more affordable rates, ultimately reducing the likelihood of dieback incidents in their orchards.

The model's chi-square (χ^2) value of 28.86, along with a log-likelihood ratio of -45.61975, suggests that all variables included in the model significantly affect the likelihood of dieback occurrence. The pseudo-R^2 value of 0.2403 means that about 24.03% of dieback incident decisions are governed by the tabulated variables, i.e., the model fits 24.03% of the given data.

Table 5. Logistic regression analysis and marginal effect after logistic analysis of dieback incident with different factors causing incident of dieback

Dieback Score	Odds ratio	Std. Err.	Z	p>|z|	dy/dx	p>|z|
Land types	3.44	3.94	1.08	0.27	1.48	0.27
Years of experience	0.59	0.20	-1.49	0.13	-0.062	0.12
Time spend in orchard	1.46	0.26	2.14	0.03**	0.046	0.02**
Slope of land	1.72	1.43	0.65	0.51	0.065	0.51
Direction of Land	0.20	0.13	-2.51	0.01**	-0.187	0.006**
Distance to office	0.99	0.020	-1.38	0.70	-0.000	0.70
Soil amendments	1.00	0.89	0.01	0.99	0.001	0.99
Road access to orchard	0.14	0.10	-2.80	0.00***	-0.230	0.00***
Irrigation facility	0.16	0.14	-2.10	0.03**	-0.215	0.02**
Quality saplings	3.22	2.38	1.58	0.11	0.140	0.10
Farmers group	0.59	0.55	-0.56	0.57	-0.619	0.57
Access to inputs	0.76	0.76	-0.27	0.78	-0.032	0.78
Bordeaux paste	0.48	0.51	-0.68	0.05**	-0.087	0.49
Orchard sanitation	1.70	1.45	0.63	0.53	0.064	0.52
Training	1.45	1.38	0.39	0.69	0.045	0.69
Subsidies	0.98	0.01	-1.74	0.08*	-0.002	0.07*
Constant	47.51	130.74	1.40	0.16	-	-
Summary statistics						
Number of observations	120					
LR chi^2 (14)	28.86					
Prob>chi^2	0.0249					
Pseudo R^2	0.2403					
Log likelihood	-45.61975					

Note: The symbols *, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.

3.7. Ranking of the Major Constraints Faced by the Walnut Growers in Rukum-East, Nepal

According to reports from farmers, the successful establishment of walnut orchards faces several constraints. When ranked using an indexing technique, the high mortality of imported walnuts emerged as the primary constraint, recognized by the majority of respondents. The index value for this issue was the highest (0.75), making it the most serious challenge in the research site, as depicted in (Table 6) below. Irrigation facilities and shortages of storage tanks were ranked second with an index value of 0.63, followed by fencing constraints with an index value of 0.499, placing them in third place. Constraints such as fencing (0.499), nurseries and quality-grafted scions (0.4932), effective and practical training (0.497), insect/pest and disease severity (0.479), and high labor costs (0.43) were ranked 3rd, 4th, 5th, 6th, and 7th, respectively.

3.8. Ranking of the Major Attraction Factors by the Walnut Growers in Rukum-East, Nepal

Among the sampled respondents, the primary attraction for walnut cultivation was marginal land utilization, followed by agro-climatic suitability for successful orchard establishment. The index value for marginal land utilization was the highest (0.77) and ranked as the most appealing aspect in the research site, as shown in (Table 7) below. As reported by the farmers, the second most important factor for establishing a walnut orchard is the agro-climatic suitability of the region, with an index value of 0.62. Government support and prioritization are ranked third, with an index of 0.59. The unsuitability of other crops is ranked fourth

with an index value of 0.54. Similarly, storage possibilities, marketing, and lower risks for final production rank 5th and 6th, respectively.

Table 6. Ranking of the major problems faced by the walnut growers in the study area

Constraints of walnut production	Index	Ranking
High mortality of exotic walnut varieties	0.75	I
Irrigation facility and shortage of storage tanks	0.63	II
Fencing	0.499	III
Nurseries and quality-grafted scions	0.492	V
Effective and practical trainings	0.497	IV
Insect/Pest and disease severity	0.479	VI
High labor cost	0.43	VII

Source: Field survey, (2023)

Table 7. Ranking of the attitudes of the major attraction factors for the walnut growers in the study area

Attraction factor for walnut production	Index	Ranking
Marginal land utilization	0.77	I
Agro-climatic suitability	0.62	II
Storage possibilities & marketing	0.50	V
Government support & prioritization	0.59	III
Unsuitability of other crops	0.54	IV
Less risk for final production	0.43	VI

Source: Field survey, (2023)

4. Limitations

While the study's findings may assist dispersed farmers nationwide, the ability to generalize about the overall agricultural situation in the country is hindered by its narrow focus on a single region. The study's limitations, including a restricted period and financial constraints, resulted in limited information acquisition. Despite these constraints, the study remains a valuable resource for future research academics. This study will examine the various factors prevailing in the area that lead to hindrances in production. This study aims to determine the actual cause of the problems concerning walnut cultivation and management practices.

5. Conclusion and Policy Recommendations

5.1. Conclusion

Walnut cultivation is highly income-generating if orchards are appropriately managed. The insights from this study extend beyond Nepal and are highly relevant to other mountainous and subtropical regions where walnuts are cultivated. Farmers face similar challenges in adopting sustainable orchard management practices in many walnut-growing areas, such as parts of India, Turkey, Iran, and Central Asia. Factors like gender, age, education, landholding size, and access to essential resources such as irrigation, roads, and subsidies play a key role in shaping their decisions. Recognizing these influences is crucial for developing extension programs that support farmers in improving productivity, maintaining quality standards, and overcoming trade barriers.

Furthermore, the study emphasizes the need for climate-resilient, high-yielding walnut varieties and sustainable farming techniques to ensure long-term orchard health. Common issues, including limited time spent in orchards, improper land orientation, and the prevalence of dieback due to poor management, affect walnut production globally. By addressing these challenges and tailoring extension programs to local conditions, policymakers and agricultural experts can promote best practices that enhance the sustainability and resilience of walnut farming across diverse agro-climatic regions.

5.2. Policy Recommendation

The major problems like dieback and root rot disease, and trunk borer should be prioritized by the farmers. The government and the concerned projects should focus on improving knowledge of cultivation techniques, training on several varieties and their performance in their region, post-harvest aspects, and marketing the soft-shelled walnuts. Further studies on economic efficiency, technical efficiency, and value-chain analysis of the farmers adopting improved management practices than non-adopters can be recommended. The government should motivate growers by promoting certified planting materials that are climate-suited and high-yielding and training in managing the farm. The growth performance of exotic walnuts should be further verified at different altitude levels, especially at higher altitudes, before mass distribution to farmers. Adaptation and the production potential of Jumlish walnuts should be checked and verified.

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APPENDICES

Appendix 1. Number of years of experience of commercial walnut orchard growers in Rukum-East

Years of experience of walnut growing farmers	Frequency
1 year	30(25)
2 years	42(35)
3 years	40(33.3)
More than 4 years	8(6.7)
Total	120(100)

Figure in the parentheses indicates the percentage

Appendix 2. Different age groups of the respondents on the study site

Age groups (Years)	Frequency
Below 30 (15-29 years old)	27(22.5)
Between 30-60 (30-60 years old)	75(62.5)
Above 60 (61-75 years old)	18(15)
Total	120(100)

Figure in the parentheses indicates the percentage