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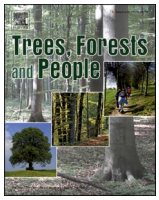

Challenges in harvesting and utilization of *Ziziphus* tree fruits in Ethiopia

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ABSTRACT

Ziziphus tree species commonly known as "jujube" are wide sources of nutritious and socio-economically important fruits in arid and semi-arid regions of Asia and Africa. However, understanding of local communities' engagement in harvesting and utilization of these fruits remains limited consequently undermining sustainable harvesting and broader utilization. Household interviews (HHIs), focus group discussions (FGDs) and key informants' interviews (KIIs) were used to investigate the level of harvesting and utilization of fruits from different tree species of jujube in Ethiopia. Multiple linear and binary logistic regressions were utilized to investigate factors influencing the annual fruit yield per tree and to discern factors impacting the local community's capacity to grow and sell jujube, respectively. Fruit yield per tree, market involvement and the principal challenges to growing were found to vary among two study sites. Bosset district's yield exceeded Bati's by 0.87 times. Women and children played significant roles in fruit collection, sale and management. Less rainfall reduced annual yield by 33 kg per tree while planting seedlings instead of relying solely on naturally regenerated trees boosted yield by 42 kg per year. With each advancing year in age, older respondents were 0.04 times less likely to sell harvested jujube fruits. The increasing impact of pests, water shortage and cultural influences decreased community interest in growing jujube by factors of 1.15, 1.41 and 2 times, respectively. Suboptimal involvement in jujube cultivation, fruit harvest and market activities was frequently ascribed to inadequate community support, organizational oversight and depressed market prices. These findings highlight the need to enhance awareness, management and market access for jujube fruits to broaden community benefits in Ethiopia.

1. Introduction

Wild fruit trees play a pivotal role in the global food market and are essential for addressing malnutrition in developing nations. They serve as a cornerstone for local populations, ensuring food security and income generation as well as adaptation to the negative impacts of climate change (Lulekal et al., 2011; Pasternak et al., 2016). Despite their significance, many wild fruit tree species remain underutilized and largely overlooked in the global markets, despite efforts to domesticate them since the 1980s (Leakey et al., 2022). Among the vast diversity of underutilized fruit tree species in Ethiopia, the *Ziziphus* genus commonly known as Jujube stands out, comprising over 135 plant species (Ara et al., 2008). Jujube belongs to the family Rhamnaceae mostly growing and utilized in the Mediterranean region, Saharan and sub-Saharan African countries, Southern and Eastern Asia and South China (Maruza et al., 2017). Ethiopia hosts four *Ziziphus* species i.e. *Z. spina-christi* (L.) Desf, *Z. mucronata* Willd., *Z. mauritiana* Lam., and *Z. abyssinica* Hochst, thriving in regions with low rainfall and high temperatures. *Ziziphus mauritiana*, in particular, holds significant horticultural value and has spread across numerous tropical territories in Africa, Asia and Australia (Orwa et al., 2009; Leakey et al., 2021; Maruza et al., 2017).

Jujube fruits known as drupes boast an impressive nutritional profile rich in crude protein, fat, fiber and carbohydrates. It surpasses citrus, apple and guava in vitamin C content while also containing significantly higher levels of iron, β-carotene, calcium and phosphorus (Morton, 1987; Nyanga et al., 2013; Rashwan et al., 2020). Their versatility extends to various consumption methods including fresh eating, pickling, drying or processing into different products (Nyanga et al., 2013).

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Moreover, beyond their nutritional benefits, every part of the jujube tree finds utility: its stems are used as poles and fuelwood, its spiny branches serve as effective components for live fences, and its leaves provide fodder for animals (Miri, 2018). Additionally, jujube is utilized for medicinal purposes, treating both human and animal ailments, and is even employed for fish stupefaction to facilitate capture. The fruits are widely esteemed as supplementary foods across Asia, the Middle East and Africa (Deshmukh and Waghmode, 2011; Maruza et al., 2017; Leakey et al., 2021).

Jujube fruits have become important commodities in both rural and urban markets, significantly contributing to income generation for rural communities (Faye et al., 2010; Nyanga et al., 2013). Their importance is highlighted by their inclusion among the top five prioritized fruit trees for planting and consumption in Sahelian and Sub-Saharan regions (Faye et al., 2010). Across Africa, local communities predominantly harvest and utilize wild jujube trees (Leakey et al., 2017; 2022). Breeding programs in countries like Burkina Faso, Mali, Niger, and Senegal aim to combine the prolific fruiting characteristics of Asian germplasm with the pest and drought tolerance of West African varieties are ongoing (Kalinganire et al., 2012).

Jujube fruits have achieved commercial status in various countries including Zimbabwe, Oman, Iran, Armenia, Syria, China, India, Pakistan, Egypt, the Mediterranean regions, and several West African nations (Faye et al., 2010; Abasse et al., 2017; Maruza et al., 2017; Krishna et al., 2019; Suwardi et al., 2020). In Ethiopia, jujube naturally proliferate and are utilized in seven of the nine regional states including Oromia, Amhara, Benshangul Gumuz, Tigray, Somalia, Afar and Southern Nations, Nationalities and Peoples (Seyoum et al., 2015). Jujube thrives in diverse environments including farmlands, roadsides, riverine areas, and home gardens. The trees bear evergreen foliage and fruits even during droughts (Maruza et al., 2017). Jujube tree fruits have gained increased interest as food and supplementary crops during food shortages, owing to their resilience to high temperatures and droughts coupled with their superior nutritional value.

Despite their advantages, jujube tree species have remained underutilized and non-domesticated in Ethiopia, posing challenges to their widespread harvesting and utilization by local communities (Dejene et al., 2020). This underutilization signifies a missed opportunity for smallholder farmers to capitalize on income and diversified nutritional potential amidst the growing population and the negative impacts of climate change. Addressing this issue requires thorough research to identify specific challenges confronting the harvesting and utilization of jujube fruits by local communities. This study was designed to among other investigate growing habits among local communities, fruit harvesting techniques and management practices for jujube trees and fruits in Ethiopia. Knowledge generated will be useful to

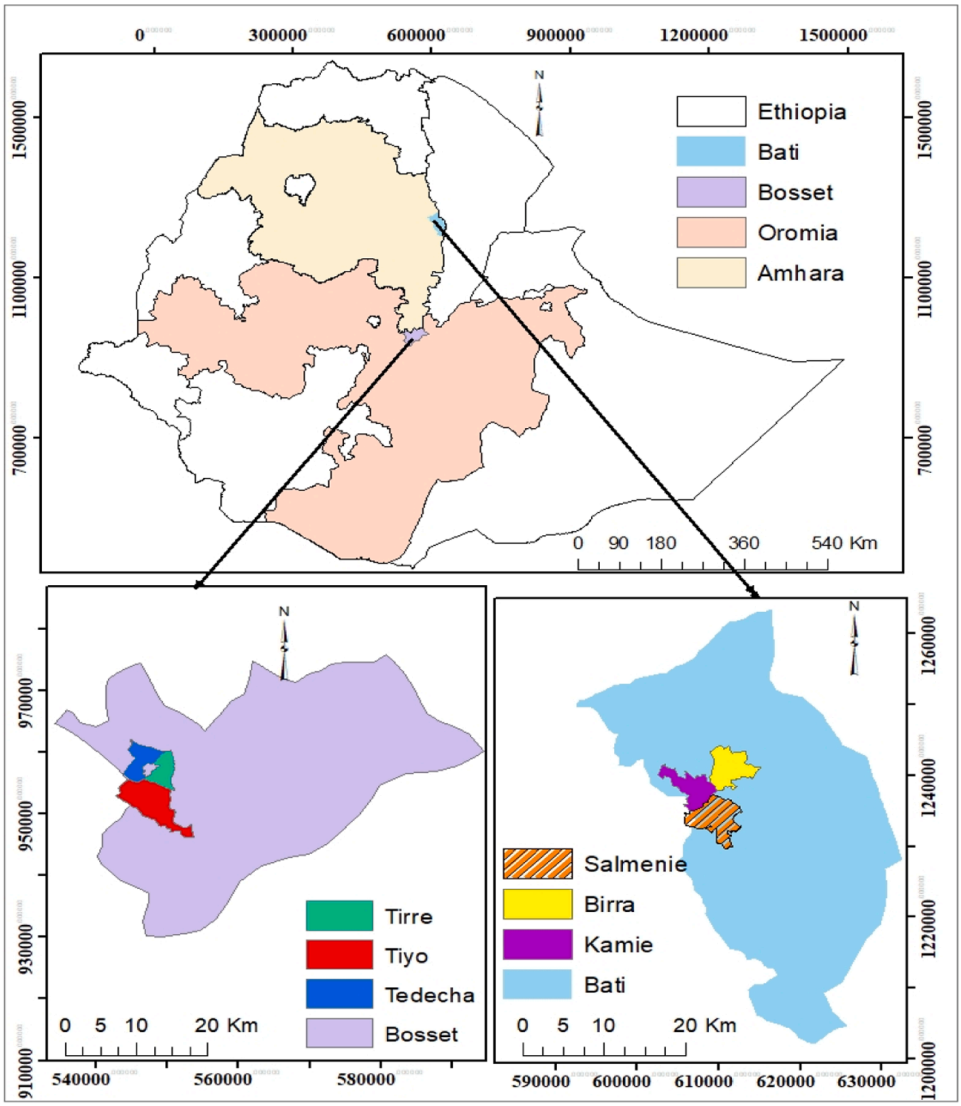

Fig. 1. Location map of the study sites in Ethiopia.

enhance awareness and utilization of jujube fruits for wider community benefits including diversified nutritional and income sources.

2. Materials and methods

2.1. Study sites

The study sites were distributed across two districts, Bosset in the Oromia regional state and Bati in the Amhara regional state in Ethiopia, representing diverse geographical and socio-economic conditions (Fig. 1 and Table 1). This diversity allowed for a more robust analysis of the factors influencing fruit yield, market participation, and community engagement. Moreover, these districts were selected because they are known for their significant jujube fruit production and consumption. The selection of these six sites was deliberate and strategic. They were chosen to provide a comprehensive understanding of jujube fruit harvesting and utilization in different contexts within Ethiopia. By studying these areas, the research aims to capture insights that can be generalized to similar regions in Ethiopia and potentially other parts of Africa and Asia where jujube is prevalent.

2.2. Sampling procedure

The sampling procedure commenced with a preliminary reconnaissance survey in the Oromia, SNNP, and Amhara States. Consultations with natural resource experts and extensive field visits helped to identify potential areas conducive to *Ziziphus* species. Given the difficulty in distinguishing between different jujube tree species; they were collectively referred to as jujube. Following this, a three-stage stratified purposive sampling method was employed to select the study sites. Initially, two primary strata were identified: the East Shewa zone of the Oromia regional state and the Oromia Special Zone of the Amhara regional state. In the second stage, two suitable districts, namely Bosset district within the East Shewa Zone and Bati district within the Oromia Special Administrative Zone, were purposefully chosen due to the presence of jujube trees and established fruit utilization practices. Lastly, in the third stage, six representative sites (Tiyo, Tedecha, and Tirre from Bosset, and Bira, Salmenie, and Kamie from Bati district) were deliberately selected based on the good abundance of jujube trees. The systematic approach ensured the inclusion of diverse geographical and socio-economic contexts for enhanced study's validity and applicability.

2.3. Sample size determination

The sample size of the respondents was determined using the equation provided by Bartlett et al. (2001):

$$n = \frac{n_0}{1 + \frac{n_0}{N}} \ldots\ldots\ldots \quad (1)$$

n = sample size for finite (countable) population; N = total population size; n_o = Sample size for the infinite (uncountable) population which is given by:

$$n0 = t2xpqE2 \quad (2)$$

t = value for a given confidence level i.e., at a 95 % confidence level t = 1.96; E= the acceptable margin of error for the proportion being estimated; p = proportion of respondents who will give a positive response; q = proportion of respondents who will give a negative response; pq = variance of the population, i.e., $p = 0.5$, $q = 0.5$ (pq = 0.25). Assuming a 95 % confidence interval, a 5 % acceptable margin of error, and a maximum variance (pq) of 0.25,

$$n0 = 1.962 \times 0.5 \times 0.50.052 = 384$$

Substituting in eq. 1, the final formula to be used will be represented in Eq. (3).

$$\textit{Sample size}\ (n) = \ 384/(1 + 384\ /\ N) \ldots\ldots\ldots \quad (3)$$

N = population size.

The population size used for the six sites was 47,676. After substituting values of n_0 384 and N values 47,676 in Eq. (3), the final total sample size for each district was calculated.

$$\textit{Sample siza}\ (n) = \ 384/(1 + 384\ /\ 47676) = 380$$

To ensure equal representation at each site, the sample size was determined based on the percentage of each population relative to the total population. From the initially calculated sample size of 380, we reduced the number of respondents by 25 % (with 62 % from Bosset and 31 % from Bati based on the relative population sizes) due to the high similarity in responses and cultural characteristics within each district, as confirmed during preliminary household surveys and the first round of actual data collection. According to Mumtaz et al. (2020), a sample size of 150 or more is considered adequate, while Kline (2016) suggests that a sample size exceeding 200 is also sufficient. Consequently, we engaged a total of 285 households (176 from Bosset and 109 from Bati) with jujube trees in their vicinity, based on the population sizes of each district.

2.4. Data collection methods

The data for this study were collected from both primary and secondary sources. Primary data were obtained through household surveys (HHSs), key informant interviews (KIIs), and focus group discussions (FGDs). Secondary data were gathered from various national and regional data repositories. The household survey utilized a questionnaire with 47 questions, including 28 open-ended, five closed-ended, 11 multiple-choice, and three ranking questions. Out of these, three questions were numeric, while 44 were categorical (comprising eight binary, six ordinal, three ranking, and 27 descriptive responses). The HHSs primarily focused on four key areas: the socio-demographic profile of households, the characteristics of jujube tree cultivation, harvesting and management practices, and farmers' perceptions of jujube fruit consumption and sales. The collected data emphasized jujube tree management practices, uses, and the opportunities and challenges associated with cultivating jujube trees in farmlands, home gardens, and along

Table 1
The agro-ecological zone, soil and climate information for study districts in Ethiopia.

District	Altitude (m. a.s.l)	Type of agro-ecological zones (% total district area)			Latitude	Longitude	Rainfall (mm)	Temperature (°C)	Soil type
		Highland	Mid land	Low land					
Bosset	1400–2500	1	20	79	8° 34′ 59′' N	39° 28′ 59′' E	600–900	26–34	Vertisols (Alternating wet-dry conditions, shrink-swell clays), Luvisols (High-activity clays, high base status)
Bati	18,002,200	–	19	81	11°11′N	40°1′E	550–780	23–30	Fluvisols (stratified fluviatile, marine and lacustrine sediments), Cambisols (moderately developed), Alluvial (loamy soil to silt clays), and Cambisol Arenosols (sandy)

roadsides in the Bosset and Bati districts.

The HHSs included structured questions aimed at capturing demographic information, local practices related to jujube tree and fruit cultivation, challenges encountered, and opportunities for enhancement. Respondents were asked to estimate the annual fruit yield per tree (measured by fruit weight) while considering consistent fruit collection throughout the year. They also discussed key factors affecting fruit yield, the influences on jujube tree growth, fruit production, harvesting, market participation, and obstacles to selling jujube fruits. Additionally, respondents shared their perceived challenges related to jujube cultivation and utilization. The survey utilized various types of variables, including numeric, binary, and ordinal (Table 2).

A Likert scale was employed for the ranking questions due to its effectiveness in capturing the nuanced opinions and attitudes of respondents, allowing them to express the degree of their agreement or disagreement with specific statements. Additionally, KIIs were conducted with district agricultural and natural resource officers, extension officers, and local elders, as these individuals possess valuable knowledge and influence within their communities. In total, 14 interviews were conducted, including six with extension officers (one from each site), two district agricultural officers (one from each district), and six elders (one from each village).

Furthermore, FGDs were held, with each district hosting three sessions that involved groups of 8 to 10 participants. These groups included both male and female attendees representing various age demographics including youth, middle-aged, and older individuals as well as individuals with different levels of literacy and education (Ashebo, 2019). The FGDs employed a checklist of questions to guide discussions, aimed at supplementing any information that may have been overlooked during the HHSs and validating the findings gathered during the interviews.

The KIIs aimed to capture the community's perceived interest in jujube cultivation and to understand the roles of various stakeholders, such as extension officers, NGOs, and research institutions. Meanwhile, the FGDs served as an essential supplement to the household surveys, focusing on community participation in jujube growing, harvesting, and utilization, as well as identifying major challenges and available opportunities. Additionally, relevant secondary data, including population demographics, climate data, soil types, vegetation patterns, and farming systems, were sourced from official documents (both national and regional) and annual reports from the respective districts to enhance the dataset and provide comprehensive information.

Table 2
Captured dependent variables and explanatory variables asked for the respondents during the HHSs in Bosset and Bati Districts in Ethiopia.

Dependent (Outcome) Variables		
Variable	**Description**	**Nature**
Annual fruit yield per tree	This variable captures the total fruit yield harvested per tree per year in kilograms.	Numeric
Market participation	Whether the household sells Ziziphus fruits (Yes = 1, No = 0)	Binary
Perception of cultivation challenges	Households were asked to rank the level of difficulty they face in growing Ziziphus (1 = Very easy, 5 = Very difficult), using a Likert scale.	Ordinal
Utilization of Ziziphus tree parts	Whether a household uses other parts of the Ziziphus tree, such as leaves or wood (Yes = 1, No = 0)	Binary
Explanatory (Independent) Variables		
Age of household head	Age in years, typically ranging from 18 to 71	Numeric
Gender of household head	Male = 0, Female = 1	Binary
District	Bosset = 1, Bati = 2	Categorical
Seedling shortage	Whether the household reports a lack of seedlings (Yes = 1, No = 0)	Binary
Market challenges	Respondents were asked to identify specific challenges they face when selling Ziziphus fruits such as: Transportation issues = 1, Low prices = 2, Broker interference = 3, Lack of buyers = 4	Categorical
Water shortages	This was measured on a scale from 1 (Very limited) to 5 (Plentiful)	Ordinal
Impact of pest	Whether pests are reported to damage the fruits (Yes = 1, No = 0).	Binary
Educational level	Whether the respondent is illiterate or educated is measured based on their educational level.	Numeric
Management methods	This was measured on a scale from 1 (applying good management like other horticultural crops) to 3 (no management was applied)	Ordinal
Lack of raining	Whether the respondent received training or not particularly in jujube tree growing, fruit production and utilization (Yes = 1, No = 0)	Binary
Season of flowering and maturity	Is season affecting the production and utilization of jujube in their locality (Yes = 1, No = 0) - impact of 'Season flowering and maturity' and harvesting seasons	Binary
Other Factors	This variable captured any additional challenges mentioned by participants that were not covered by the predefined categories. These could include social and cultural impacts, individual perceptions and interests, other environmental factors, and economic factors, such as community support or the availability of local cooperatives.	Categorical

2.5. Data analysis

Multiple linear regression was used to analyze the factors affecting the annual fruit yield per tree, while binary logistic regression identified the factors influencing the community's ability to sell jujube fruits and the primary challenges related to growth and harvest. Farmers' perceptions, which refer to the data collected on their attitudes and opinions regarding issues such as the ease of cultivating jujube trees and the challenges of selling their fruits, were measured using a Likert scale.

Descriptive analyses, including frequencies, percentages, means, and standard deviations, were employed to describe various variables such as household demographics (age, gender, education), opportunities for growing jujube trees, fruit production and sales, and key challenges in cultivation and harvesting. Factors hindering engagement in jujube production and fruit marketing were also examined. The perspectives of respondents including households, key informants, and focus group participants were analyzed using descriptive statistics to summarize categorical and ordinal data related to jujube cultivation, pest management, post-harvest handling, income generation potential, improvements in soil fertility and conservation, as well as other benefits provided by jujube trees beyond their fruits.

These perspectives were assessed using a Likert scale (ranging from 1 for "strongly disagree" to 5 for "strongly agree"), with subsequent frequency analyses conducted to evaluate the findings. The median value, which serves as the ideal summary statistic for analyzing an individual sample's overall impression, was utilized. Consequently, the Kruskal-Wallis test, a nonparametric method for categorical data, was applied to evaluate respondents' perceptions regarding the aforementioned jujube issues. Statistical analyses were performed using SPSS version 26, ensuring model adequacy through normality checks against all necessary assumptions. The regression model used to assess the influence of explanatory variables is represented by Eqs. (4) and (5).

Multiple linear regression was employed to model the factors influencing continuous dependent variables, such as the annual fruit yield per tree (in kilograms). The independent (explanatory) variables in the model included the district, demographic factors (age, gender, education level), water shortages, management practices, seedling availability, lack of training, market challenges, frequency of extension visits, and the timing of flowering and fruit maturity, as well as the availability

of individuals to collect the fruits.

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_i X_i \ldots\ldots\ldots \quad (4)$$

Where y is the dependent variable (fruit yield); β0 is the y-intercept; β_i is the 'slope coefficient (coefficients representing the strength and direction of the relationship between the independent variables and the dependent variable) associated with the reference group and X_i explanatory variables. The underlying hypothesis is that at least one explanatory variable has a significant effect on the annual fruit yield per tree.

Additionally, logistic regression was used to model binary outcome variables, such as the major challenges in growing jujube trees and the factors hindering market engagement. The explanatory variables included in this regression analysis were the district, amount of fruit harvested, demographic factors, market challenges, pest issues, availability of collectors, and lack of training. The logistic regression model utilized is as follows::

$$\text{logit}(p) = \ln\left[\frac{p(y)}{1-p(y)}\right] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_i X_i \ldots\ldots\ldots \quad (5)$$

Where P is the probability of the outcome occurring (probability of market participation and hindering factors to grow jujube); β_0 is the y-intercept; $\ln\left[\frac{p(y)}{1-p(y)}\right]$ is thelog (*odds*)of the outcomes; β_i is the 'slope coefficient (coefficients representing the strength and direction of the relationship between the independent variables and the dependent variable) associated with the reference group and X_i explanatory variables. The odds ratios derived from the logistic regression model indicated the likelihood of an outcome occurring (participating in the market), given the presence of the independent variables. The underlined hypothesis was at least one explanatory variable has a significant effect on the likelihood of growing jujube trees and fruit market participation.

3. Results

3.1. Socio-demographic characteristics of the respondents

Among all the respondents i.e. 285 households, 141 were from Bosset (92 males, 49 females) and 144 from Bati (89 males, 55 females) districts. Overall, 36.5 % of the respondents were females while 63.5 % were males (Table 3). The age distribution among respondents showed that 4 % were aged between 18 and 25 years old, 25 % between 26 and 35 years old, 43 % between 36 and 45 years old, 21 % between 46 and 55 years old, and the remaining respondents were over 55 years old. The overall mean age of the respondents was 40 years with ages ranging from 18 to 71 years.

3.2. Jujube fruit tree growing habits and utilization

The data reveals that naturally grown jujube trees in farmlands and home gardens are more prevalent across both districts, accounting for 73.5 % of instances compared to planted trees (26.5 %). No variation was observed in the mode of growing and in the utilization of different parts of the tree among districts. Almost all the tree parts were utilized by respondents whereas only a minority (2 %) utilized exclusively the fruits. The flowering and fruit set seasons varied throughout the year with August to October cited as the peak season by 36 % of respondents followed by January to February (12 %). Fruit maturity and collection also varied, starting in the first week of August in Bosset and mid-October in the Bati district of Ethiopia (Table 4).

3.3. Fruit collection methods, collection materials and storage

In fruit collection methods, a diverse array of practices emerged serving both household consumption and commercial sales. Predominant methods included gathering fallen fruits and shaking trees, accounting for 36 % and 27.5 % of respondents, respectively. Also, 21 % of respondents were utilizing all the available techniques including direct picking. About 12 % of the respondents abstained from fruit collection, household consumption and selling at nearby markets. Women and children played a significant role in selling fruits (11 %), contrasting with men who contributed minimally (2 %) to collection and selling efforts. Red fruits were favoured (62 %) in the market followed by yellow fruits (30 %). Each method carried its advantages and drawbacks (Table 5). Locally accessible materials like sacks, plastic bags, cloths, plates and buckets were commonly used for collection, with sacks and jars utilized for transportation (Fig. 2).

For sale measurement, small tea cups, water cups, jars, and sacks were utilized, while storage practices involved drying fruits for future use, with most respondents citing durations ranging from three months to one year in dry environments.

3.4. Farmer's jujube tree and fruit management methods

Jujube tree and fruit management practices were largely neglected with a significant majority (92 %) of respondents reporting not doing any including protection from animal encroachment and control of pests (Table 6). Surprisingly, extension officers had not engaged in discussions regarding jujube fruit collection or harvesting with farmers, highlighting a notable lack of awareness among both parties regarding the significance of these good silvicultural practices. While some individuals sporadically used insecticides based on their experiences in other crop productions, practices like pruning and pollarding were primarily aimed at mitigating bird impact on other crops rather than specifically addressing jujube management. Extension officers and relevant authorities had not conducted any training or follow-up efforts to address jujube-related concerns; instead, they had focused more on cereal and other horticultural crops. It became evident during interviews that both the community and extension officers exhibited limited awareness and interest in jujube fruits.

Table 3
Total number of male (M) and female (F) populations, percentage of urban and rural populations and number of household surveys (HHSs), focus group discussion (FGD), key informant interview (KII) respondents in study districts of Ethiopia.

District	Site	Total population		Population (%)		Number of respondents					
		M	F	Rural	Urban	HHS		FGD		KII	
						M	F	M	F	M	F
Bosset	Tiyo	4961	2046	72	28	26	16	4	4	5	2
	Tedecha	5238	4194			35	22	5	5		
	Tirre	5703	3786			35	21	5	3		
Bati	Bira	4471	1538	83	17	21	14	5	5	6	1
	Salmenie	5884	5094			41	25	5	5		
	Kamie	3127	1634			18	11	5	4		

Table 4
Local community's mode of growth and utilization of jujube tree parts (frequency of the respondents) in Bosset and Bati districts in Ethiopia.

District	Site	Mode of growing		Parts of the tree utilized				
		Naturally grown in farmlands	Planted in home gardens	Only fruits	Fruits and leaves	Fruits and wood	Fruits, wood, and leaves	Fruits, wood, leaves, stem, bark and roots
Bati	Birra	82	18	6	10	8	75	2
	Kamie	68	32	3	0	0	94	3
	Salmenie	71	29	0	0	2	98	0
Bosset	Tedecha	70	30	0	2	8	89	2
	Tirre	75	25	0	2	8	81	9
	Tiyo	75	25	3	3	17	75	3
% of responders		73.5	26.5	2	2.8	7.2	85	3

Table 5
The advantages and disadvantages of the jujube fruit collection methods employed by local communities, and their color preferences for harvesting in the Bosset and Bati districts of Ethiopia.

Collection methods	% of the respondents	Advantage	Disadvantage
Collecting by picking directly from the tree	3.5	Helps to collect only mature, healthy, and fresh fruits. Reduces damage on untargeted and immature fruits and flowers.	Can cause physical damage to the collectors such as falling during climbing or collecting or cause wounding by the thorn of the tree
Collecting the fruit by shaking the tree	36	Helps to get fresh fruits. Easy to collect	It causes the tearing of fruits. It can cause wastage i.e. immature fruits and flowers can fall together. Can cause damage to the branches
Collecting those fallen on the ground	27.5	Easy, as matured fruits only will fall due to wind. Every family member can collect easily.	The fruits may not have qualified as they might fall days or weeks before collections. Fruits might be affected by fungus, insects, goats or other animals.
All collection methods	21	No efforts are needed, as you eat what you found	You can find damaged fruits when you pick them up after some days.
Don't collect	12	–	–

Districts	Fruit colour preferences for collection (% of respondents)		
	Red	Yellow	Both colors
Bati	42	3	3
Bosset	20	27	5
Total %	62	30	8

3.5. Farmer's perception of jujube fruit harvest and utilization

The perceptions of respondents regarding jujube fruit harvesting and utilization revealed prevalent sentiments within the community. A significant majority of respondents expressed strong agreement regarding the ease of jujube tree growing after planting (204) and its adaptability to various land uses (195 respondents) (Table 7). Moreover, the frequency analysis revealed that a strong consensus emerged among respondents regarding the importance of jujube as a source of fodder and fuelwood (225) and its utility for farm utensils (those sticks utilized to make the different traditional farming materials including spad sticks, axes, yokes, etc.) (199 respondents).

However, uncertainty prevailed concerning certain aspects, with respondents expressing ambiguity regarding the feasibility of managing insects (121 respondents), the potential impact of jujube trees on soil fertility (95 respondents), and their aesthetic value (108) (Table 7). The majority of the respondents disagreed with the prospect of jujube tree regarding creating employment opportunities within the community (129 respondents) (Table 7). Conversely, respondents strongly disagreed with the notion of fruits less susceptible to insects and diseases and perceived the application of insecticides to jujube fruit as challenging.

3.6. Opportunities to grow jujube fruit trees

The findings underscored numerous opportunities for local communities to engage in the harvesting and utilization of jujube fruits. Foremost among these opportunities is the tree's remarkable drought tolerance, coupled with its capacity to yield fruits when managed effectively, even during dry seasons. Moreover, the ample availability of land in the study areas for cultivating jujube trees, along with its adaptability to diverse land uses and the potential for multiple fruiting cycles per year, presents further avenues for engagement. Furthermore, the profound reverence shown by Muslim communities towards the tree, considering it a divine gift mentioned in the Quran and incorporating it into funeral ceremonies, highlights additional cultural significance. Beyond these opportunities, the multifunctional nature of the tree leaves serves various purposes including beautification and treatment of ailments such as constipation, and fever

3.7. Factors affecting the amount of fruits harvested per tree

Several significant factors influence the quantity of fruit harvested (in kg) per tree per year in the study sites. These include the district, the availability of collectors, water availability, and the shortage of seedlings. The district which encompasses the specific cultural, social, and economic characteristics of local communities emerged as a key factor affecting fruit harvests. In Bosset, district influences were found to be 0.87 times greater than in Bati, negatively impacting fruit harvesting. The availability of collectors also played a crucial role; the number of collectors involved in fruit collection was significantly lower in Bosset, with a factor of 1.42 compared to Bati. Interestingly, water availability showed a negative correlation, with a coefficient of −0.40, suggesting that the trees are relatively resilient and that water shortages are not a primary challenge to fruit yield.

Conversely, the shortage of seedlings had a clear adverse effect on fruit harvesting. As challenges related to seedling shortages increased, the likelihood of communities achieving high fruit yields decreased by a factor of 0.60. Extension visits also play an insignificant positive role, although with a relatively higher p-value. Together, these factors explain approximately 20 % of the variance in fruit harvest, as indicated by the model's adjusted R-squared value of 0.195 (Table 8).

3.8. Local community participation in selling jujube fruits

Local community engagement in selling jujube fruits in Ethiopia was significantly influenced by several factors. The district emerged as a major influencer, indicating that ethnic and cultural beliefs strongly impact fruit sales. As a result, market participation among local communities declined by a factor of 1.76 due to these ongoing influences in each district (Table 9). Additionally, the abundance of fruit affects jujube sales; lower yields correlate with reduced market engagement.

Fig. 2. Jujube tree and fruit, and women selling jujube fruits in Bati market during the market day (Photo taken February 2022, from Bati district, Ethiopia).

Table 6
Percentage of local communities' jujube tree and fruit management methods employed in Bosset and Bati districts in Ethiopia.

District	Type of jujube tree and fruit management methods used (% of respondents)		
	Don't apply any management.	Utilizing insecticides and locally available methods	Applying pruning, supplementary irrigation
Bati	44	2	5
Bosset	45		4
Total	89	2	9
%			

The age of the collectors was also negatively associated with fruit sales, indicating that as respondents age, their likelihood of participating in the sale of jujube fruits decreases. Specifically, their participation diminishes by a factor of 0.04 (Table 9). Other factors, such as cultural beliefs and lack of interest, similarly demonstrated a negative relationship with fruit selling. These factors collectively explain almost 26 % of the variance in engagement (Table 9).

3.9. Major challenges of growing jujube fruit trees

Cultivating jujube seems to be a challenging endeavour with respondents predominantly citing the age, pests, management practices and water availability as the primary obstacles encountered (Table 10). A significant variation was also observed in the growing of jujube trees mainly due to the variation expressed by district which may be due to the variation of the social, economic and cultural views among the communities of the districts.

For every unit increase in age, the community's interest in growing jujube trees decreased by 0.06 (Table 8). On the other hand, for every unit increase in challenges of pests the community interest in growing jujube trees reduced by a factor of 1.15 times. Additionally, due to increasing challenges in water shortage, and cultural influences in the study districts, the community's interest in growing jujube trees was reduced by 1.41, and 2 times, respectively (Table 10).

4. Discussion

The harvest of jujube fruits is influenced by various factors encompassing practical management strategies, cultural norms and perceived gaps in extension services support. It appears that both local communities and experts have overlooked crucial tasks such as fruit harvesting and tree maintenance, leading to limited awareness about the benefits of these activities. Several contributing factors to diminished fruit harvests have been identified including free grazing during seedling and flowering stages, insect damage and market-related issues like low demand, depressed market prices, the presence of brokers and inadequate

Table 7
Perceptions of respondents concerning the growth, production, utilization and management of the jujube tree and its fruit in Bosset and Bati districts in Ethiopia.

Respondents perceptions on jujube growth, management and utilization	Frequency					N	S.E	Median	S.D
	5	4	3	2	1				
The species grows easily after planting	204	79	2			285	0.03	5	0.47
Easy to raise seedlings from seeds	122	104	39	2	18	285	0.06	4	1.08
Grows in all land use types easily	195	67	9	11	3	285	0.05	5	0.82
Easy to grow and manage with other crops	84	182	3	14	2	285	0.04	4	0.73
Easily manageable by weeding and pruning	74	161	13	34	3	285	0.06	4	0.94
Easy to manage the fruits from insects and diseases by applying insecticides	11	19	121	69	65	285	0.06	3	1.04
Not affected by pests and diseases	8	37	10	79	39	285	0.06	2	1.04
Increases household income	36	77	49	98	25	285	0.07	3	1.21
Can be stored for a long time	125	121	24	7	8	285	0.05	4	0.91
Increases soil fertility	91	75	95	17	7	285	0.06	4	1.04
Conserves soil and water resources	89	161	30	2	3	285	0.04	4	0.72
Can be used for fodder and fuelwood	225	56	2		2	285	0.03	5	0.53
Has aesthetic value	56	69	108	37	15	285	0.07	3	1.10
Has medicinal value	53	94	49	78	11	285	0.07	4	1.18
Can be used as a construction wood	132	147		4	2	285	0.04	4	0.64
Creates employment for the community	25	52	53	129	26	285	0.07	2	1.13
Farm Tools	199	83			3	285	0.04	5	0.59

SE = standard error of the mean; S.*D*= standard deviation; 5= strongly agree; 4=agree; 3=unsure; 2=disagree and 1=strongly disagree.

Table 8
Major factors influencing the amount of jujube fruit yield harvested per tree in Bosset and Bati districts in Ethiopia.

Variables	Coefficients (β)	S.E	Exp of β	t-value	p-value	95 % C.I. for EXP (β)		Collinearity Statistics	
						Lower	Upper	TIF	VIF
District	0.87	0.14	0.37	6.16	<0.0001***	0.59	1.15	0.78	1.29
Collectors	1.42	0.40	0.20	3.57	<0.0001***	0.64	2.21	0.90	1.15
Water shortage	−0.40	0.18	0.15	−2.19	0.03*	−0.76	−0.04	0.60	1.68
Seedling shortage	0.60	0.27	0.16	2.27	0.024*	0.08	1.12	0.59	1.69
Education level	−0.02	0.02	0.04	−0.71	0.48	−0.06	0.03	0.81	1.23
Gender	0.12	0.13	0.05	0.95	0.36	−0.12	0.38	0.98	1.02
Age (years)	0.01	0.01	0.04	0.69	0.49	−0.01	0.02	0.77	1.29
Market challenges	0.13	0.19	0.04	0.67	0.51	−0.25	0.51	0.87	1.15
Insect pests	0.08	0.16	0.03	0.49	0.62	−0.24	0.39	0.82	1.22
Lack of training	−0.48	0.37	0.08	−1.29	0.20	−1.22	0.26	0.69	1.44
Extension visits	0.32	0.46	0.05	0.70	0.48	−0.58	1.22	0.69	1.45
Flowering season	0.10	0.08	0.07	1.24	0.22	−0.06	0.25	0.92	1.08
Maturity season	−0.02	0.06	0.02	−0.34	0.72	−0.147	0.10	0.86	1.17
Constant	−0.89	1.32		−0.67	0.50	−3.49	1.72		
R square	0.232								
Adjusted R square	0.195								
RMS	7.017								
MSE	1.113								
$p > F$	6.304								

*** $= p < 0.001$.
* $= p < 0.05$; Binary answers (yes =1, no = 0, or Female =1, Male = 0); VIF = Variance inflation factor; TIF = Tolerance inflation factor; CI = confidence interval; β = slope coefficient; SE = Standard error; Exp = exponential; RMS = Root mean square; MSE = Mean square error.

Table 9
Major factors influencing local community market participation in selling jujube fruits in Bosset and Bati districts in Ethiopia.

Variable	Coefficients (β)	S.E	Exp of β	p-value	95 % C.I. for EXP(β)	
					Lower	Upper
District	1.76	0.39	5.90	<0.0001***	2.74	12.73
Other factors	−0.98	0.37	0.38	0.01*	0.18	0.78
Fruit amount	0.36	0.14	1.43	0.01*	1.10	1.86
Age of collector	−0.04	0.02	0.96	0.02*	0.92	0.99
Education level	−0.03	0.05	0.10	0.96	0.90	1.11
Gender	−0.16	0.33	0.85	0.64	0.44	1.64
Market challenges	0.28	0.45	1.32	0.54	0.54	3.20
Insect pests	0.59	0.41	1.80	0.15	0.80	4.02
Collectors	0.46	0.84	1.58	0.59	0.30	8.25
Lack of training	−0.62	0.85	0.54	0.46	0.102	2.82
Constant	2.27	1.51	9.68	0.13	−0.147	0.10
R square	0.169					
Adjusted R square	0.257					
Model Sig.	0.000					

*** $= p < 0.001$.
* $= p < 0.05$; Binary answers (yes =1, no = 0; Female =1, Male = 0); β = slope coefficient; CI = confidence interval; SE = Standard error; Exp = exponential.

Table 10
Factors influencing the local communities not to grow and produce jujube fruits in Bosset and Bati districts in Ethiopia.

Variable	Coefficient (β)	S.E	p-value	Exp (β)	95 % C.I. for EXP(β)	
					Lower	Upper
Age	−0.06	0.02	<0.0001***	0.93	0.89	0.96
District	2.00	0.32	<0.0001***	7.38	3.80	14.35
Water shortage	1.41	0.35	<0.0001***	4.08	2.06	8.09
Pests	−1.15	0.34	0.001**	0.32	0.16	0.62
Gender	0.70	0.32	0.03*	2.01	1.09	3.73
Management	−1.76	0.73	0.02*	0.17	0.04	0.72
Education level	0.02	0.05	0.73	1.02	0.93	1.11
Other factors	0.59	0.36	0.11	1.80	0.88	3.68
Lack of training	1.13	0.83	0.17	3.10	0.62	15.60
Constant	1.91	1.55	0.23	6.73		
R square	0.304					
Adjusted R square	0.409					
Model sig.	0.000					

*** $= p < 0.001$.
** $= p < 0.01$.
* $= p < 0.05$; Binary answers (yes =1, no = 0, or Female =1, Male = 0) β = slope coefficient; CI = confidence interval; SE = Standard error; Exp = exponential.

marketplace infrastructure. Additionally, the theft of branches for fencing and fruits for consumption has exacerbated these challenges, along with the absence of quality fruits and improved seeds and seedlings.

The amount of fruits harvested per tree per year varies significantly depending on factors like water availability, the presence of fruit collectors and seedling health (availability of seedlings for planting which is free from biotic and abiotic defects rather). While studies specifically focusing on the cultivation and management of naturally growing jujube fruit trees are scarce, it is acknowledged that sufficient water and optimal temperature conditions are crucial for sustainable harvests and high-quality fruit yield (Li et al., 2015; Jiang et al., 2020). Additionally, irrigation practices have been shown to enhance various parameters including branch length, branch number, collar diameter, soil moisture content and fruit yield (Ismail and Almarshadi, 2013). Genetic variation within wild and semi-wild populations of African food tree species, including jujube, contributes to variations in fruit harvest quantity per tree, nutritional content and other fruit traits (Jamnadass et al., 2011; Leakey et al., 2021; 2022). Pests and diseases directly impact fruit quality, with small-sized fruits among native genotypes being particularly vulnerable to pest damage (Muhammad et al., 2022). The variation in harvested fruit quantity has been documented as a challenging factor across different production sites globally, with factors such as insect pests, prolonged drought, inadequate tree management, and varietal differences predominant (Kalinganire et al., 2012; Ismail and Almarshadi, 2013; Acharya and Meena, 2017; Karar et al., 2020; Rashwan et al., 2020).

The district, which encompasses the unique cultures, beliefs, and social and economic characteristics of its communities, was identified as a significant factor influencing various analyzed variables, such as fruit yield, participation in jujube cultivation, and marketing activities. These influences may stem from cultural beliefs in certain districts that discourage engagement in jujube farming. For instance, cultural factors were notably stronger in the transition from Bosset to Bati, where active harvesting and utilization of jujube fruits occurred. Similar findings in Zimbabwe (Nyanga et al., 2013) and Sudan (Adam et al., 2022) indicated that cultural, social, and economic influences deter local communities from participating in jujube cultivation, resulting in the fruit being underutilized for years.

Additionally, in the current study, insect pests, inadequate management practices, water availability, and demographic variables such as age and gender were observed to significantly influence the number of jujube fruits harvested. Market participation among fruit harvesters was remarkably low, resembling patterns observed in Sudan where women and children primarily engage in the harvesting and selling of jujube fruits (Saied et al., 2008; Adam et al., 2022). Selling wild fruits, including jujube fruits, remains uncommon in Ethiopia, largely due to cultural beliefs (which undermine the participation of the local communities in jujube production and utilizations such as participating in jujube production is like a calling poverty to your house, disrespecting the culture of their ethnic groups) and low market demands (Seyoum et al., 2015; Dejene et al., 2020; Duguma, 2020). Seyoum et al. (2015) reported that selling jujube fruits in Ethiopia has historically been associated with being very poor or having bad habits. Local communities connect the use of wild edible plants with drought, famine, and other forms of calamities and crises (Duguma, 2020). The study revealed minimal allocation of family labour towards managing, harvesting, and selling of jujube fruits (<2 %), with trees often growing and fruiting without any management practices (no supplementary water, digging, weeding, or pest management). Sometimes, seedlings grow under the trees, which households transplant within their yards and as fences between farms and their homes.

While edible wild fruits are preferred over cultivated commercial fruits by many Ethiopians (Seyoum et al., 2015), there exists a significant opportunity for enhanced utilization of jujube, which could help address market-related challenges. It is imperative to dispel misconceptions surrounding the fruit and demonstrate its potential nutritional and economic benefits to the community. Increased knowledge and adoption of feasible management practices to mitigate the impact of insect pests and address market-related issues are essential. Additionally, ensuring water availability, despite the tree's relative drought tolerance, remains a critical concern (Ismail and Almarshadi, 2013).

The current study identified the bottleneck challenges in growth, production, harvesting and consumption of jujube fruit trees in different agroecological zones and different ethnic groups in Ethiopia. The findings of the current study underscore the importance of emphasizing community benefits and providing targeted training on management practices to optimize jujube fruit production, improve socio-economic benefits and demonstrate largescale production and sustainable production of jujube fruits in particular and agroforestry trees species in general.

5. Conclusion and recommendations

In conclusion, this study underscores the essentiality of research interference in reducing the factors hindering production and utilization, and unlocking the full potential of jujube fruits which are crucial in addressing nutritional security and generating income. Despite their nutritional richness and versatility, jujube remains underutilized, presenting missed opportunities for smallholder farmers. Challenges such as insect pests, water scarcity and market accessibility hinder widespread harvesting and utilization. However, opportunities abound, including the tree's drought tolerance, adaptability to diverse land uses, and cultural significance. To maximize these opportunities and mitigate challenges, intensive efforts are needed to enhance community awareness, extension services, and sustainable management practices and invest in research to improve varieties and market development. By harnessing the potential of jujube tree fruits Ethiopia can enhance food security, income generation and rural livelihoods, as in other regions.

Ethical statements and consent to participate

Written permission to conduct the research was obtained from the Sokoine University of Agriculture (SUA) Office of the Vice-Chancellor research committee (Ref. no. SUA/FSC/D/2020/0011/11, dated

February 18, 2022), and the two chosen district government heads (Bosset and Bati District) were given authorization for the field study and data collection via an official letter (Ref No: 3025/4.28/14, dated April 24, 2022). Before providing oral informed consent, study participants were given a brief explanation of the study's objectives. Each participant gave his or her free consent to take part in the study. Finally, all interviewees' private information was protected and kept private because of their interests and unwillingness to publish it.

CRediT authorship contribution statement

Tigabu R. Alle: Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Samora M. Andrew:** Writing – review & editing, Visualization, Validation, Supervision, Conceptualization. **Miriam F. Karlsson:** Writing – review & editing, Visualization, Validation, Supervision, Conceptualization. **Abdella Gure:** Writing – review & editing, Visualization, Validation, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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