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Production practices and agronomic approaches of Khat (*Catha edulis* Forsk) in eastern Ethiopia

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Abstract

This study investigates the integrated production practices, cultivation trends, and agronomic approaches of khat (*Catha edulis* Forsk) in the East and West Hararghe zones of Eastern Ethiopia. Addressing a notable gap in agronomic research on stimulant crops, we employed a mixed-methods approach combining structured household surveys (n = 238), focus group discussions, key informant interviews, and field observations. Quantitative data were analyzed using SPSS v26 and MS Excel 2010 to generate descriptive statistics and conduct t-tests and Chi-square analyses. Findings reveal that *Dalacha* and *Hamercot* (gray) are the most preferred khat varieties, receiving first-rank preferences from 65.2% and 53% of farmers, respectively, while *Dima* (red) was less favored. Intercropping emerged as the dominant expansion strategy in East Hararghe, with cultivation rates increasing by 37.7% and 63.6% in East and West Hararghe, respectively. Irrigation practices were shaped by water source availability, with boreholes and rivers being most common. Planting material quantity was influenced by moisture, soil type, land access, and material health. Propagation relied primarily on stem cuttings (59.2%) and suckers (32.8%). Harvesting was timed to optimize market demand and plant maturity, with manual picking during cooler morning hours being standard.

Keywords: Khat, Intercropping, Propagation, Fertilizer use, Eastern Ethiopia, Agronomic practice

1) Introduction

Khat (Catha edulis Forsk) is an evergreen, perennial shrub that is cultivated as a consumable plant [1][1]. Khat is in the genus Catha, phylum Plantae, order Celastrales, family Celastraceae, species Edulis, and Magnoliopsida [2][2]. Khat is also known by other names such as Qat and Chat in Yemen and Ethiopia, Muguka and Miraa in Kenya, Jaad, and Qaad in Somalia, and Jimaa in Afan Oromo. It is classified as a drug in most Western countries. [1] Khat is reportedly indigenous to Ethiopia and spread to East Africa and Yemen [3][3]. In Ethiopia, it has a long history dating back to the 13th century and is an abundant product that is commonly chewed and cultivated [4][4] ; in fact, it is the second most important foreign exchange earning activity in Ethiopia after coffee in 1999/2000 [5].

Khat performs best on soils with a pH of 6.0-- 8.2. Nonetheless, formerly established, Khat grows well under a wide range of soil types and climatic conditions. In Ethiopia, Khat is considerably grown and thrives stylish in the middle of the country(1500 – 2500 m above sea level), but it can also be grown with irrigation down to 1000 m above sea level if the area is free of frost. At the early development stage of plants, the water supply is more critical than the soil type. Khat is the most extensively grown cash crop, and Ethiopia is the leading producer of khat [6][5]. Khat is grown in pure stands on steep slants and borderline arrives, whereas it is inter-cropped with sludge and other food crops on nicely rich soils.

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[1] Ngari et al., (2018) Khat (Catha edulis Forsk) is an evergreen perennial shrub produced as a consumable plant; the majority of Western countries recognize it as “khat”.
[2] Sikiru, 2012) Taxonomy: class Magnoliopsida; order Celastrales; family Celastraceae; genus Catha; species edulis; kingdom Plantae.
[3] Khat is reportedly indigenous to Ethiopia and spread to East Africa and Yemen.
[4] In Ethiopia, khat has a long history dating back to the 13th century and is commonly chewed and cultivated.
[5] Cafer, A. (2016). Tef, Khat, and community rigidity a mixed styles examination of smallholder handover of sustainable intensification practices

The world's largest producer of Khat, it has become the fastest growing export product. Development institutions state their displeasure with crops and offer quiet support, but Khat is grown and expanding in different corridor of Ethiopia. Khat is presently being grown for trade in Jimma, Shashemene, Sidama, Kembata, Gurage, and indeed as far as Debre Libanos, Gojam, Wollo, and Tigray in addition to traditional Hararghe areas. Substantially in the East and West Hararghe zones, Oromiya is the most important center of Khat product (7). In Ethiopia, the two zones alone contribute half of the total product.

Hararghe is also considered the world's leading producer of quality Khat [7][6]. Rainfed Khat yields only two main crops at the end of the rainy season. Under irrigation, three or more primary crops can be produced, which facilitates cost reduction [4][7]. Khat, which is cultivated by farmers in many regions of Ethiopia, is used as a stimulant and provides a much higher yield than other cash crops, including coffee.

Khat cultivation requires less inputs and less labor than other cash crops [7]. Because khat requires minimal off-farm inputs, its production is compatible with poor farmers who are limited to credit [8][8]. It is a significant crop in Ethiopia's eastern and western Hararghe, with many cultivars named by their place of origin. Khat farming necessitates fewer labor resources and other inputs than other cash crops [7].

Khat requires little off-farm resources. In Hararghe, Ethiopia's eastern and western regions, it is a significant crop with numerous cultivars named after their place of origin. However, there is a dearth of comprehensive research on production constraints and integrated production practices, and there is a lack of information on cultivar variation particularly across the east and west Hararghe zones of eastern

[6]Rainfed khat yields two main crops in one year; irrigation may increase the frequency of cultivation to three or more cycles, thereby lowering the cost of production per unit.
[7]The eastern and western Hararghe districts of Oromia are the main centres of khat production and are noted for their high quality khat.
[8]Tensay Hailu.(2019) The Conceptualization of Khat, Its product and Its Socio- Economic Counteraccusations in Eastern Ethiopia

Ethiopia. This makes it more difficult to estimate the stability of mixed populations and develop effective production management strategies[9]

According to farmers, the main challenges in producing khat are limited access to irrigation, high costs for chemical fertilizers, insufficient manure, and inadequate credit facilities[10]. The selection of suitable planting materials, land preparation methods, planting techniques, irrigation methods, optimal irrigation timings, fertilization, cultivation procedures, pest and disease management, harvesting practices, and post-harvest handling are just a few examples of the agronomic management that may be used to overcome these limitations[11].

Thus, the aim of this study was to document the integrated production practices, cultivation trends, and agronomic approaches used for khat (*Catha edulis* Forsk) production in the East and West Hararghe zones of Eastern Ethiopia. This academically rigorous approach to systematically documenting historical production methods and how they evolved provided an academically rigorous account of the prevailing agricultural practices and techniques in the region.

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[9]Khat production requires minimal off-farm inputs and is therefore affordable for small farmers with limited credit

[10]Study objective: to document integrated production techniques, cultivation trends and agronomic approaches in the eastern and central regions of the cultivation of khat (Catha edulis Forska).

[11]Agronomic responses: The listed management areas summarize recommended focus areas (planting material, irrigation scheduling, pest control, post-harvest handling) rather than prescriptive protocols.

2. Materials and methods

2.1 Description of the Study Area

2.1.1 Geographical Description

The research took place in the East and West Hararghe areas of the Oromia region in Ethiopia[12] and this spot is east of the nation. The places chosen from East Hararghe were Grawa and Dadar and Fadis and Haramaya plus Kombolcha and Meta. [13]From West Hararghe the areas included Chiro and Habro and Tulo as well as Oda Bultum[14]. Now this region has a mix of high lands and low lands. This mix really affects both the weather and the way people do farming there.

2.1.2 Ecological Description

The East and West Hararghe areas are important for growing khat. Khat is a plant whose leaves people chew to get a boost of energy. The natural conditions like the type of soil and the amount of rain plus the temperature in these areas make it perfect for growing khat. The high lands are cooler, the soil is good, the low lands are warmer, and this helps with different parts of growing khat. The variety of life in the region also helps grow many other crops and animals and this adds a lot to how much farming stuff people can produce.

[12] The East and West Hararghe Zone of Oromiya Regional State, Eastern Ethiopia
[13] Grawa, Dadar, Fadis, Haramaya, Kombolcha, and Meta are Districts of East Hararghe Zone
[14] Chiro, Habro, Tulo as well as Oda Bultum are Districts of West Hararghe Zone

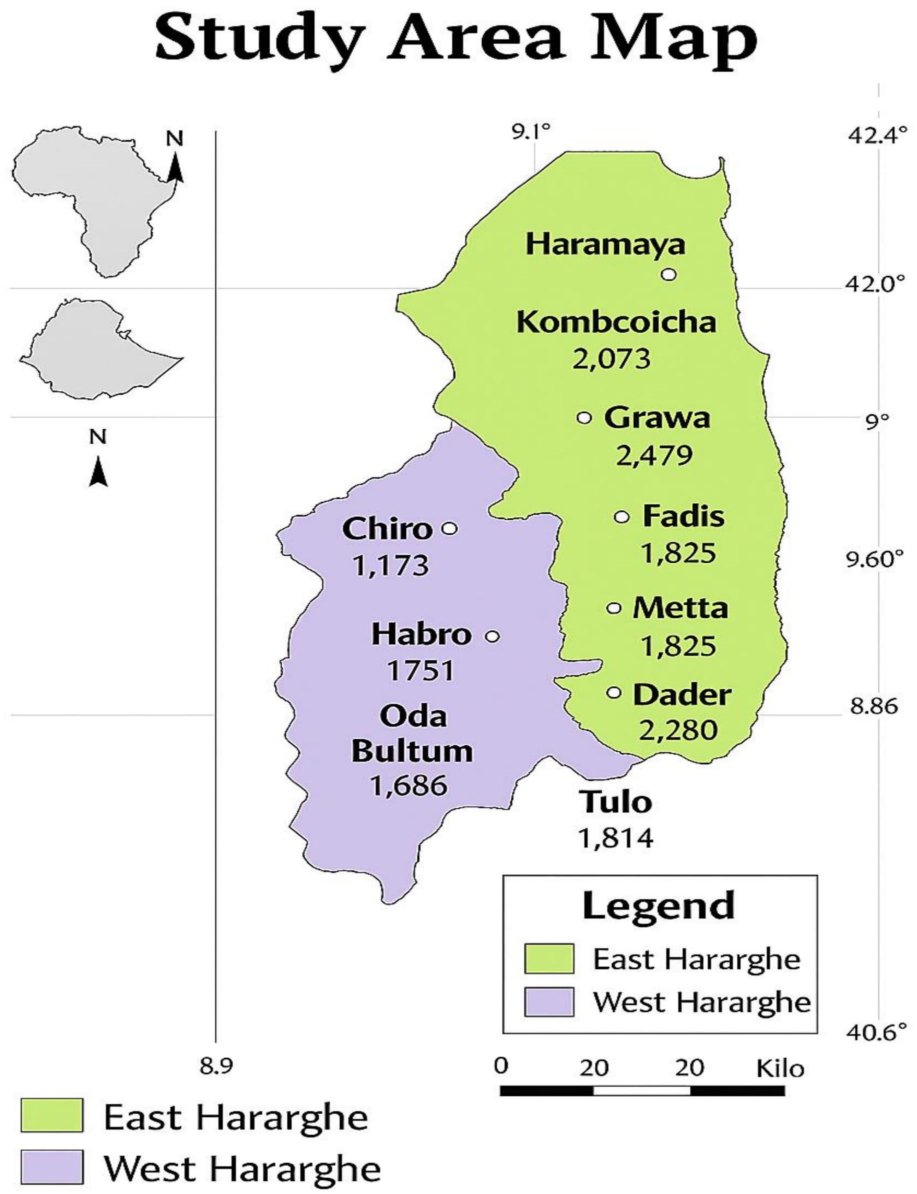


Figure 1: Study Area Map of East and West Hararghe zones

2.3 Target Population, Survey Design, Sampling, and Data Collection Methods

The target population for this study comprised smallholder khat-producing households across selected districts in East and West Hararghe zones. A structured household survey was administered using a face-to-face interview approach. In accordance with prevailing cultural norms in rural Ethiopia, the male head of household typically served as the primary respondent. However, in households led by women due to widowhood, divorce, or absence of the husband female heads were interviewed. In cases where the husband was temporarily unavailable during fieldwork, the wife provided responses on behalf of the household.

To ensure consistency and data quality, the lead researcher provided practical training and supervision to agricultural development agents who conducted the majority of the 2024 fieldwork. The questionnaire was prepared in English but administered in Afaan Oromoo to facilitate comprehension and accurate responses.

Quantitative data were collected through structured questionnaires covering livelihood activities, production methods, socioeconomic status, and challenges. Enumerators were trained professionals with academic backgrounds in crop and animal sciences, and they were fluent in the local language. The house-to-house survey method ensured broad coverage and minimized sampling bias.

In parallel, qualitative data were gathered through focus group discussions (FGDs), key informant interviews (KIIs), and field observations. About 174 individuals participated in FGDs 147 men and 27 women while 53 individuals (46 men and 7 women) were engaged in KIIs. Key informants included agricultural development agents, environmental and climate change experts, water resource professionals, and peasant association leaders. Participants were purposively selected based on their knowledge of khat production systems and community dynamics.

Particular emphasis was placed on involving older farmers in FGDs, recognizing their deep experiential knowledge of local production practices and socioeconomic conditions. Although they were not part of the household survey sample, elderly men and women were grouped separately and engaged in guided discussions using open-ended questions. These sessions explored themes such as livelihood strategies, cropping systems, and market participation. Moderators created a respectful and inclusive environment that encouraged participants to share personal insights and lived experiences.

The triangulation of data sources survey responses, FGDs, KIIs, and field observations enhanced the validity and reliability of the findings. The sample frame was constructed by purposively selecting two peasant associations from each district. The number of farmers (n) to be selected from each Peasant association was calculated as the sample size. This was done by using a simplified equation of [9][15]:

Equation no (1) $\quad n = \frac{N}{1+N(e)^2} \ldots \quad n = \frac{1200}{1+1200(0.05)^2} \ldots = 300$

Where n is the sample size, N is the population measure, and e is the level of precision (0.05). The households were selected using a systematic sampling technique, which divided N by n (N/n = i) and selected each ith head of the household starting from the first title of the head household based on the list at their Peasant association level. A lottery method has been used to obtain the first household from the i ranges appropriately. [10] States that the percentage of the sampled population had been computed using the formula.

Equation no (2) $\quad C = \frac{n}{N} \times 100 \ldots \quad C = \frac{238}{1200} \times 100 \ldots C \approx 20\%$

2.3 Source of Data and Method of Collection

To become acquainted with the study areas and obtain firsthand knowledge of the socioeconomic effects of Khat, an initial exploratory survey was carried out. The results of this survey were then used to modify the semi-structured interview schedule, which was subsequently pre-tested among respondents who were not sampled but had similar characteristics.

The next step was to collect qualitative data through personal observation, interviews with key informants and targeted group discussions. Other sources of secondary data were reports and published material. The administrators of the farmers' associations, the Ministry of Finance and the Ministry of Agriculture were among the stakeholders from whom social and economic data were collected.

[15] Sampling formula: Yemane’s simplified sample-size formula used to compute; full bibliographic details appear in the References.

2.4 Method of Data Analysis

The quantitative and qualitative data were analyzed using MS Excel 2010 and the Statistical Package for Social Sciences (SPSS) version 26, respectively. SPSS was used to analyze descriptive statistics like frequencies, create tabulated reports and charts, and determine the factors influencing respondents' behavior as producers or traders. The T-test and Chi square tests, respectively, were also computed to signify mean differences among continuous and discrete variables. The Microsoft Excel 2010 database system was used to compute common themes and narrate the results. Qualitative data from group interviews and Focus Group Discussions (FGDs) was described, analyzed, and interpreted on-site during data collection to avoid missing relevant information.

3. Results and discussions

3.1 Trends of Khat cultivation and expansion

The study results (Table 1) indicated that, in East Hararghe, the predominant method of khat cultivation expansion was inter-cropping, with a significant increase (20.6%) compared with a decrease (12%) or no change (11.8). The method of changing the lands of other crops also shows an increase in khat cultivation (5.5%). However, there was a notable decrease (3.4%) and no change (2.5%), which suggests that this method was not as consistently favored as inter-cropping. Similarly, in West Hararghe, khat cultivation expansion was inter-cropping; with a significant increase, (30.3% compared with a decrease (7.6%) or no change (5.9%). The method of changing the lands of other crops also shows an increase in khat cultivation (1.7%). The chi-square values (104.1 for East Hararghe and 86.3 for West Hararghe) suggest that there was a statistically significant difference in the trends of the cultivation and expansion methods between the two zones[16].

The total percent revealed that in both zones, the increasing in khat cultivation was predominant (37.7%) and 63.6 respectively. This study is related with the work of [11] found that intercropping khat with maize is 2.7 times more profitable per hectare than maize mono cropping. This significant profitability drives farmers to adopt inter-cropping, maximizing land use efficiency and ensuring better economic returns. The increase in khat cultivation through inter-cropping observed in your study supports these findings. [12] Observed at the economic significance of khat in the Ethiopian economy, and noted that because of its high-income elasticity, khat production is spreading quickly in certain areas, because demand increases more quickly than for other crops as incomes rise. The preference for inter-cropping and changing the lands of other crops aligns with the desire to capitalize on this economic advantage. [13] Provided a historical overview of khat production in Ethiopia, highlighting the

[16]Table interpretation: Percentages and chi-square values summarize respondents' reports on cultivation methods; see Table 1 for raw counts and cell percentages.

significant increase in the production rate and the number of farmers involved[17]. The social and cultural acceptance of khat, as discussed by [14] and [15], reinforces its cultivation and expansion, particularly through inter-cropping with other crops[18].

Inter-cropping offers several agronomic benefits, such as improved pest control, climate resilience, and resource use efficiency. [16] & [17] explored these benefits, explaining why farmers might prefer inter-cropping khat with other crops[19]. These benefits contribute to the sustainability and resilience of agricultural systems in East and West Hararghe, justifying the significant increase in inter-cropping observed in your study. [14] Provides a historical overview of khat production in Ethiopia, noting that the production rate and number of farmers involved in the sector have increased significantly

[17]Historical context: Eshetu (2020) documents trends in production and farmer participation; full bibliographic details are in the References.
[18]Cultural drivers: Klingele (1998) and Getachew (1996) describe social acceptance and customary uses that support cultivation decisions.
[19]Agronomic benefits: Gurr et al. (2017) and Lehmann et al. (2020) summarize pest-management, resilience, and resource-efficiency advantages of intercropping.

Table1 Descriptive results of trends in khat cultivation and expansion of farmland

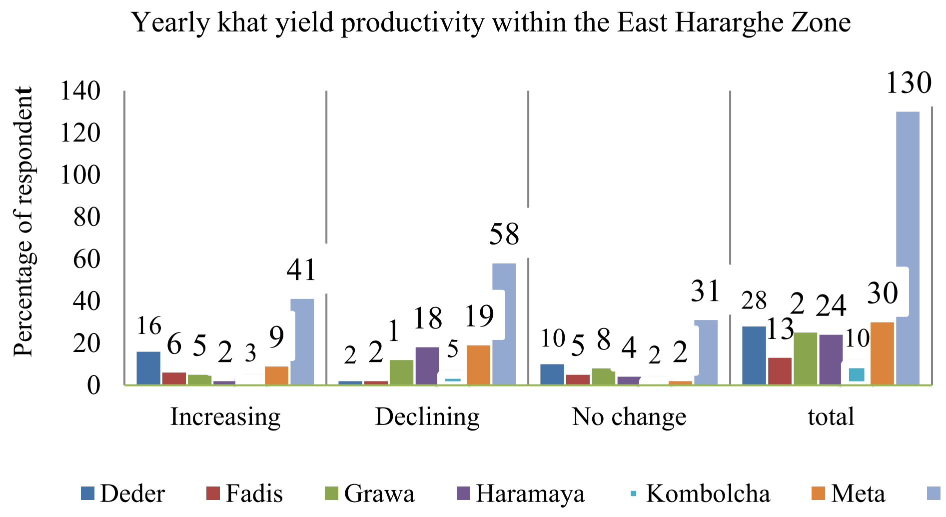
Zones	Khat cultivation	Expansion method			
		Inter cropping	Changing lands to other crops	Total	Chi-Square value
East Hararghe	Increase	49	13	62	104.1***
	Decrease	28	8	36	
	No change	26	6	32	
		103	27	130	
West Hararghe	Increase	72	4	76	86.3***
	Decrease	18	0	18	
	No change	14	0	14	
Total		104	4	108	
Sum total		207	31	238	

Sources: Own survey results, 2024***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

3.2 Trends of yearly khat yield productivity within the East Hararghe Zone.

The results of the present (Figure 2) study indicated that out of 130 responses, 41 (31.5%) indicated an increase in yield productivity (Figure 3) with Deder had the highest number of respondents (16, 12.3%) reporting an increase. Fifty-eight (44.6%) respondents reported a decline in khat yield productivity, with Meta having the greatest effect (19, 14.6%). Thirty-one (23.8%) respondents reported no change in productivity, Deder also leading in this category (10, 7.7%). The results suggested that there were significant differences in the yearly yield productivity changes among the districts.

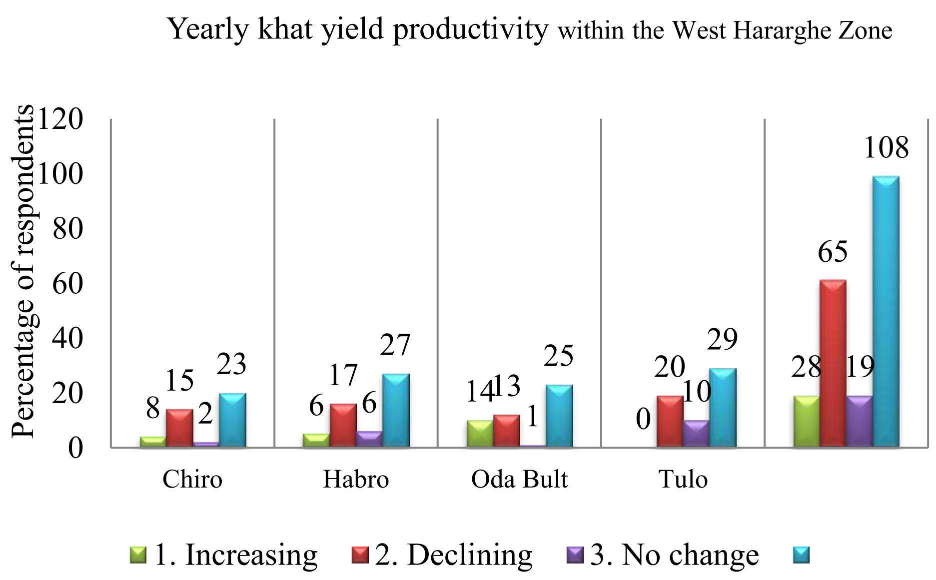
Figure 2 Trends of yearly khat yield productivity within the East Hararghe Zone.



3.3 Trends of yearly khat yield productivity within the West Hararghe Zone.

The (Figure 3) shows the specific survey results related to the trends of yearly khat yield productivity across four districts in West Hararge: Chiro, Habro, Oda Bultum, and Tulo. The study results indicated that 28 (25.9%) respondents reported an increase in khat yield productivity, with the majority (10, 9.3%) from Oda bultum. The majority 65 (60.2%) of respondents reported a decline in khat yield productivity, with Tulo having the highest (19) number, and 19 (17.6%) respondents reported no change in productivity, with no reports from Tulo.

Figure 3 Trends in yearly yield productivity within the West Hararghe Zone.



The study results (Figure 3 and 4) indicate that khat productivity varies significantly across different districts, with some areas experiencing declines due to pests, diseases, and adverse weather conditions. These findings are consistent with existing literature on khat production challenges and trends in Ethiopia[20].

Pest Control Practices: Khat faces a wide range of insect pests, diseases, and weeds that can severely influence its yield and quality. Traditional pest control methods, such as hand picking and botanical solutions, are commonly used. However, increasing pest damage has led to the adoption of synthetic insecticides. This study also similar with the study of [18]: Discusses the lack of scientifically suggested pest control solutions for managing pests in Ethiopian agriculture, highlighting the reliance on traditional practices[21]. [19]: Explores the expansion of khat cultivation in the Ethiopian highlands and the associated pest control challenges[22].

Market Challenges: Effective khat marketing is hindered by inaccessibility to markets and price fluctuations. The availability of basic infrastructure, such as roads and proximity to market centers, is crucial for successful marketing. This study also similar with the study of [12]: Emphasizes the importance of infrastructure and market access for khat marketing and export performance[23].

Productivity Trends: The study's findings on productivity trends align with other research, showing a general decline in productivity due to factors like pest infestations, diseases, and weather conditions. This study also similar with the study of [21]: Discusses the implications of khat production on land use and crop variety, underscoring the need for sustainable agricultural practices[24].

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[20] Figure interpretation: Figures 3 and 4 summarize district-level productivity trends; see figures for district names and raw values.

[21] Pest control context: Dechassa et al. (2020) note limited scientific pest-management guidance in some Ethiopian cropping systems; full citation in References.

[22] Khat expansion and pests: Feyisa and Aune (2017) discuss khat expansion in highlands and related pest issues; full citation in References.

[23] Market infrastructure: Tolcha (2020) emphasizes roads and market access as key determinants of khat marketing and export performance; full citation in References.

[24] Land use implications: Beyene W. Ademe et al. (2017) discuss khat’s effects on land use and crop diversity and recommend sustainable practices; full citation in References

3.3 Trends in irrigation practices related to Khat production

The study results (Table 2) indicate that for irrigation practices, in both the East and West Hararghe Zones, a total of 125 farmers practice irrigation in khat farming 26.5%, and 26% respectively, whereas 113 do not 28.2% and 19.3% respectively practice the trends (Table 2). Among those who practiced irrigation, the most common source of water was boreholes/groundwater (19.7%), followed by rivers/streams (21.4%) and then public water tankers/supply (0.84%). Harvesting rainfall was the least common method, with only two (0.9%) respondents using it. (Table2). The Pearson chi-square values were 50.3 for the East Hararghe and 49.8 for the West Hararghe zone. These high values suggest a strong association between the practice of irrigation and the choice of water source[25].

The study results highlight that irrigation practices in khat farming are influenced by the choice of water source, with boreholes/groundwater and rivers/streams being the most common sources. This suggests that farmers in both East and West Hararghe Zones prefer reliable and accessible water sources for irrigation, which is crucial for maintaining consistent khat production. This study also in lined with the study of [22]: This review discusses the trends, status, and challenges of irrigation development in Ethiopia, emphasizing the importance of reliable water sources for agricultural sustainability. [23]: This research explores farmers' perceptions of irrigation roles in climate change adaptation and determinants of water use efficiency-improving practices in Southern Ethiopia. [24]: This review addresses the challenges and opportunities of irrigation practices in Ethiopia, highlighting the need for improved water governance and management.

[25]Irrigation statistics: Table 2 contains raw counts, percentages, and chi-square values used to assess associations between irrigation practice and water source.

Table 2 Descriptive results of trends in irrigation practices related to Khat production in the East and West Hararghe Zones

Zones	Irrigation practice	Source of water for irrigation					Chi-Square
		Groundwater	River/Stream	Public Water Supply	Harvest Rainfall	Total	
East Hararghe	Yes	28	18	16	1	63	50.3***
	No	0	0	0	0	67	
	Total	28	18	16	1	130	
West Hararghe	Yes	19	33	9	1	62	49.8***
	No	0	0	0	0	46	
	Total	19	33	9	1	108	
Sum Total		47	51	25	2	238	

Sources: Own survey results, 2024***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

3.4 Khat harvesting practices

The study (table 3) found that in the East Hararghe Zone, out of 130 respondents, 33.6% reported harvesting khat leaves in the early morning, while 7.98% did so in the morning. 33.2% used manual picking, followed by 14.7% who pruned with tools, and 7.6% who used a combination of both methods. The Pearson chi-square statistic (154.2, $p < 0.001$) indicated a significant association between harvesting time and method[26].

[26] Table interpretation: Percentages and chi-square statistic summarize respondents' reports on harvesting time and method; see Table 3 for raw counts and cell percentages.

In the West Hararghe Zone, out of 108 respondents, 34.9% preferred early morning harvesting. 32.8% used manual picking, 21.4% used tools, and 12.6% combined both methods. The Pearson chi-square statistic (86.3, $p < 0.001$) also confirmed a significant association[27].

Overall, manual picking was the most common method across both zones, with early morning being the preferred time due to cooler temperatures and favorable conditions. East Hararghe had more respondents (130) compared to West Hararghe (108), indicating more harvesting activity or a larger sample size (table 4). The study results indicate that khat-harvesting practices vary significantly between the East Hararghe and West Hararghe Zones. In both zones, manual picking is the most common method, with a preference for early morning harvesting. This preference could be due to cooler temperatures and favorable conditions during this time of day. This research in lined with [25]: Their research on "Chat: Coffee’s Rival from Harar, Ethiopia" provides insights into the traditional practices of khat harvesting, including manual picking and pruning. [26]: This study discusses the average production of khat and the importance of timely harvesting to maintain quality[28].

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[27]Statistical significance: Pearson chi-square values and associated values indicate a statistically significant association between harvesting time and method in both zones; full test details are in the Results section.
[28]Related literature: Getahun & Krikorian (1973) and Hill (1966) are cited for historical and agronomic context; full bibliographic details belong in the References section.

Table 3 Descriptive results of information about Khat harvesting practices

Zone	Harvesting time	Manual picking	Pruning with tools	Combination of manual and tools	Total	Chi-Square
East Hararghe	Early morning	53	22	5	80	154.2***
	Morning	12	5	2	19	
	Evening	1	0	2	3	
	No specific time	13	8	7	28	
	Total	79	35	18	130	
West Hararghe	Early morning	58	13	12	83	86.3***
	Morning	14	0	0	14	
	Evening	1	0	0	1	
	No specific time	5	4	1	10	
	Total	78	17	13	108	
Sum Total		157	51	30	238	

Sources: Own survey results, 2024***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

3.5 Multiple harvests in khat farming

The study results (Table 4) indicated that in the East Hararghe Zone, among those who practiced multiple harvests, the growth stage of khat plants (26%), and market demand (2.1%). Weather conditions (5%) did affect the timing of multiple harvests were key factors influencing the timing The Pearson chi-square statistic (63.6) indicated a statistically significant association between multiple harvests and these factors ($p < 0.001$)[29].

In the West Hararghe Zone, similar trends were observed. The growth stage (21%) and market demand (10.5%) were influential, while weather conditions played a minor role. The Pearson chi-square statistic (64.9) confirmed a significant association between multiple harvests and these factors ($p < 0.001$)[30].

Overall, both zones prioritized the growth stage and market demand when planning multiple harvests. The chi-square tests highlighted the significance of these associations. The study results (table 4) indicated that multiple harvests in khat farming are influenced by the growth stage of the plants and market demand, rather than weather conditions. This suggested that farmers prioritize the optimal growth stage and market needs when planning their harvests, ensuring the best quality and economic return. [14]: This research provides yield data for khat, indicating the productivity of well-managed khat stands[31].

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[29]Table interpretation: Table 4 shows percentages and the Pearson chi-square (63.6) used to test associations between multiple harvests and factors; see Table 4 for raw counts and cell percentages.
[30]Statistical significance: Pearson chi-square (64.9) and associated values indicate statistically significant associations; full test details are in the Results section.
[31]Related literature: Getahun & Krikorian (1965) and Klingele (1998) are cited for historical and agronomic context; full bibliographic details belong in the References section.

Table 4 Descriptive results of multiple harvests in khat farming

Zone	Growth Stage	Market Demand	Weather Conditions	Total	Chi-Square
East Hararghe					
Yes	62	5	12	79	62.5***
No	0	0	0	51	
Total	62	5	12	130	
West Hararghe					
Yes	50	25	6	81	64.9**
No	0		0	27	
Total	50	25	6	108	
Summation	102	30	18	238	

Sources: Own survey results, 2024***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

3.6 Number of planting materials per hole

The study results (Figure 4) indicated that, in the East Hararghe Zone, out of 130 respondents, only three (1.3%) respondents used 2--4 materials/holes, which indicated a lower frequency of using a smaller number of planting materials, whereas only one (0.4%) respondent reported using this range (3--4 materials/holes), which is quite rare. On the other hand, with 74 (31.1%) respondents (4 materials/hole), using exactly four planting materials per hole was the standard practice, especially for suckers[32]. This was the most common in this zone. Moreover, (4 to 5 materials per hole) was quite common, with 50 (21) respondents showing a preference for slightly more than four but not more than five materials per hole. Only two (0.84%)

[32]Standard practice: Four planting materials per hole was the modal response among respondents in East Hararghe; see Figure 5 for counts and percentages.

respondents used five materials per hole, which was rare, suggesting that there was little variation and that the standard was close to four[33].

However, in the West Hararghe Zone, out of 108 respondents, 16 (6.7%) respondents used 2--4 materials per hole, which was more common than in the East Hararghe Zone, and 26 (10.9%) respondents used 3--4 materials per hole, indicating greater variability in the use of planting materials than in the East Hararghe Zone. Sixty-two (26%) respondents used this range (4 materials per hole), which is the most common usage, although it is less common than in the East Hararghe Zone. In addition, 4 (1.7%) respondents used (4 to 5 materials per hole) this range, which was significantly less frequent than in the East Hararghe Zone. Nevertheless, there were no respondents in which exactly five materials were used per hole. The study results indicate that in East Hararghe, 31.1% of respondents used exactly four planting materials per hole, which is the standard practice, especially for suckers. A smaller proportion (0.4%) used 2-4 materials per hole, and only 0.84% used five materials per hole. The preference for using four materials per hole suggests an established practice aimed at optimizing plant growth and resource use. This study also in lined with the study of [28]: This study emphasizes the importance of using 2-4 suckers per planting pit for optimal growth and productivity, aligning with the observed practices in East Hararghe.

In West Hararghe, 26% of respondents used four planting materials per hole, showing consistency with East Hararghe. However, there was more variability, with 6.7% using 2-4 materials per hole and 10.9% using 3-4 materials per hole. This variability could be attributed to differences in moisture availability, soil type, and other local conditions. This work is in lined with the work of [28]: Highlights that the number of suckers or cuttings used for planting can depend on local conditions such as soil fertility and moisture availability, supporting the variability observed in West Hararghe

[33]Variation: Very few respondents used fewer than four or more than five materials per hole, indicating limited variation around the four-material standard.

The most common practice in both zones is the use of four planting materials per hole. However, East Hararghe shows a higher overall frequency of planting material usage, while West Hararghe displays greater variability. The use of five materials per hole is rare across both zones, indicating a consensus on the optimal number of planting materials for khat cultivation. [29]: Discusses the socio-economic and cultural factors influencing khat cultivation practices, including the number of planting materials used per hole. [30]: Explores the phenotypic diversity of khat cultivars, emphasizing the role of planting material quantity in maintaining plant health and yield. According to Focus Group Discussions (FGDs), the number of planting materials used depends on moisture availability, soil type, land accessibility, and the health of the planting materials. These factors reflect agricultural practices, resource availability, and standard protocols in the respective zones [31]: Highlights how local conditions such as soil type and moisture availability influence planting practices and the number of materials used per hole[34]. [32]: Discusses the impact of agricultural practices and resource constraints on planting material usage.

The data suggest that adherence to the standard practice of using four planting materials per hole can optimize khat growth and yield. Deviations from this standard may indicate experimentation or adaptations to local conditions. Agricultural extension services can use these findings to reinforce best practices and provide targeted support based on local needs. Further research should investigate the long-term effects of different planting material quantities on khat yield and quality. Understanding the socio-economic factors influencing these practices can inform the development of tailored agricultural support programs[35].

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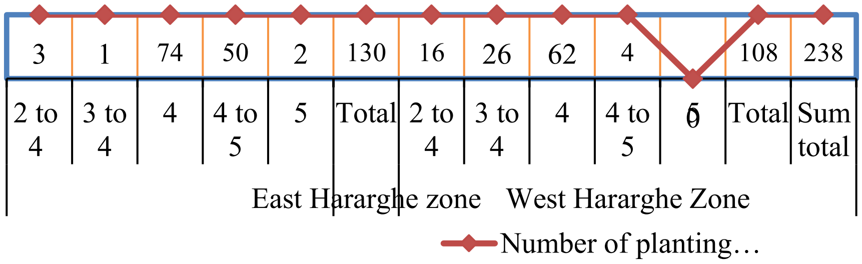
[34]Practice recommendation: Four planting materials per hole was the modal response; extension services can promote this as a best practice while monitoring local adaptations.
[35]Research gap: Recommend longitudinal trials comparing 3, 4, and 5 materials per hole to measure yield, quality, and economic return; socio-economic drivers should be included.

Figure 4 Number of planting materials per hole



3.7 Spacing maintained between the plants, the holes, and the rows

The study results (Figure 5) indicated that, in the East Hararghe Zone, out of the 130 respondents, for spacing between holes, 130 (99.2%) maintained a specified spacing of 25–30 cm between plants within the hole, 80–100 cm between the holes, and 180–200 cm between the rows. In contrast, in the West Hararghe Zone, out of 103 respondents, all 103 respondents (100%) maintained the specified spacing of 25–30 cm between plants, 80–100 cm between the holes, and 180–200 cm between the rows. In summary, both zones have a high level of adherence to the recommended spacing between planting holes, which is crucial for optimal plant growth and yield. These data are valuable for agricultural extension services and resource allocation to support farmers in these zones. The slight discrepancy in the total percentage for East Hararghe might require clarification. The chart visually represents data that are likely to be presented as frequencies and percentages, reflecting the high level of adherence to the spacing guidelines[36]**.**

The study results indicate a high level of adherence to recommended spacing guidelines among khat farmers in both East and West Hararghe Zones. In East Hararghe, 100% of respondents maintained a spacing of 25–30 cm between plants within the hole, 80–100 cm between the holes, and 180–200 cm between the rows. Similarly, in West Hararghe, all respondents (100%) adhered to these spacing

[36]Figure interpretation: Percentages and counts summarize respondents' adherence to spacing guidelines; see Figure 6 for raw counts and any rounding notes.

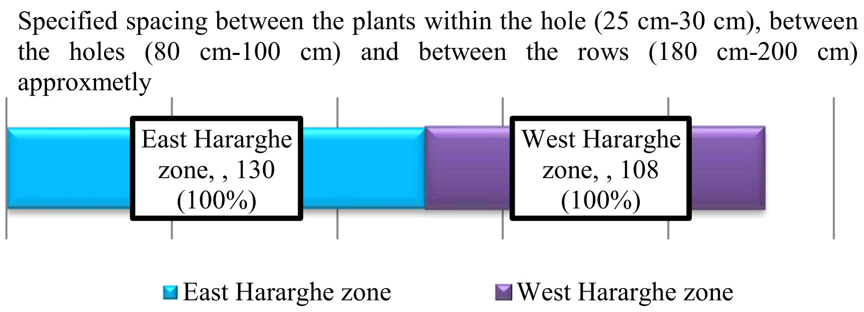
guidelines. This consistency in maintaining proper spacing is crucial for optimal plant growth and yield[37]. This study also in lined with the study of [31]: This study highlights the importance of maintaining appropriate plant spacing for optimal growth and yield. Proper spacing ensures that plants receive adequate sunlight, water, and nutrients, reducing competition and promoting healthy growth. [32][38]: Research on crop spacing in semi-arid regions emphasizes the benefits of maintaining recommended plant spacing to enhance water and nutrient use efficiency, supporting the findings from the Hararghe Zones.

Implications for Agricultural Practices: Adherence to recommended spacing guidelines suggests that farmers in both zones are aware of and committed to best practices for khat cultivation. This consistency can enhance crop productivity and quality, providing better economic returns for farmers. Agricultural extension services can use these findings to reinforce the importance of proper spacing and provide targeted support to ensure continued adherence. Further research could explore the impact of spacing variations on khat yield and quality. Understanding the reasons behind the slight discrepancy in adherence in East Hararghe may also provide insights for improving extension services and resource allocation. Additionally, studies on the long-term effects of maintaining proper spacing on soil health and sustainability could inform future agricultural practices. By integrating these findings with relevant literature, this discussion provides a comprehensive understanding of the importance of proper spacing in khat cultivation and its implications for agricultural productivity and sustainability.

[37]Agronomic rationale: Proper spacing reduces competition for light, water, and nutrients and supports yield; see Belay et al. (2012) and Degu et al. (2014) in References.

[38]Extension implication: Extension services can promote the four-material standard while monitoring local adaptations and testing long-term effects.

Figure 5 Descriptive survey results of the spacing between plants, holes, and rows in two zones



3.8 Typical size and shape of the planting hole

The study results (Figure 6) indicated that, in the East Hararghe Zone, out of the 130 respondents, 25 (10.5%) used plots of 100 cm × 50 cm (rectangular shape), and 59 (24%) used plots of 100 cm × 100 cm. (Square shape), and 46 (19.3%) respondents had plots of 50 cm × 50 cm. (Square shape). The percentages indicated that 19.3% used the smallest plot size, 24% used the medium size, and 10.5% used the largest plot size. For the West Hararghe Zone, out of 108 respondents, 21 (8.8%) had plots of 100 cm × 50 cm (rectangular shape), and 32 (13.4%) used plots of 100 cm × 100 cm. (Square shape), and 55 (23%) respondents had plots of 50 cm × 50 cm (Square shape).

The percentages revealed that 23% of the plots used the smallest plot size, 13% used the medium size, and 10.5%used the largest plot size. In both zones, the 100 cm × 100 cm plot size was the most popular practice. The 50 cm × 50 cm plot size was the second most popular in East Hararghe but the most popular in West Hararghe. The 100 cm × 50 cm plot size was the least utilized among respondents in both regions[39]. This information could be useful for understanding agricultural practices in these areas, such as the preference for certain plot sizes for Khat cultivars, which might be influenced by factors such as cultivar type, irrigation methods, labor availability, and market demand[40]. This study also highlights zonal differences in farming practices between East Hararghe and West Hararghe.

In East Hararghe, the preference for the 100 cm × 100 cm plot size by 24% of respondents is notable[41]. This square shape allows for optimal plant spacing, which can enhance water and nutrient use efficiency. The 50 cm × 50 cm plot size is also significant (19.3%), indicating its suitability for more intensively managed plots. The least utilized plot size is 100 cm × 50 cm (10.5%), possibly due to less favorable growing conditions or less efficient management practices. This study also in lined with the study of [33]. The impact of intercropping on plant growth and yield in different regions of Ethiopia[42]. This study highlights how different plot sizes and shapes can impact plant growth, aligning with the preference for square plots in East Hararghe for optimal resource utilization. [34]. Agricultural practices and their implications on crop productivity in Hararghe region. This research discusses the benefits of specific plot sizes for crop productivity, supporting the findings that square plots are preferred for better resource management. Popular Plot Sizes in West Hararghe: In West Hararghe, 50 cm × 50 cm plots are most popular (51.5%), suggesting they are more manageable and easier to irrigate. The 100 cm × 100 cm plot size is still used (27.3%) but less prevalent than in East Hararghe. The least utilized plot size is 100 cm × 50 cm (21.2%).

This study also in lined with the study of [35]. Smallholder irrigation practices and water management in semi-arid regions. This study provides insights into the preference for smaller plots in water-scarce areas, supporting the trend in West

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[39] Figure interpretation: Figure 7 shows counts and percentages by plot size and zone; check the figure for raw counts and any rounding notes.
[40] Data note: If totals do not sum to 100% exactly, verify rounding or missing responses in the dataset.
[41] Figure interpretation: Figure 7 shows counts and percentages by plot size and zone; check the figure for raw counts and any rounding notes.
[42] Practice recommendation: Four planting materials per hole was the modal response; extension services can promote this as a best practice while monitoring local adaptations.

Hararghe for manageable plots. [36]. Crop management practices and their effect on water conservation. The research highlights the importance of efficient water use, explaining the preference for smaller plots in West Hararghe. Comparative Analysis: The significant difference in preferred plot sizes between the zones, indicated by the Chi-square values, reflects regional variations in agricultural practices. Factors such as khat cultivar type, irrigation availability, labor practices, and market demand contribute to these differences. Larger plots may be favored in areas with abundant water and labor, while smaller plots may be preferred where water conservation and labor efficiency are critical.

This research discusses how market demand influences crop management decisions, supporting the trends observed. Implications for Agricultural Practices: Understanding plot size preferences can guide agricultural extension services and policymakers in tailoring recommendations. In regions with smaller plots, improving irrigation efficiency and laborsaving technologies can be beneficial. In areas with larger plots, strategies to optimize plant spacing and resource distribution are essential. [37] Strategies for enhancing agricultural productivity in Ethiopia. This study emphasizes the need for tailored agricultural support based on plot sizes and regional conditions[43]. [38]. Agricultural extension services and their role in crop management.

Recommendations for Future Research: Further research should explore the economic, environmental, and social factors behind regional plot size preferences. Additionally, investigating the impact of different plot sizes on crop yield and quality can provide valuable insights for optimizing farming practices [39]. The socio-economic factors influencing crop management decisions. This study explores the various factors affecting agricultural practices, supporting the need for further research [40]. The impact of plot size on crop yield and quality[44]. The research

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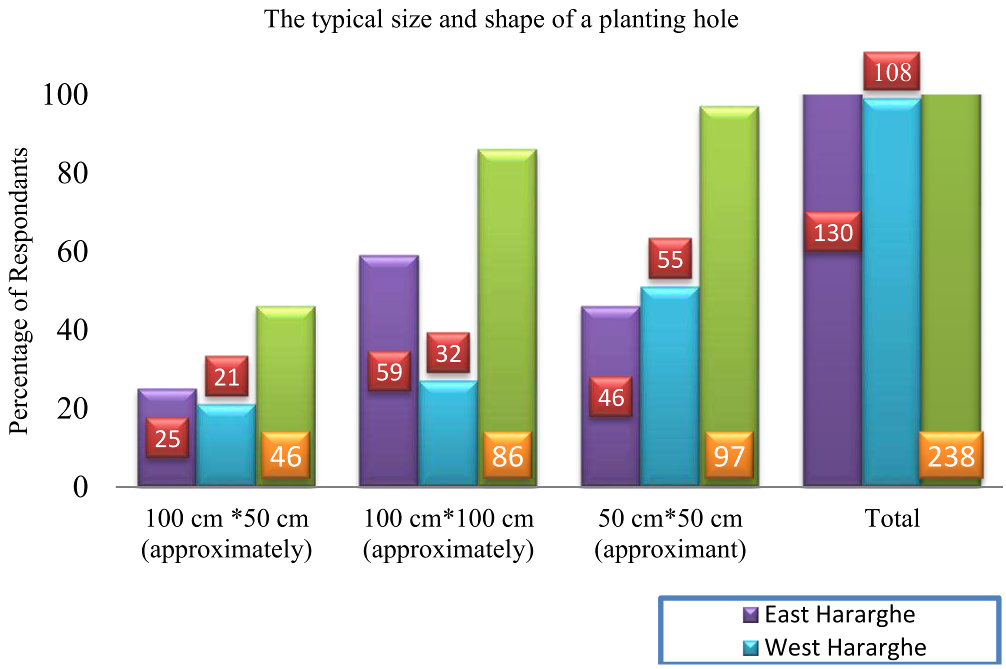
[43]Policy implication: Tailored extension and resource allocation should reflect local plot sizes, water access, and labor constraints.
[44]Research need: Recommend comparative trials across plot sizes to measure yield, quality, and socio-economic returns.

highlights the importance of understanding how plot sizes affect agricultural outcomes, aligning with the recommendations for future studies.

Fig. 6 Descriptive results of a survey that indicates the typical size and shape of a planting hole



3.9 Sources of Khat Cultivars and Parts Collected for Propagation

The study results (table 5) indicate that, in the East Hararghe Zone, out of 130 respondents, 16 (6.7%) respondents reported that the most common part collected was suckers from previous plants, followed by 12 (5%) from neighbors or local farmers and 1(0.4%) from local markets, whereas 65 (27.3%) respondents collected stems from previous plants, followed by 15 (6.3%) from neighbors or local farmers and 3 (1.3%) from local markets. nine respondents (3.8%) collected both stem cuttings and suckers from previous plant 1(0.43%) respondent from local markets, and 15 (6.3%) respondents were collected from neighboring/local farmers[45].

[45]Counts source: Local market and neighbor counts reported by respondents; see Methods for sampling details.

However, in the West Hararghe Zone, out of 108 respondents, 34 (14.3%) reported that, as sources of khat cultivars, the most common part collected was suckers from previous plants, followed by 14 (5.9%) from neighbors or local farmers and 1 (0.4%) from local markets, whereas 49 (20.6%) respondents collected stem cuttings from previous plants, followed by 9 (3.8%) from neighbors or local farmers. No respondents collected both stem cuttings and suckers from previous plant. In terms of the parts collected for propagation, the most common parts collected were stem cuttings 141 (59.2%), suckers 78 (32.8%) and both parts 19 (14.3%). The Pearson chi-square value for East Hararghe was 165.4, and for West Hararghe, it was 86.2, which is significant at the 1% level and suggests a very strong association between storage duration and minimizing spoilage/waste[46].

The study results indicate significant regional differences in the sources and methods of khat propagation between East and West Hararghe Zones. In East Hararghe, suckers from previous plants were the most common source (6.9%), followed by stem cuttings (27%). In contrast, West Hararghe showed a higher preference for suckers (14.6%) and stem cuttings (21%). The Pearson chi-square values (11.57 for East Hararghe and 28.81 for West Hararghe) suggest a strong association between storage duration and minimizing spoilage/waste. This study also in lined with the study of Addis Ababa University (2009): This study highlights the importance of propagation methods in khat cultivation, noting that branches arising at ground level were commonly used for propagation. [29]: This review discusses the socio-economic and cultural factors influencing khat cultivation practices in Ethiopia. [30][47]: This research explores the phenotypic diversity of khat cultivars, emphasizing the role of propagation methods in maintaining genetic diversity.

[46]Statistical note: Chi-square values reported are significant at ; see Results for test tables.
[47]Contextual sources: Addis Ababa University (2009) and recent reviews provide propagation and diversity context; full citations belong in References.

Implications for Agricultural Practices: Understanding these regional differences can help develop targeted interventions to improve khat cultivation practices. For instance, promoting the use of stem cuttings in East Hararghe and suckers in West Hararghe could enhance propagation success rates and reduce spoilage. For instance, further research should investigate the socio-economic factors influencing the choice of propagation methods and their impact on khat yield and quality. Additionally, studies on the long-term effects of different propagation techniques on soil health and plant resilience could provide valuable insights for sustainable khat farming[48].

[48]Research priorities: Recommend mixed-methods studies combining FGDs, household surveys, and on-farm trials to measure yield, quality, and soil impacts across propagation methods.

Table 5 Descriptive results of the sources of khat cultivars and parts collected for propagation in the East and West Hararghe Zone

Variables	Parts Collected for Propagation	Count	Expected Count	Chi-Square
East Hararghe Zone				165.4***
Stock from previous plant	Suckers	16	6.7	
	Stem cutting	65	27.3	
	Both Stem cuttings and suckers	8	3.4	
	Total	89	37.4	
Local market	Suckers	1	0.4	
	Stem cutting	3	1.3	
	Both Stem cuttings and suckers	1	0.4	
	Total	5	2.1	
Neighbors/local farmers	Suckers	12	5	
	Stem cutting	15	6.3	
	Both Stem cuttings and suckers	9	3.8	
	Total	36	15.1	
Total	Suckers	29	12.2	
	Stem cutting	83	34.9	
	Both Stem cuttings and suckers	18	7.6	
	Total	130	54.6	
West Hararghe Zone				86.2***
Stock from previous plant	Suckers	34	14.3	
	Stem cutting	49	20.6	
	Both Stem cuttings and suckers	1	0.4	
	Total	84	35.3	
Local market	Suckers	1	0.4	
	Stem cutting	0	0	
	Both Stem cuttings and suckers	0	0	
	Total	1	0.4	
Neighbors/local farmers	Suckers	14	5.9	
	Stem cutting	9	3.8	

	Both Stem cuttings and suckers	0	0
	Total	23	9.7
Total	Suckers	48	14.3
	Stem cutting	58	24.4
	Both Stem cuttings and suckers	1	0.4
	Total	108	45.4.0
Sum total		238	100.0

Sources: Own survey result, 2024 ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

3.7 Ranking of harvest quality for three types of consumable part of the khat

The study results (Figure 7) indicated a clear preference for Dalacha in terms of harvest quality in both East and West Hararghe zones. Dalacha was ranked first by a majority of respondents in both zones, followed by Gray and then Red. The significant chi-square values indicated strong preferences that were not due to random chance[49].

Importance of Variety Preferences: The overwhelming preference for *Dalacha* suggests that this variety has certain qualities highly valued by consumers or growers. These qualities could include taste, appearance, yield, or resilience. Further research could focus on identifying these specific attributes to understand why *Dalacha* is preferred and why Red is less favored. This study is related with the work of several studies support the findings of preference for certain khat varieties: [11]. They discuss the rapid expansion of khat production in the Ethiopian highlands, particularly in Habro District, West Hararghe. They highlight that intercropping khat with maize is 2.7 times more profitable per hectare than maize mono cropping. This supports the notion that specific varieties like *Dalacha* could be highly valued for their profitability [11] .This study examines the economic importance of khat in the Ethiopian economy, noting the expansion of khat production due to its high-income elasticity. This aligns with the preference for high-quality varieties like *Dalacha*[50].

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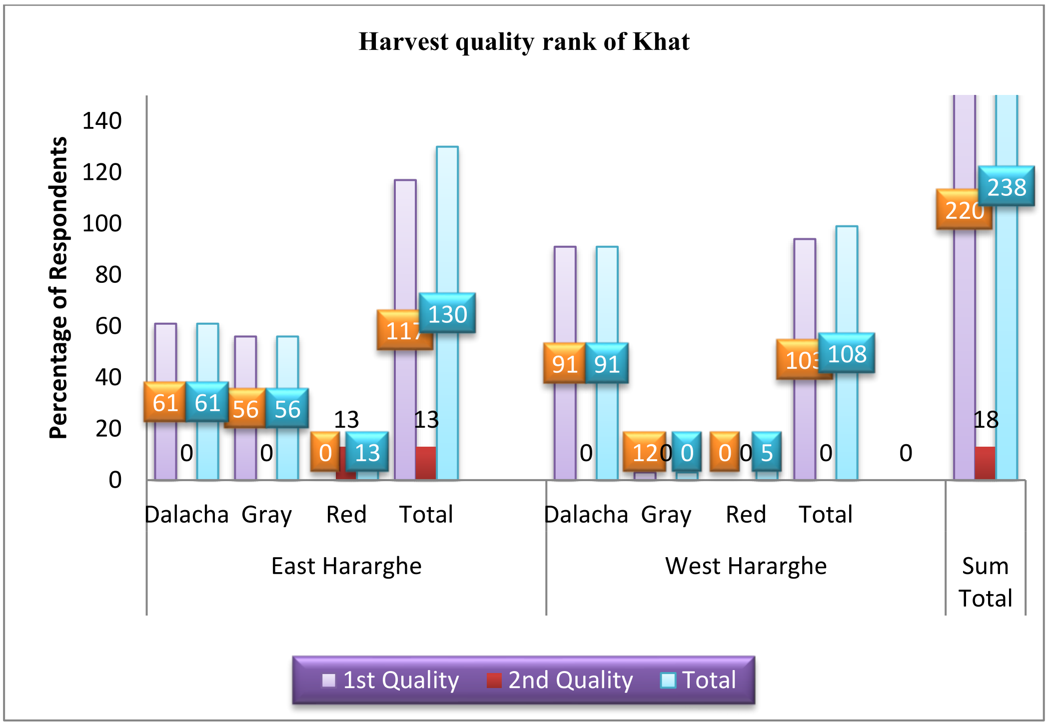
[49]Figure note: Figure 7 shows variety rankings by zone; chi-square values indicate non-random preference patterns.

[50]Context sources: See Feyisa & Aune (2017), Tolcha (2020), Eshetu (2020) and others in References for economic, cultural, and agronomic context.

[13]. Provides a historical overview of khat production in Ethiopia, noting the increase in production rate and number of farmers involved. This supports the trend of favoring certain high-quality varieties. The widespread consumption of khat in Ethiopia is culturally accepted, and this may lead to a preference for varieties such as *Dalacha* and *Hamarcot* (Gray) [15]. Social and cultural impact in Ethiopia [16]. Intercropping for pest control, climate resilience, and resource use efficiency may explain the preference for intercropping khat in East and West Hararghe [17].

Figure 7 Descriptive results of the ranking of harvest quality for three types of khat Leave.



3.10 Fertilizer application

The majority of the respondents (175, 73.5%) applied organic fertilizer during the dry season. Sixty-three or 26.5% of the respondents applied organic fertilizer under specific moisture conditions; however, for the rainy/irrigation season, no one reported applying organic fertilizer during the rainy season or when irrigation was available. The timing of organic fertilizer application was closely related to the dry season because of slow decomposition. The application of organic fertilizer during the dry season might be aimed at preparing the soil for the upcoming planting season, especially in highland and middle lowland areas, whereas its application during the rainy season could ensure that nutrients are immediately available for plant uptake. This occurred because moisture helps in the breakdown of organic matter and the release of nutrients, especially in lowland areas where the decomposition rate is faster than that in other agro-ecosystems, which are then more readily available to plants. The remarkable majority of respondents adhered to this practice, suggesting that it was a well-established and accepted method in the area. This information highlights the importance of considering moisture availability when planning fertilizer application, as it could significantly affect the efficiency and effectiveness of fertilizer use[51].

The survey data suggested that, out of 238 respondents, 116 (48.7%) reported not applying inorganic fertilizer at all. During crop planting, 40 respondents (16.8%) applied inorganic fertilizer during the crop-planting phase. After crop planting, 75 respondents (31.5%) applied inorganic fertilizer after the crop was planted. A significant portion of the respondents did not use inorganic fertilizer, which could be due to various reasons, such as cost, availability, or preference for organic methods. The data also indicated that there was a split between applying inorganic fertilizer during and after planting, with a preference for post planting application. This information could be useful for understanding local agricultural practices and for developing targeted interventions or support for farmers in the zone[52].

Inorganic Fertilizer Application: The data indicates that 48.1% of respondents did not use inorganic fertilizer, which could be due to cost, availability, or a preference for organic methods. Among those who did use inorganic fertilizers, 17.6% applied it

[51]Practical implication: Applying organic fertilizer in the dry season prepares soil for planting; applying during rainy/irrigation seasons increases immediate nutrient availability.
[52]Data note: Percentages are based on the survey sample (n = 238); see Methods for sampling and rounding details.

during the crop-planting phase, while 32.8% applied it after planting. This split in timing suggests a strategy to ensure nutrient availability when crops need it most.

Implications for Agricultural Practices: Understanding these fertilizer application practices can help tailor agricultural interventions and support. For regions favoring organic fertilizers during the dry season, promoting moisture conservation techniques can enhance nutrient availability. In areas favoring post-planting inorganic fertilizer application, providing access to affordable and timely inputs can support better crop growth. [53]Further research should explore the reasons behind the preference for organic or inorganic fertilizers and the impact of these practices on crop yield and soil health. Understanding socio-economic factors influencing fertilizer use can inform the development of targeted support programs.

[53]Program recommendation: Promote moisture-conserving practices where organic fertilizer is preferred and improve timely access to affordable inorganic inputs where post-planting application is common.

4. Conclusion and policy implications

This study provides a detailed assessment of production practices, cultivation trends, and agronomic strategies for khat (*Catha edulis* Forsk) in eastern Ethiopia, with a focus on the eastern and western Hararghe areas. Using a robust mixed method approach, integrating focus group discussions, key informants, field visits and structured household surveys, the research effectively bridges the critical gap in understanding the integrated Khat production system. Advanced statistical analysis using SPSS for descriptive and inferential tests such as t-tests and chi-squared tests provided a robust framework for examining factors influencing production processes and provided insights that were insightful. Research and development: give priority to integrated production processes, improved post-harvest management, and modern agronomic management strategies. Pest and disease control: Implement robust measures to alleviate biotic stress. Market and infrastructure expansion: expand market access and strengthen support infrastructure to strengthen the khat value chain. Optimized fertilizer application and extension services: Start targeted training programmed to address knowledge gaps and promote optimal fertilizer spacing and nutrient management. In addition, research into technological innovation, such as advanced irrigation systems and precision farming, offers promising opportunities to improve resource efficiency and overall yield performance.

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7. Declarations

Funding Statement

This research was internally funded (project code HUGG_2022_01_02_36), which funded fieldwork, data collection, and analyst time, but had no role in study design, data collection, data analysis, interpretation of results, or the decision to submit the manuscript for publication.

Author contributions

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Supervision: Abdi Mohammed.

Funding acquisition: Abdi Mohammed.

Declaration of competing interests:

All authors declare that they have no competing interests to declare related to the conduct of this research.

Ethics approval

Ethical approval for the study was obtained from the Dire Dawa University Institutional Review Board (IRB reference: DDU-IRB/2022/045). Study procedures for household surveys, focus group discussions, key informant interviews, and field observations complied with institutional and national research ethics requirements.

Consent to participate

All adult participants gave informed consent before participating; participants were informed of the study goals, confidentiality measures, and their right to withdraw at any time, and verbal consent was documented in field notes as per the IRB-approved protocol for focus group discussions and interviews.

Consent for publication

All authors agree to the publication of this Data Note in Discover Sustainability. Participants were asked for permission to publish non-identifiable photographs and aggregated data during fieldwork; permission forms for any potentially identifiable persons and third-party image permissions are available from the corresponding author on request.

Data availability

The data presented in this Data Note are publicly available in public repositories; raw audio files and any restricted materials are available from the corresponding author on reasonable request and subject to local data-sharing agreements to maintain participant confidentiality.

Code Availability

Analysis scripts (SPSS v26 syntax files, Excel macros, and NVivo export summaries) used to produce descriptive outputs is archived and available in the repository.

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Figure 8 Khat Cultivars in Picture


Dalacha type 1 Cultivar **Dalacha type 2 Cultivar**


Hamercot (Gray type) Cultivar Dima (Red type) Cultivar

Source: Farmers field and Aweday town, eastern Ethiopia