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Evaluation of smallholder farmers' use of indigenous knowledge in Ethiopian avocado (*Persea americana* Mill.) production and fruit preference criteria

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Abstract

Background Avocado is a versatile fruit that has been farmed for its flavor, nutritional worth, and socioeconomic benefit in Ethiopia and other parts of the world. The purpose of the current study was to evaluate smallholder farmers' indigenous knowledge of avocado production, harvesting, repinning, preference, management, and utilization in southern Ethiopia.

Methods Data were collected from 295 avocado farmers using participatory research evaluation instruments and techniques. The descriptive statistics and the chi-square test were used to analyze the data.

Results The results of this study demonstrated that smallholder farmers, who vary in age, education, and ethnicity, have a wealth of indigenous knowledge in the areas of production, fruit preference, postharvest handling, and avocado use. Based on their long-term experience in cultivating this crop, farmers determined the best avocado races using different fruit quality traits such as size, color, and appearance. The findings revealed that the three most preferred qualities that can influence consumers' impressions while buying or consuming avocados were fruit size, skin color, and flesh taste. The findings also demonstrated a significant positive association between farmers' age and the amount of seedlings they produced (Spearman's rho, $rs = 0.604$, $p < 0.01$). Furthermore, our results showed that younger farmers with higher education grow improved avocado varieties but have less experience with seedlings production, indicating a decline in indigenous knowledge about growing seedlings, particularly among young and more educated people in the study areas.

Conclusion Findings indicated a need for creating awareness for avocado farmers about modern agronomic practices through a participatory technique to expand avocado seedling farming for future use. The results from this study call for geneticists or researchers to conduct further research on the genes associated with the most essential qualities (e.g., fruit size, skin color, taste, etc.) chosen by avocado farmers or consumers to recommend them for future breeding purposes.

Keywords Avocado, Indigenous knowledge, Smallholder farmers, Farmers' preferred traits

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Introduction

Indigenous knowledge is described as the collective response of local communities to a variety of natural and social factors that enhance their adaptation to their dynamic environment (Sillitoe 1998). Farmers' own descriptions for categorizing and controlling landraces have been produced (Tewodros 2016). Farmers' comprehension of their landraces contributes to a better understanding of the genetic basis of environmental adaptability as well as the efficient use of genetic resources (Girma 2014). The relevance of recognizing, interpreting, and applying local knowledge in natural resource management research is expanding (Alemu 2019; Barrios and Trejo 2003). Thus, indigenous knowledge systems are valuable resources that can help rural people in underdeveloped nations improve their efficiency, efficacy, and sustainability in environmental conservation (Dominics and Fuchaka 2016).

Smallholder farmers in relation to agriculture can be defined as small-scale producers who grow crops on an average farm size of less than two hectares of land (Knight 2022; Lowder et al. 2016; Rapsomanikis 2015). They are often characterized as family farmers because many rely on relatives' labor to meet production needs, and they typically retain a portion of their harvest for household consumption (Knight 2022; Rapsomanikis 2015). Approximately two-thirds of the developing world's 3 billion rural people live in about 475 million small-farm households, working on land plots smaller than 2 hectares (Lowder et al. 2016; Rapsomanikis 2015). In Africa, smallholder farms can be relatively larger, but only marginally. Kenyan smallholder farmers farm 0.47 hectares, and in Ethiopia, the average small farm size is 0.9 hectares (Rapsomanikis 2015). Many avocado farmers in Ethiopia and other countries are small-scale farmers.

Growing trees on farms diversifies smallholder farmers' crop production possibilities and can provide a greater range of nutritious crops for healthy diets, economic revenue, and ecological services (Hughes et al. 2020; Jamnadass et al. 2015). Avocado (*Persea americana* Mill.) is a tropical, perennial, evergreen fruit crop native to México and Central America that is one of the world's most important tree crops (Gopi et al. 2021). It is a diploid (2n = 24) basal angiosperm of the Lauraceae family, which includes flowering plants in the order Laurales (Hardham 2005). Avocados are classified into three horticultural races based on their characteristics and ecological adaptations: Mexican (*P. americana var. drymifolia*), Guatemalan (*P. americana var. guatemalensis*), and West Indian (*P. americana var. americana*) (Rendón-Anaya et al. 2019; Chanderbali et al. 2013). The majority of present vegetatively propagated 'subtropical' types are hybrids of Mexican and Guatemalan races, either by chance or from superior seedlings (Schaffer et al. 2013). Currently, research has classified approximately 500 commercial or improved avocado varieties (Yahia and Woolf 2011). 'Hass', 'Bacon', 'Fuerte', 'Gwen', 'Pinkerton', 'Reed', and 'Zutano' avocados are the most common, with many chefs preferring the 'Hass' variety (Dreher and Davenport 2013).

Avocado is an atypical fruit in that it has a smooth, buttery consistency and a rich flavor. A study conducted by Mpho et al. (2013) revealed that smallholder farmers or consumers prefer avocado fruits based on flavor, odor, texture, fruit size, and flesh color. In addition, ripeness, attractiveness, quality, convenience, and value for money are the main drivers for its consumption (Mpho et al. 2013; Yahia and Woolf 2011). Avocado fruit and its other parts have been utilized for a variety of uses. Its monounsaturated fatty acids have the ability to reduce the incidence of coronary heart disease, cataracts, diabetes, prostate and other malignancies, and macular degeneration (Ding et al. 2007; Kawagishi et al. 2001).

In recent years, avocado production has increased exponentially due to its flavor, market demand, and nutritional contributions (FAOSTAT 2018). The countries with the highest production capacity in 2020 were Mexico (2,393,849 tons), Columbia (829,147 tons), and Peru (672,232 tons) (FAOSTAT 2020). It is also considered an alternative crop to coffee farming, and its cultivation is on the rise among small landholders in various African countries (Cervantes-Paz and Yahia 2021; Trinh et al. 2018). The leading producers of avocado fruits in Africa include Kenya, Ethiopia, Malawi, South Africa, Cameroon, and Morocco, with annual production of 322,556, 245,336, 93,565, 84,775, 74,871, and 69,940 tons, respectively (FAOSTAT 2020; Nyakang'i et al. 2023). In Ethiopia, the production of avocado was estimated at 115182.63 tons from 116,284.63 hectares of land in the 2019–20 spring seasons. In the same year, the national average yield was estimated at approximately 4.2 tons per hectare, which is far lower than the global average and potential yield of avocado (7.2 tons per hectare) (FAO 2019; Jalata 2021).

According to various studies, the avocado tree was initially introduced to Ethiopia in 1938 by private orchardists in Hirna (the eastern highlands of Ethiopia) and Wondo-genet (the Sidama region) (Etissa 1997; Megerssa and Alemu 2013; Shumeta 2010), and thereafter its production extended throughout the country, including southern Ethiopia, due to the suitability of agro-ecological conditions for growing this product. The most grown areas of avocado in southern Ethiopia include Sidama (14769.75 tons), Wolayta (12462.57 tons), and Gedeo (4878.48 tons) (CSA 2020).

Smallholder farmers in Ethiopia's midland or lowland agro-ecological areas have been using avocado for many years due to its numerous uses and benefits, and farmers of different localities may develop their own specific knowledge during these years on avocado production, selection, preference, cropping system, use, conservation, etc. However, this indigenous knowledge has not been researched or documented, perhaps leading to insufficient agricultural development measures. As a result, the current study was carried out to assess smallholder farmers' indigenous knowledge of avocado production, harvesting, repinning, preference, management, and utilization in southern Ethiopia. Understanding these farmers' knowledge is vital for planning research, development activities, post-harvest handling, and management strategies for the avocado in Ethiopia. Furthermore, through evaluating smallholder farmers' indigenous knowledge in avocado crop production and consumer preferences, the study's findings will provide synergistic insights for avocado farmers, industry, consumers, horticultural sectors, breeders, and the scientific community.

Materials and methods

Description of the study areas

This study was carried out primarily in avocado production areas between 2022 and 2023, particularly Sidama, Gedeo, and Wolayta (Fig. 1). The study sites were chosen for their great production potential and long history of avocado farming. The Sidama region is bordered by Oromiya in the north, east, and southeast, Gedeo in the south, and Wolayita in the west. The region is located between latitudes 6° 14′ 54″ and 7° 15′ 10″ north and longitudes 37° 10′ 05″ and 39° 15′ 01″ east. Wondogenet, Dalle, Bensa, and Dara districts were chosen for this study from among the region's 36 administrative districts based on their avocado production potential and agro-ecology. The Gedeo zone is located between 5° and 7° north latitudes and 38° and 40° east longitudes in the southeastern Ethiopian highlands, overlooking the rift valley, on a short strip of land that goes from north (Sidama region) to south (Oromia region). Dilla Zuria, Wonago, and Yirgachefe are three of the zone's eight avocado-producing districts (CSA 2020). As a result, the Dilla Zuria and Wonago districts were included in

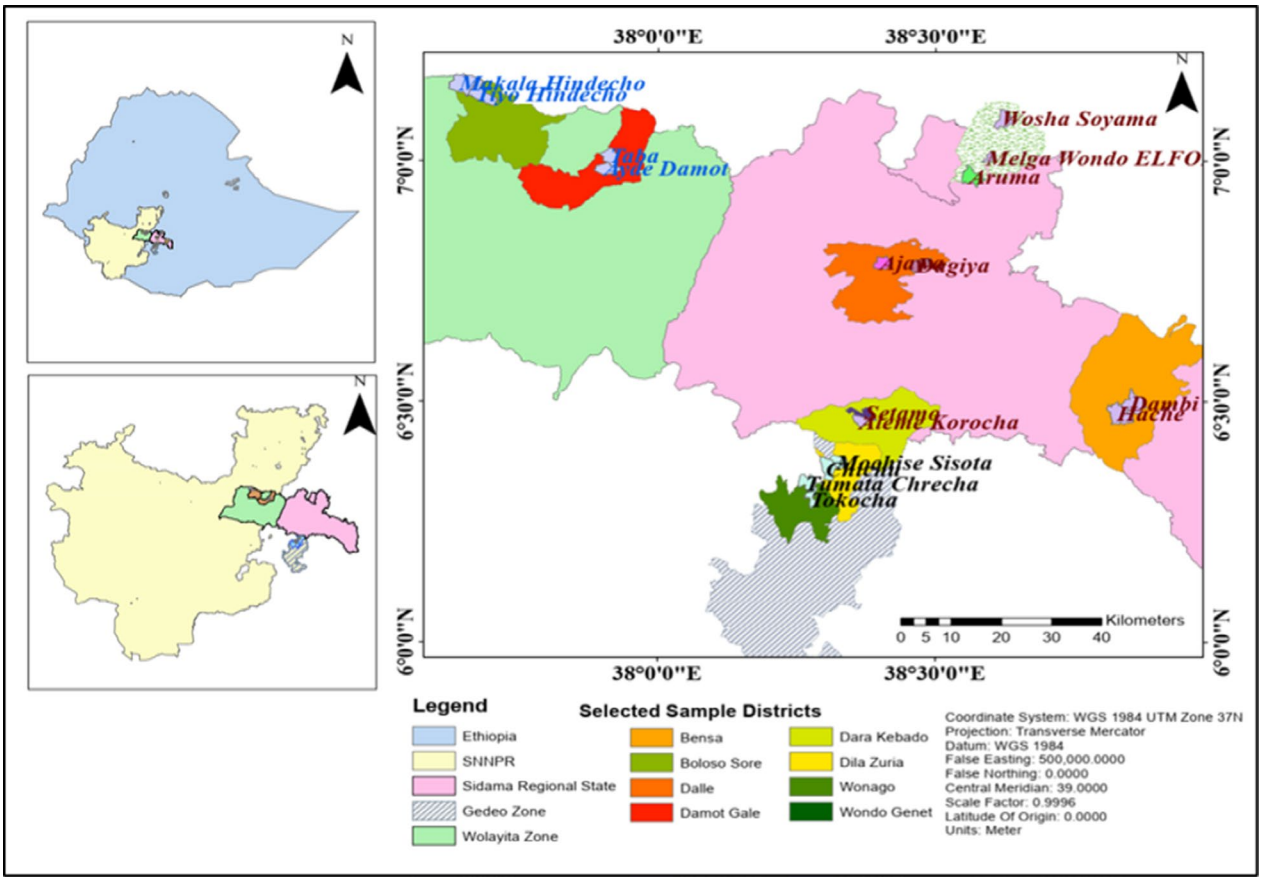

Fig. 1 Map showing the study sites

this study. Wolayta is bounded in the south by the Gamo Gofa zone, in the west by the Dawro zone, in the east by the Sidama region, in the north by the Kambata, Tambaro, and Hadiya zones, and in the northern east by Oromia state. It is situated between the latitudes of 6° 51″ and 7° 35″ north and the longitudes of 37° 46″ and 38° 1″ east. The current study covered the Boloso Sore and Damote Gale districts from this zone, as well as two *kebeles* (*kebele* is the lowest administrative division in Ethiopia) from each district. The study locations are situated at an elevation of 1100–2993 m above sea level. The typical annual temperature is 15–26 °C, and the average annual rainfall is 1200–1800 mL (Biazin et al. 2016; W/Yohannes et al. 2014).

Study strategies and sample size

Different sample stages, as well as purposive sampling procedures, were used to define the sampling units in this study. A reconnaissance survey of avocado growing areas was conducted from February to April 2021 to obtain a better understanding of avocado and to choose study sites. Before deciding on the study locations, the researchers discussed with experts from the area horticulture department about avocado growth zones, districts, or *kebeles*. As a result, three sites (Sidama, Gedeo, and Wolayta) were purposefully sampled based on their avocado production potential. For the purposes of this study, Sidama was divided into four districts, such as Wondo-genet, Dalle, Bensa, and Dara. Moreover, two districts were selected from each zone. After speaking with horticulture department officers or agricultural specialists, 16 *kebeles* (two from each district) were chosen based on their geographical position, accessibility, and number of avocado farms.

Secondary records (zonal or district horticulture departments) were used to obtain the total number of smallholder farmers (N = 7996) from each *kebele*. The entire sample size (n = 295) was then estimated from all smallholder farmers using Yamane's (1967) simplified formula and the population size's probability proportion to the random sampling technique. Thus, the sample size required to represent the true population was calculated using a 94% confidence level and a 6% precision level.

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

where n is the number of sample sizes (respondents), N is the total number of avocado farmers in *Kebeles*, and e is the level of precision. The sample size formula provides the number of responses that must be obtained. Here, 10% was added to the sample size to compensate for farmers that the researcher was unable to contact (Yamane 1967). As a result, the total sample size was 295. Next, these 295 respondents (254 males and 41 females) were carefully selected with the assistance of regional authorities and plant specialists from each *kebele*'s farmers' organizations using a population list of all farmers who produced avocado fruit in the sampled *kebele*. In addition, 32 key informants were identified from the respondents, two from each *kebele*, based on their extensive knowledge of avocado farming in the region or their connections to regional extension organizations.

Data sources and collection methods

The researchers used primary and secondary data sources to gather trustworthy and valid data. Secondary data were gathered from published and unpublished documents, the internet, journals, and reports available in the study areas. Respondents' primary data were collected using participatory research appraisal tools and techniques such as semi-structured interviews, guided field walks, pairwise ranking, focused group discussions, and key informants' discussions in local languages (*Sidaamu Afoo*, *Amharic*, *Gedeofa*, or *Wolaytota*). Local language translators were employed to mediate communication between interviewers and respondents in the third and fourth cases. The responses of the respondents were recorded in English.

When arriving in the sampled districts, support letters were first delivered to each district agriculture office's horticulture department, introducing the research aims. The agriculture specialist from each district then presented each *kebele* agricultural extension agent who would lead us to study areas. After arriving at each *kebele*, the purpose of the research was explained to the local leaders again, and verbal consent was secured before conducting the interviews and discussions. Then guided field observations were conducted with each agricultural extension agent. Before gathering respondents' perceptions, they were informed about the research's objectives and benefits, and they were promised that the data would be kept confidential and used only for the purpose of the study. When farmers said clearly that this research is valuable and consented to provide the necessary information (Wada et al. 2022), they were interviewed primarily on their farms and occasionally in chosen common places near their farms. The primary data that were gathered from avocado farmers using semi-structured interviews include sex, age, education level, the total number of avocados they own, the types of avocado they plant, cropping systems of avocado, management of avocado, ripening techniques, timing of harvesting and ways of harvesting, criteria they used for timing of harvesting, their desirable traits for locally adapted and improved varieties of avocado, socioeconomic and other uses of avocado, threats to avocado, etc.

Fourteen focused group discussions (one discussion per *kebele*) were conducted in the selected *kebele*, involving a total of 99 farmers (4–8 members) from local and avocado growers' network leaders and community elders, and a full consent of collaboration based on the principle of free prior informed consent was settled (Perrault 2004) to identify indigenous knowledge on timing of harvesting and ways of harvesting, ripening techniques, farmers' desirable traits of avocado, and how they manage and conserve avocado trees through the traditional practices. However, in the Alem Korocha and Setamo *kebeles*, focus group discussions were not held because the number of respondents was only five; thus, data from these *kebeles* were obtained through a semi-structured interview, and the interview results were cross-checked through key informant discussion.

A total of thirty-two key informants (two from each *kebele*) were selected among respondents to cross-check and clear contradictory ideas on the timing of harvesting and ways of harvesting, conservation status and threats to avocado, and types of farming systems they adopt from individual interviews and group discussions with farmers throughout the tested districts. In addition, the key farmers were asked to rank the preferred traits for local consumption and market values. Accordingly, the pairwise ranking approach was conducted to understand local people's perceptions of preferred traits for local consumption and market values, and the number of possible pairs was calculated using the relation $N\ (N-1)/2$ (Martin 1995), where N is the number of preferred traits. Consequently, the seven preferred traits (four external and three internal) to purchase avocado were identified with the key informants. The total number of pairs was determined using the formula, and the twenty-one pairs were arranged and presented to the 32 key informants (16 males and 16 females) to choose one of the two preferred traits at a time. Then the scores from each respondent were summed, the ranks determined, and the preferred traits that received the highest score were ranked first. However, the farmers' or consumers' preferred fruit skin colors and shapes, as well as their preferences for avocado production, were identified during semi-structured interviews and focus group discussions. Interviewing a farmer or a key informant took 45–60 min and 25–35 min, respectively. The group discussion, on the other hand, lasted 30–40 min. The discussions at the individual, group, and key informant levels were free and open-ended, with no time limits, as described by Dansi et al. (2013).

Statistical analysis

The data collected from respondents were coded and structured in Microsoft Excel before being analyzed using the Statistical Package for Social Scientists (SPSS) version 20. The respondent farmers' sociodemographic data were analyzed using descriptive statistics and the linear regression techniques in SPSS version 20. The Spearman rank correlation test was used to look at the relationships between cultivators' age and education level, as well as their level of experience, using SPSS version 20. The sex and age distributions of the respondents were tested using the chi-squared (χ^2) goodness-of-fit test in Minitab version 21.4.1.

Results

The sex profile of avocado farmers

The majority (86.1%) of respondent farmers who participated in this study were males, while a significantly lower proportion (13.9%) of them were females ($\chi^2 = 153.79$, $df = 1$, $p < 0.001$) (Fig. 2). Among these, 40.3% and 36.9% of male farmers were included from Sidama and Gedeo, respectively, while 8.8% of them participated from Wolayta. Approximately 7.8% of females were from the Gedeo ethnic group (Table 1).

Age profile of avocado farmers

Regarding age groups, the number of interviewed and discussed farmers between 41 and 60 years old (57.3%) was significantly higher than those 40 years old (27.5%) and > 60 years old (15.3%) ($\chi^2 = 82.77$, $df = 2$, $p < 0.001$), as shown in Fig. 2. The mean age of the farmers was about 50 years. Spearman's correlation coefficient indicates that there was a strong significant positive correlation (Spearman's rho, $rs = 0.939$, $p < 0.01$) between the age of farmers and their experience cultivating avocados. In addition, the farmers' age and the number of seedlings cultivated by them were significantly and positively correlated at the 0.01 level. However, these findings revealed a significant inverse relationship ($rs = -0.177$, $p < 0.01$) between the farmers' age and the number of grafted trees they produced (Table 2).

Educational profiles of farmers

Most farmers (51.2%) completed primary education (grades 1–8) along with agriculture work; 16.3% of them were in secondary school (grades 9–12); and 5.1% had a certificate or above award for formal education, while 27.5% of them were not formally educated (Fig. 2). The results of the Spearman correlation test revealed a significant negative correlation between the level of agricultural education and their experience growing avocados ($rs = -0.293$, $p < 0.01$). In addition, educational level and the number of avocado trees owned by farmers were also significantly and negatively correlated ($rs = -0.536$, $p < 0.01$) (Table 2). However, the number of grafted fruits that the farmers cultivate was positively correlated with their

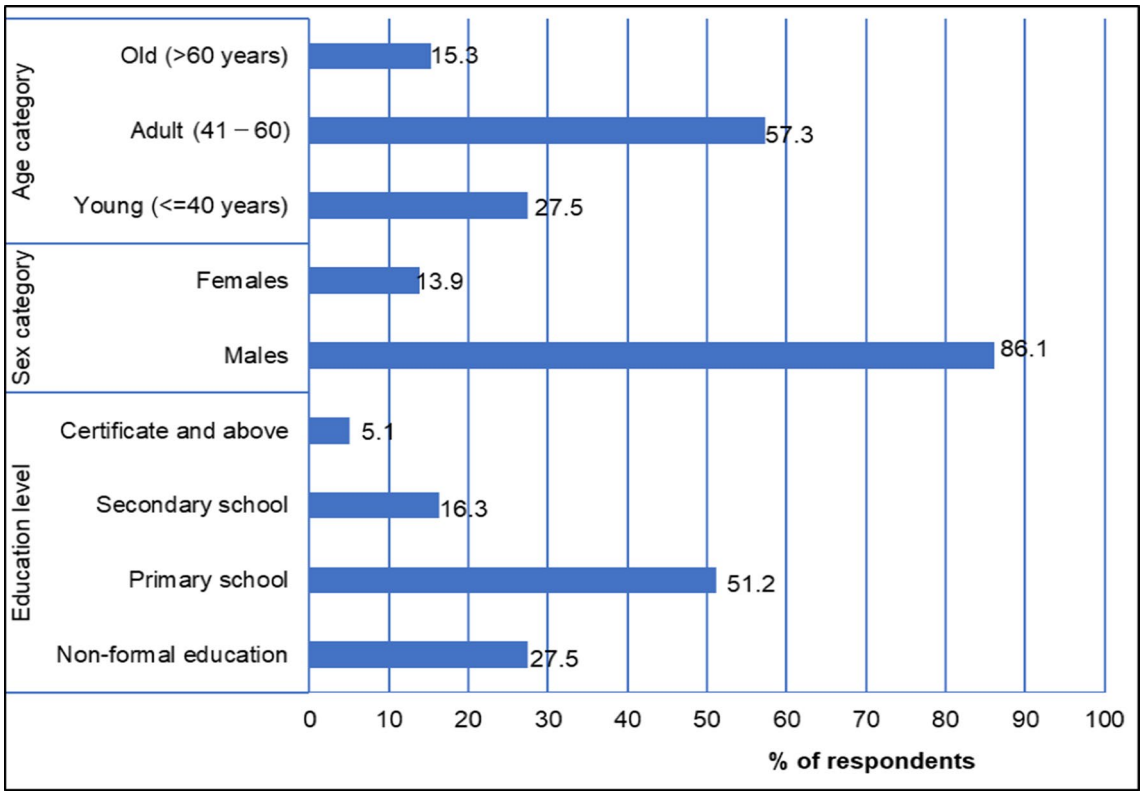

Fig. 2 Sociodemographic characteristics of farmers

educational level (rs = 0.146, p < 0.01), and the correlation was significant.

Farmers' experience in avocado production

The farmers who participated in this study had been growing seedling fruits for 10 to 60 years. Most farmers (52.2%) had been using seedlings for more than 20 years. The maximum number (55.6%) of Gedeo farmers have 10–20 years of experience growing avocados. On the other hand, 6.3% of Sidama farmers have more than 50 years of experience in the cultivation of this crop among the respondents (Table 1).

Dominant types of avocado, its cropping system, and agronomic practices

According to smallholder farmers, seedlings dominate southern Ethiopian avocado production, based on the study's findings. Approximately 48.5% of the informants have cultivated grafted avocados, particularly 'Hass'. However, 51.5% of the farmers in this study were unfamiliar with grafted fruits grown in the study locations. Avocado producers in the Sidama region were typically aware of grafted fruits and their fruit's value in external markets. All farmers contacted in the Sidama region's Dalle district primarily grow grafted types such as 'Hass', 'Fuerte', and 'Pinkerton'. Grafted fruits are still being grown in the Gedeo and Wolayta districts. 'Hass' is the most planted and widely spread grafted fruit in the studied locations. 'Fuerte' is also the second most common grafted fruit (36.6%) in many farmers' fields, followed by 'Pinkerton' (Fig. 3).

The avocado production system evolved mostly in a home garden and in an open agricultural production zone. The majority of farmers (98.7%) plant avocados using mixed or intercropped farming methods with enset (*Ensete ventricosum*), banana (*Musa acuminata*), coffee (*Coffea arabica*), mango (*Mangifera indica*), chat (*Chat edulis*), and, to a lesser extent, annual crops such as maize (*Zea mays*) and teff (*Eragrostis tef*), while the remaining farmers use mono-crop systems. All avocado farmers who participated in this study from the Wolayta zone grow avocados using only intercropped farming systems (Fig. 4). On the other hand, all farmers (100%) who participated in the study areas complained that the intercropping system of avocados had a negative environmental impact and that the yields of coffee, enset, and other crops grown under avocado trees were reduced.

In the study locations, the majority (94.5%) of local farmers noted that many avocado trees on their farms were grown from seeds, which were discarded as waste

Table 1 Avocado farmer's profiles from Sidama, Gedeo and Wolayta

Study variables	Number of respondents from each ethnic group[a]			
	Sidama	Gedeo	Wolayta	Sum (N = 295)
Sex				
Males	119 (40.3%)	109 (36.9%)	26 (8.8%)	254 (86%)
Females	8 (2.7%)	23 (7.8%)	10 (3.4%)	41 (14%)
Experience (in years)				
10–20	58 (45.7%	62 (47.3%)	20 (55.6%)	140 (47.5%)
21–30	42 (33.1%)	33 (25.2%)	8 (22.2%)	83 (28.1%)
31–40	16 (12.6%)	15 (11.5%)	4 (11.1%)	35 (11.9%)
41–50	3 (2.4%)	14 (10.7%)	2 (5.6%)	19 (6.4%)
51–60	8 (6.3%)	7 (5.3%)	2 (5.6%)	17 (5.8%)
Growing systems of seedlings				
Throwing seeds as waste	119 (40.3%)	126 (42.7%)	34 (11.5)	279 (94.5%)
By digging holes and burying seeds	8 (2.7%)	7 (2.4%)	2 (0.67%)	17 (5.7%)
Use artificial fertilizers				
No	127 (43.5%)	132 (44.7%)	36 (12.2%)	295 (100%)
Yes	0	0	0	0
Use compost				
Yes	14 (4.7%)	12 (4.1%)	5 (1.7%)	31 (10.5%)
No	113 (38.3%)	120 (40.7%)	31 (10.5)	264 (89.5%)
Use field spacing for seedlings				
No	121 (41.0%)	128 (43.4%)	35 (11.9)	284 (96.3%)
Yes	6 (2.0%)	4 (1.4)	1 (0.3%)	11 (3.7%)
Pruning the avocado trees				
Yes	12 (4.1%)	15 (5.1%)	5 (1.7%)	32 (10.9%)
No	115 (38.9%)	117 (39.7%)	31 (10.5%)	263 (89.1%)

[a] The numbers in parentheses are the percentage of respondents; N represents total number of avocado farmers who participated in this study

after home consumption. In other words, after consuming avocado flesh or pulp, users throw the seeds or stone parts as waste products on intercropped farms, such as in enset, cabbage, maize, and others. Most seeds germinate as seedlings without sufficient agronomic practice. Farmers then begin to manage newly germinated seeds (planting, watering, weeding, etc.) with other crops on their farms. However, 5.7% of avocado producers plant their crops by first digging 15-cm-diameter holes and then filling them with water. They bury the avocado seed's head (top) in the soil to form the shoot, and the seed will begin to grow in 8–10 weeks. Our findings revealed that the farmers in the study areas did not use any artificial fertilizers, but about 10.5% of them applied compost such as dung and domestic wastes for both seedlings and grafted avocados. According to the results of interviews and group discussions, the majority of smallholder farmers (96.3%) also did not use field spacing for seedlings growth due to a lack of spacing knowledge. Nearly 3.7% of those interviewed reported having planted an avocado tree within 6–8 m (8–10 steps) of their residence (Table 1). However, nearly half of professional avocado growers (48.5%) have cultivated this crop within a 6-meter radius. During our guided field observation, we noted that many producers did not have available space due to the close planting spacing of avocados. As a result, the tree grows very tall, fruits form in the highest portion of the tree, and harvesting becomes difficult. However, to keep the trees' height and shape, some avocado growers (10.9%) encourage lateral development and multiple branching by pruning the plants (Table 1).

Indigenous knowledge on the timing of picking avocado fruit from the tree

Farmers in the research locations use avocado fruit characteristics such as color change, smoothness, and appearance to determine the ripeness of the fruit. All responders (100%) agreed that the color of avocado fruit changes from green to black or brown as it matures or loses its brilliant green color. Other informants said that there are still some avocado races that reach maturity without changing color. The smoothness of the skin is also a reliable indicator of maturity in most varieties in the study areas.

Table 2 Spearman's correlation between farmers' age, education, cultivation experience, and the number of avocados they produced

Variables	Sex	Age	Education	Seedlings©	Grafted fruit©	Experience (in years)
Age						
rs	0.081					
p value	0.083					
Education						
rs	−0.264**	−0.313**				
p value	0.000	0.000				
Seedlings©						
rs	0.141**	0.604**	−0.536**			
p value	0.008	0.000	0.000			
Grafted fruit©						
rs	−0.128*	−0.177**	0.146**	−0.025		
p value	0.014	0.001	0.006	0.336		
Experience (in years)						
rs	0.077	0.939**	−0.293**	0.561**	−0.182**	
p value	0.093	0.000	0.000	0.000	0.001	
N	295	295	295	295	295	295
Mean	1[a]	50	1[b]	17	13	26

**, *Correlation is significant at 1% and 5% levels (1-tailed), respectively; rs: Spearman's correlation coefficient; N: total number of avocado farmers who participated in this study; ©in number

[a] Majority of farmers were males

[b] Majority of farmers were at a primary school level

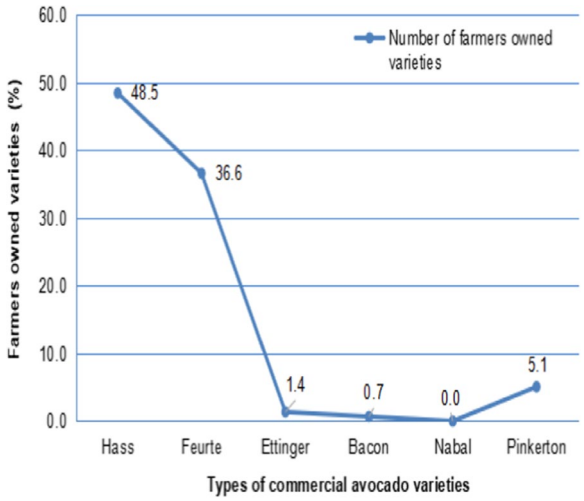

Fig. 3 The percentage of farmers owned different avocado varieties in the study areas

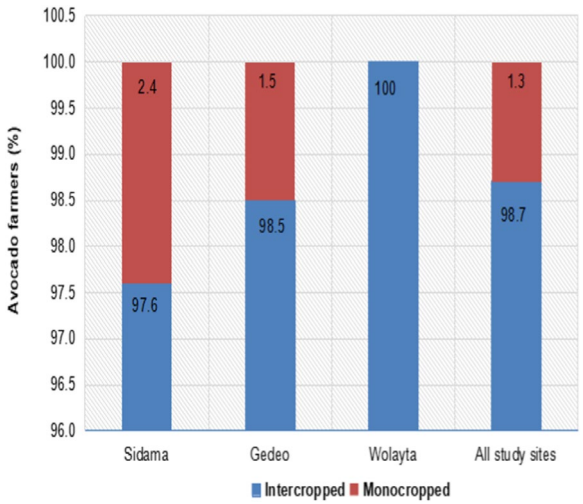

Fig. 4 Cropping systems of avocado in the study areas

The findings of this study showed that avocados grown from seedlings carry heavy fruits in 1 year and little or none in the next. This means irregular crop loads from year to year (biennial types). Some trees bear fruit annually, while others bear fruit biennially. Thus, avocado farmers clearly know in which year avocados on their farm produce large yields. The local farmers classified the harvest periods of the avocado crop as maximum and minimum. In this study, all informants (100%) reported that the maximum harvest period for avocados lasts from February to April and the minimum from October to January. According to farmers' knowledge, the yield of fruit per tree varies due to the avocado type, cultivation, and climatic conditions.

Indigenous ways of harvesting avocado fruit

The common harvesting techniques for avocado crops in the study areas were harvesting by using bamboo trees, a thin tong like wood, or picking poles. Other harvesting techniques reported by avocado farmers during this study were that harvesters (children and young people) climb the trees with or without a ladder and beat with sticks to make fruits fall off or collect the fruits. All farmers in the study areas said that when harvesting avocado using this technique, the fruit can crack when it falls to the ground from the tree, and there are no proper postharvest handling techniques for this kind of loss. In addition, they noted that this harvesting technique not only leads to fruit cracking but also that the person who climbs the tree may fall and become fractured, sustain injuries, or even die. Our field observation results show that during this harvesting technique, many fruits also fall and become unmarketable. The smallholder farmers in the study areas also gather the mature avocado fruit by having two people hold sacks on the ground while kids climb the avocado trees and slowly drop the fruits onto the sacks. However, 55% of growers of avocados said they harvest the fruit by shaking the trees or branches until the avocados fall to the ground.

Indigenous knowledge on ripening techniques for avocado

Local people had good knowledge of fruit tree species, including their times of fruiting and ripening. After harvesting, the avocado fruit must be carefully transferred from the picking bag into the field crates to avoid mechanical injuries. Sidama, Gedeo, and Wolayta people use fertilizer sacks and put them in plastic bags to ripen avocados. Besides, avocado farmers use enset fibers (*Haanxiicho*, Sidama language) and teff's wastes (*Chid*, Amharic) to ripen avocado fruit. To perform this, local people first place enset fibers (*Haanxiicho*) or teff's wastes on the ground, then put unripe avocado fruits on the enset fibers or teff's wastes, and eventually cover them with these materials to retain moisture or temperature until the fruits are ripe. Approximately 23.2% of informants noted that they ripened avocado fruit by placing it at room temperature in a dark room for 3 to 5 days. Furthermore, about 15.4% of farmers reported that they ripened this fruit using basket-like materials prepared from bamboo (*Gimboola*, Sidama language) until the fruit was ripe.

Avocado farmers' trait preferences for production, consumption, and market values

The study's findings revealed that several factors influence avocado production, consumption, and marketing. The pairwise ranking approach was applied to identify the seven desired attributes (four external and three internal traits) of avocado used for local consumption and market value with 32 key informants for this study (Table 3). As a result, the size, color, shape, and texture (smooth or rough) of the fruit are among the external traits that farmers prefer, whereas taste, pliability, and seed size (small seed size) are among the qualities that consumers (end-users of avocado fruit) prefer when consuming this fruit. According to the findings, growers in the research locations ranked fruit size as their top choice. The key informants also stated that skin color and flesh flavor are the second and third most important characteristics that can influence customers' impressions of avocados throughout the buying or eating process, respectively.

The semi-structured interview and focused group discussion results indicated that the color of the avocado fruit peel is strongly related to the flavor of the pulp. The majority of respondents (89.1%) agreed that black is a good predictor of avocado fruit quality. Black avocado fruit skin is sweeter than other colors of fruit. Others (8.9%) believed speckled and purple colors were also popular in the research locations. A few people (2.1%) favored red colors as well (Fig. 5). Green, on the other hand, is an unappealing color to purchasers due to its watery flavor. However, some green-colored avocados have a sweet flavor. Furthermore, people classify an excellent avocado based on the color of the pulp. They reported that yellow pulp is sweeter and more appealing than green pulp. Avocado fruit with fibers in the pulp is unattractive to customers due to the dark color acquired during ripening. The buttery and nutty pulp of the avocado fruit is sweeter than the watery pulp. As a result, all (100%) respondents believed that avocado pulp with a buttery flavor was the most desirable quality for consumers or buyers.

The shape of the fruit was ranked as the fourth preferred external quality trait of avocado fruit in the study areas. Approximately 95.8% of farmers included in this study noted that the most preferred shape of avocado was pyriform (Fig. 5). Others preferred the rhomboidal shape of the avocado fruit. Round-shaped avocado fruits do not attract consumers or buyers at all. Furthermore, pliability, seed size, and skin texture were other important traits of avocado fruit that were ranked by key informants as fifth, sixth, and seventh, respectively (Table 3). Our findings highlight that an avocado with a brittle skin is sweeter than a pliable avocado. Moreover, avocado consumers also consider the small seed of the avocado fruit when they consume or buy it. Approximately 74.2% of the respondents indicated that the smooth skin surface is better and more acceptable than the rough skin surface.

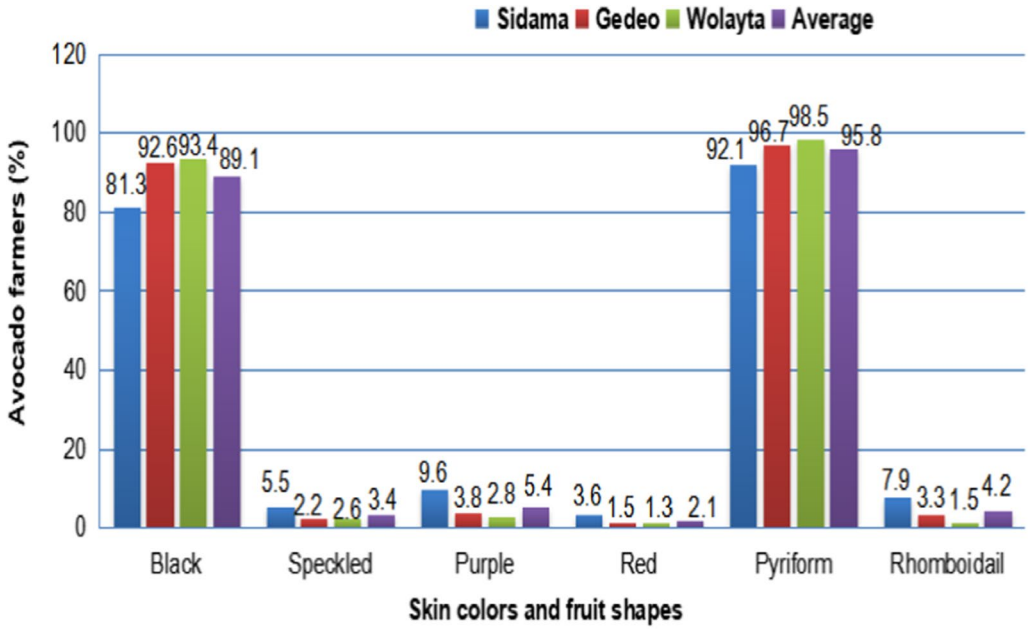

Fig. 5 The preferred fruit skin colors and shapes reported by farmers in each ethnic group

However, 26.8% of them reported that they preferred rough-surfaced avocado fruit skin, as shown in Fig. 5.

Farmers also select avocado trees for production based on different characteristics. The regularity of fruit bearing, branching pattern, early maturity, high yield, and high market demand are additional characteristics that farmers reported as being indicative of avocado trees with high tree quality. Avocado farmers also use tree branches to determine the yields of avocado. The only criteria used to choose the grafted avocados were fruit yield and eating quality.

Utilizations of avocado

Avocados are quickly becoming a substantial source of extra revenue, particularly for smallholder farmers. It is safe for both human and animal consumption, and it is drought-resistant in the study areas. Its flesh is mostly consumed in the study regions and other parts of Ethiopia as food with other components such as *Kocho* (a staple cuisine of many southern parts of Ethiopia derived from enset products), bread, pepper, and vegetables, and as fresh juice in local markets and cities. The Gedeo people called the avocado tree "*Buurinqaa*" (butter tree) because of its buttery flavor. They discovered that eating avocado is equivalent to consuming fat- and protein-rich foods such as meat and eggs, and as a result, it improves dietary appetite. Furthermore, the drought affected Sidama and other Ethiopian regions in 2022. During this difficult time, all informants (100%) in the Sidama districts have used young leaves, rotting fruits, bark, and seeds of avocados as animal feed. Mature fruits are consumed by humans in the research regions. Avocado flesh is used as a cosmetic by women in the study areas to enhance their beauty. Smallholder farmers in the research areas recognized avocado as a versatile plant since they utilized it to produce firewood, charcoal, and lumber.

Farmers' avocado germplasm management system

The study's findings showed that farmers in the study areas conserved their avocado crops using both in-situ and ex-situ techniques. They manage this crop as a mixed agroforestry tree and/or garden tree on their farmland. Other farmers traditionally practice conservation through fencing, enset cultivation, or coffee production. In contrast, 14.9% of farmers manage avocado trees by retaining seedlings when preparing new farmland and clearing the ground beneath the canopy to make it easier to collect any fallen fruit. However, some (17.3%) informants stated that despite the lack of knowledge about the nutritional benefits and other issues, people in the study areas still have a hard time conserving avocado. In the study areas, 28.1% of farmers who were interviewed stated that there were fewer seedlings in their area. Farmers claim that the decrease in the variety of seedling types of avocado was mainly due to the introduction of grafted avocados and firewood. Similarly, during our field observation, it was discovered that firewood had a significant negative impact on avocado plants. The production of charcoal and wood, according to informants, has a negative effect on avocado germplasm.

Table 3 The pairwise ranking result of farmers' preferred traits of avocado fruit for consumption and marketing

Key informants	Preferred traits for consumption and marketing						
	Fruit skin color	Fruit size	Fruit shape	Seed size	Skin texture	Taste	Pliability
MH1	5	6	2	2	1	4	1
MH2	5	4	4	0	1	5	2
TH1	2	6	3	3	0	5	2
TH2	3	4	3	3	1	5	2
AD1	3	6	2	2	1	5	2
AD2	4	4	1	2	1	6	3
T1	5	6	2	1	1	4	2
T2	5	5	2	2	1	4	2
TC1	5	6	3	0	0	4	3
TC2	4	6	2	2	1	5	1
To1	5	6	3	0	2	4	1
To2	5	5	2	2	1	4	2
C1	4	6	3	1	2	3	2
C2	5	5	4	1	1	4	1
S1	4	6	4	1	2	3	1
S2	5	6	3	1	1	4	1
D1	5	6	3	1	1	3	2
D2	4	6	4	2	0	3	2
H1	5	6	3	1	1	3	2
H2	4	6	3	1	2	4	1
AK1	5	6	4	1	0	4	1
AK2	3	6	3	1	2	4	2
Se1	4	6	4	0	1	5	1
Se2	4	6	3	1	2	3	2
Da1	4	6	4	2	1	3	1
Da2	5	6	3	1	1	3	2
A1	5	6	2	2	1	4	1
A2	5	6	3	1	1	4	1
W1	5	6	3	2	1	3	1
W2	5	6	3	2	0	4	1
Ar1	4	6	4	1	1	3	2
Ar2	3	6	4	2	0	4	2
Total score	139	183	96	44	32	126	52
Rank	2nd	1st	4th	6th	7th	3rd	5th

The key informants' codes were MH = Matala Hembecho, TH = Tiyo Hembecho, AD = Ayde demote, T = Taba, TC = Tumata Chirecha, To = Tokicha, C = Cicu, S = Sisota, D = Dembi, H = Hache, AK = Aleme Korocha, Se = Setamo, Da = Dagiya, A = Ajawa, W = Wosha, and Ar = Aruma

Discussion

Age and education are sociodemographic factors that significantly affect how people perceive, use, and dispose of assets (Usman et al. 2013). In this study, we found a strong, significant, and positive correlation ($rs = 0.939$, $p < 0.01$) between the age of farmers and their experience of cultivating avocados. The findings indicated that the older farmers cultivated a greater number of avocado seedlings, and they had better experience cultivating this crop than youngsters; however, they had less experience cultivating grafted avocados. Age is an indication of the level of experience of farmers, which can have direct implications for their decision-making processes and physical ability to manage enterprises and trees (Burton 2006). According to a study done in Kenya's coastal provinces, older farmers knew more about fruit trees (Fukushima et al. 2010). Similarly, the study conducted by Gachuiri et al. (2022) revealed that younger men and women knew the least about food tree species such as avocado and mango.

This study further demonstrated a decline in indigenous knowledge about the cultivation of seedling types

of avocado, particularly among young and more educated people in the study areas. According to Table 2, Spearman's correlation test revealed a significant inverse relationship between the farmers' education and their experience in growing seedlings ($rs = -0.536$, $p < 0.01$), indicating that farmers with higher education levels have less experience cultivating this crop. Farmers' grafted tree cultivation, on the other hand, was strongly and positively correlated with their educational level ($rs = 0.146$, $p < 0.01$). This suggests that nonformally educated and primary school-level farmers tend to grow more seedlings, and they may not be as knowledgeable about other avocado varieties. Conversely, knowledgeable farmers might be well-versed in cultivating grafted trees. In the study areas, the farmers transfer their properties to their children (especially men) when they marry or become adults. The results of the interviews and group discussions also indicated that most of the educated people inherited avocado trees from their parents and then did not cultivate and manage the trees more. This may be the reason why more educated farmers own fewer seedlings than nonformally educated ones. A similar study conducted on Ethiopian barley indicated that more educated farmers have less experience in the cultivation of barley landraces (Wada et al. 2022). Other studies have indicated that since it is assumed that farmers with more knowledge adopt better production practices, education increases farmers' ability to access and use information (Usman et al. 2013). Thus, creating awareness among nonformally educated farmers about grafted trees is mandatory to increase their productivity.

Our findings showed that avocado seedlings dominate southern Ethiopian avocado production. In contrast to Sidama, the cultivation of grafted avocados in Gedeo and Wolayta was too young due to limited access to improved varieties, as farmers cited (Fig. 3). All farmers interviewed in the Dalle district of the Sidama region mainly grow grafted fruits such as 'Hass', 'Fuerte', and 'Pinkerton'. This could be due to the availability of these grafted avocados in the Dalle area, particularly at the Dagiya avocado seedling center (a local nursery), or to training opportunities for growers or farmers about improved varieties and market networks provided by Yirgalem Agroindustry Park. The level of awareness among farmers regarding grafted avocados and their value on external markets determined the type of avocado to be grown (Juma et al. 2019). Thus, creating awareness about the grafted avocados or improved cultivars among the smallholder farmers, especially in Gedeo and Wolayta districts, is crucial.

The findings of this research indicated that in the study areas, the majority (98.7%) of smallholder farmers cultivate avocados using mixed or inter-cropped farming systems with different crops. This finding was consistent with other research carried out in different parts of Ethiopia (Biazin et al. 2016; Shumeta 2010). Correspondingly, avocado is mainly intercropped with vegetables (cowpeas, tomatoes), groundnuts, maize, sorghum, or other fruit trees (banana, citrus, guava, and mango) in Kenya (Wasilwa et al. 2017). Dube et al. (2018) reported that most fruit growers in Tanzania intercrop their fruits with vegetables, maize, and potatoes to earn additional income. On the other hand, all farmers (100%) who participated in the study areas complained that the intercropping system of avocados has a negative environmental impact and that the yields of coffee, enset, and other crops grown under avocado trees have been very low due to their high demand for water and the fact that their leaves decompose or break down for a long time. A study conducted by Sommaruga and Eldridge (2020) revealed that avocado production is associated with significant water conflicts, stresses, and hot spots, as well as other negative environmental and socio-economic impacts on local communities in the main production zones. One hectare of avocado with 156 trees consumes 1.6 times more than a forest with 677 trees per hectare (Denvir et al. 2022). Thus, in the near future, further research work should be conducted in the study areas on the environmental impacts of avocado to confirm, avoid, and mitigate the negative effects of its production.

The current study also revealed that most smallholder farmers (96.3%) in the study areas did not use modern farming techniques for avocado seedlings cultivation due to a lack of knowledge. The grafted avocado producers, on the other hand, grow within a 6 m distance. This idea may be because agricultural experts clearly outline the spacing when farmers purchase avocado orchards from seedling production facilities or agricultural offices. According to previous studies, the planting distance for avocados can range from 6 to 12 m, depending on the desired plant density and the variety (Nandwani 2014). A study demonstrated that the use of modern farming techniques could increase smallholders' income as well as gains from high-value markets (Gramzow et al. 2018).

Avocado trees differ in productivity and regularity in their fruit-bearing habits (Lahav and Lavi 2013). The types of horticultural races or varieties, which in turn vary from location to location due to ecological, climatic, and genetic conditions, determine the timing and frequency of avocado fruit harvesting. Avocado farmers or growers reported that most mature avocado fruit changes its color from green to black or brown or loses its vibrant green color. In fact, most fruits eventually change color when reaching maturity. However, there are some avocado races that reach maturity without changing color, as confirmed by growers. At the time of fruit maturity, the outer waxy surface also takes on a different appearance.

Similarly, fruits will be ready for harvesting when the seed coat changes color from yellow to dark brown (Hofman et al. 2013). According to various research reports (Arzate-Vázquez et al. 2011; Cañete et al. 2018), avocado skin color and firmness are important indicators of the stage of ripening for the industry and consumers. For instance, a purple variety will turn purple into maroon, whereas a green variety will turn green into yellow. As Hass avocados ripen, their skin changes from green to purple or black as a result of an accumulation of anthocyanins and the breakdown of chlorophyll (Cox et al. 2004; Villa-Rodríguez et al. 2011).

The findings of this study indicated that all farmers in the study regions use different traditional harvesting techniques, such as harvesting by using bamboo trees, climbing the trees with or without a ladder, having two people hold sacks on the ground while kids climb the avocado trees, and shaking the trees or branches until the avocados fall to the ground. A study conducted by Abebe et al. (2022) highlighted that one of the major causes of avocado post-harvest loss to farmers was poor harvesting techniques. For tall trees, handpicking poles or ladders are used for fruit that cannot be reached easily from the ground (Köhne and Kremer-Köhne 1995). However, the grafted trees are smaller and the fruits can therefore be easily plucked, whereas the seedlings are taller and the fruits are clipped with picking poles (Hofman et al. 2013). Studies indicated that fruit cannot be harvested during wet weather conditions because the presence of water droplets on the fruit surface can favor the incidence of postharvest diseases during distribution and storage (Darvas 1982; Hofman et al. 2013).

The study's findings revealed that many factors influence avocado consumption. In the literature review, there are two classes of factors that can affect the consumption of avocado fruit: external and internal factors. The former is what consumers see when they look at a fruit on the market shelf. The latter is what they discover when they prepare the fruit for use or consumption (Storey et al. 1973). Table 3 displays key informants' seven most desired avocado qualities, including external traits (fruit size, color, shape, and texture) and internal traits (taste, pliability, and seed size).These characteristics may have a significant impact on the likelihood that avocado fruit will be purchased. Based on the study findings, fruit size was considered the most crucial attribute by farmers in the study areas. This result is consistent with another study (Storey et al. 1973).

Our findings revealed that fruit color (black is preferred to green) is a criterion on which growers base their preference. The majority of respondents (89.1%) indicated that the color black is a more reliable indicator of avocado fruit quality than the color green. In fact, there are some green-colored avocados that have a sweet taste. Therefore, farmers or growers mainly use green-colored avocado fruits for home consumption. Studies revealed that, compared to green avocados, black avocados tend to be higher in potassium and dietary fiber, making them a great snack for those looking for a boost in their diet (Cervantes-Paz and Yahia 2021). On the other hand, green avocados have a higher concentration of antioxidants than other varieties, which can help combat free radical damage in the body and reduce inflammation (Bill et al. 2014; Marín-Obispo et al. 2021).

Avocado fruit preference is also based on how watery the fruit is. The key informants stated that avocados have a buttery and nutty pulp, which is sweeter than a watery pulp. Etissa (1999) reported a similar finding. The fruit's flesh, which changes color from pale green to bright yellow, tends to be smooth and buttery in consistency and has an exquisite flavor and aroma (Bill et al. 2014). Avocados contain an enzyme called polyphenol oxidase, which causes the flesh to brown when exposed to air, or more specifically, when it is exposed to oxygen (Marín-Obispo et al. 2021), and affects the consumer's perception. Similar to other studies, taste is also considered an important quality element that has a positive and significant influence on consumers' buying intentions (Moor et al. 2014).

Our results showed that the shape of the fruit was ranked as the fourth preferred external quality trait of avocado fruit. Based on the findings of this study, the most preferred shape of avocado fruit was pyriform (Fig. 5). Similarly, in California, consumers prefer pyriform or oval fruit as the "standard" avocado associated with high quality (Storey et al. 1973). According to Storey et al. (1973), compared with fruit size, shape is not considered important in some other regions of California. Avocado fruits with brittle peels are unacceptable to both consumers and growers in the study areas. However, many prominent people have argued that avocados with brittle skin are sweeter than those with pliable skin; this is in line with Storey et al. (1973) and Marín-Obispo et al. (2021).

The current study found that avocado consumers and producers prefer the small-sized seed of the avocado fruit while consuming or purchasing it. All informants reported that the avocado consumers checked the seed size by shaking the ripened fruit. They put avocados near their ears and then gently shook them. To the farmers' knowledge, if the seed size is small, then it easily moves and is heard when shaken. The large seed inside the pulp never moves when consumers shake it. By doing so, consumers determine the size of the seed and ripeness of the fruit before peeling the skin. Skin texture is another external quality trait that can affect avocado farmers' or consumers' perceptions when purchasing avocado.

Marín-Obispo et al. (2021) noted that sensory texture and appearance attributes must be considered among the potential drivers of liking avocado pulp. In the literature on consumer studies, it has been argued that consumer choice also depends on the level of correspondence between the quality characteristics of the product and consumer preference structures (Cardello 1995). Farmers claimed that when avocado trees branch out widely, the yield increases significantly. Gama-Campillo and Gomez-Pompa (1992) claim that among the factors considered in the past in the Maya area when choosing avocados for cultivation were leaf odor, fruit size, and other uses. Thus, further research on the genes associated with the most essential qualities (e.g., fruit size, skin color, taste, shape, etc.) chosen by avocado producers or consumers should be undertaken to recommend them for future breeding purposes.

Fruit color, size, smoothness, pliability, and oil content (high oil content makes the fruit taste less watery) are all related to the three botanical races of the avocado. For example, purple and black or green colors are often attributes of the Mexican and Guatemalan races, or their hybrids (Bergh 1992), whereas yellow-green to maroon in skin color, pliable, and leathery in texture are characteristics of the West Indian and its hybrid cultivars (Joubert and Bredell 1982; Popenoe 1974). In addition, the fruits of West Indian race avocado cultivars and West Indian hybrids are generally larger, have smoother skin, and are more pliable than those of Mexican and Guatemalan races, or their hybrids. However, the Mexican race and its hybrid cultivars have a higher oil content (up to 30% by fresh weight) than those of the Mexican and West Indian races (Bergh 1992; Joubert and Bredell 1982; Yahia and Woolf 2011). This higher oil content of the mature fruit of Mexican races gives the flesh a buttery texture that is economically valuable (Popenoe 1974). Furthermore, Guatemalan races possess genes for high-quality fruit, small seeds, and late maturation (Bergh 1992; Lahav and Lavi 2013). Mexican races, on the other hand, have genes for early maturity and cold tolerance. West Indian types, or their hybrids, are important for providing diets for mostly poor people in developing countries (Chanderbali et al. 2013). For growers in Ethiopia who grow fruit from seeds, these traits may be based on the proportion of genes of each race in their seedling trees (even though their lineage may not be known). For those growing grafted trees, 'Hass', 'Fuerte', and 'Pinkerton' are Mexican x Guatemalan hybrids.

Avocado fruits are now of high economic value, and thus, the food industry is showing remarkable interest in enhancing the production and processing of this crop (Pedreschi et al. 2019; Rendón-Anaya et al. 2019). In Ethiopia, avocado fruit can contribute to the livelihoods of smallholder farmers through the income pathway through the sale of fruits and nonfruit products (fuel wood, timber, and fodder), which can also improve household food security. According to a literature review, avocados are the most popular oily crop in the global cosmetics industry as a natural alternative to synthetic chemicals (dos Santos et al. 2013; Ge et al. 2018).

The study found that growers use in-situ and ex-situ techniques to conserve their avocado crops. Smallholder farmers in the research areas, however, were responsible for deforestation by chopping older trees and not replacing them with new avocado trees. Today, many farmers remove wild and cultivated trees, including avocados, with care to produce firewood, construction materials, timber, and charcoal. The development of better technologies for avocado conservation, breeding, improvement, and propagation is crucial to maintaining the diversity of avocados throughout the world (Encina et al. 2014; Guan et al. 2016). Therefore, it is better to create awareness among smallholder farmers about the conservation and management systems of avocado trees to overcome threats.

Conclusions

This study contributes to the understanding of indigenous knowledge among farmers or growers in terms of production, fruit preference, harvesting, postharvest management, and avocado use, which varied by age, education, and ethnicity. The study found that both seedling and grafted avocados were grown in Ethiopia, with the majority of avocado producers growing seedling type of avocados. Farmers have accumulated experience from growing seedlings for the past 50 years or more. In the study areas, the proportion of male farmers (86.1%) who were engaged in the avocado growing system was significantly higher than that of female farmers ($\chi^2 = 153.79$, $df = 1$, $p < 0.001$). Surprisingly, most smallholder farmers (96.3%) in the study areas did not use modern farming techniques for seedlings cultivation due to a lack of knowledge. Therefore, it is recommended that to increase productivity, farmers should be trained in field spacing, compost or fertilizer use, crop management, and processing technologies for avocado, considering individual factors such as sex, age, and educational status.

Furthermore, farmers are familiar with the characteristics, nature, harvest time, quality, and end uses of avocado fruit. This study identified the seven important fruit quality traits that farmers or consumers considered during the purchase or consumption of avocados, including fruit size, fruit skin color, fruit shape, skin texture, taste, pliability, and seed size. In the current study, the majority (89.1%) of respondents reported that the most preferred color, shape, and taste among the consumers or buyers

were black, pyriform, and buttery, respectively. Thus, the findings from this study provide insightful information to better characterize such traits for future breeding programs of avocados.

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Author contributions
HD conceptualized the study. BS designed the study, collected and analyzed the data, and wrote the initial manuscript under the guidance of HD and YR. HD and YR reviewed and edited the manuscript. All the authors have read and approved the final manuscript.

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Availability of data and materials
All data collected for this study were analyzed, interpreted, and included in this manuscript, but other datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Before collecting data, the researchers received the support letters from Hawassa University, and then verbal agreement was obtained from the local leaders to make informed decisions on whether or not to participate in the study prior to administering the interview and discussions. Oral consent was obtained from participants after the purpose and benefits of the research were briefly explained in the local languages and the confidentiality of the data was assured. The data would be used only for the purpose of the study and never transferred to another body for commercial interest.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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