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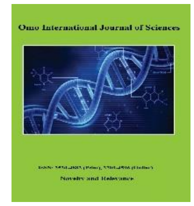

Research Article

Enhancing environmental sustainability and income diversification through agroforestry practices in the Dollo Watershed, Kamba Zuria District, Southern Ethiopia

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Abstract

This study evaluated the contributions of agroforestry to community welfare and environmental health in targeted regions. Data were collected from 231 farm households across five villages using close-ended and open-ended questionnaires, complemented by focus group discussions with community leaders male and female heads of households, and farmers with various experience levels. A relative scoring method was employed to rank preferred woody species, with results indicating that 90% of participating farmers integrated agroforestry with monocropping, while only 9% practiced non-agroforestry agricultural activities. Among the 32 most preferred tree species identified for agroforestry, 79% were native and 21% were exotic. The findings revealed that 91% of respondents viewed agroforestry as their primary source of income while the 9% relied on non-agroforestry agricultural activities. Furthermore, 51% of households believed that agroforestry enhances biodiversity compared to monoculture, and 66.67% recognized increased crop output as its main advantage. However, as data collection was confined to a specific timeframe, seasonal variations in agroforestry systems and income generation were not fully captured. This underscores the necessity for innovative extension services and proactive engagement from governmental and non- governmental organizations to enhance the role of agroforestry in improving rural livelihoods and the environment.

Keyword: Carbon sequestration; Community; Environmental sustainably; Income; Soil improvement

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1. Introduction

Ethiopia's economy is based on agriculture, which provides employment opportunities for 85% of the population, accounts for approximately 90% of exports, supplies over 90% of the raw materials for agro-industries, and generates 33.88% of the country's GDP (Zenebe et al., 2011). However, ensuring food security for the Ethiopians is becoming a big challenge, as a result of the rapid population growth, rapid urbanization, negative consequences of climate change, increasing demand for agriculture and forest products and civil conflict (Yigezu, 2021). At a rate of 2.5 percent per year, Ethiopia's population is expected to reach 171.8 million by 2050 (Bekele and Lakew, 2014). The demand for livestock and agricultural products will rise as a result (Hemathilake and Gunathilake, 2022). Adopting agroforestry techniques is crucial to reducing them. Many current and upcoming environmental issues may be resolved with the help of agroforestry, a traditional land use system (Pantera et al., 2021). The intentional integration of a woody component with an agricultural output in the lower story is part of the sustainable land management practice known as agroforestry (Damianidis et al., 2021).

In recent years, agroforestry has gained recognition as a crucial practice for promoting environmental sustainability and enhancing community livelihoods, particularly in regions such as Ethiopia. Empirical evidence confirms that agroforestry adoption supports to the farming income by generating an assured income for the local community (Rosati et al., 2020; Tesfay, 2024). Study carried out by Mulugeta and Mabrate (2017) Gedeo's indigenous agroforestry practices provided 40% of Ethiopia's premium grade coffee. Current studies of Bussa and Feleke, (2020) result revealed that increased income source and food security values of agroforestry practices for farmers had positive impression on their living standard.

The addition to the understanding of how agroforestry methods will become a conduit for sustainable agricultural land management, environmental benefit, and as such, help link science to practice, is what makes this special issue novel. According to Mosquera-Losada et al. (2020), agroforestry is a way to meet the European and global biodiversity targets while addressing the world's biodiversity problems. An extremely promising technique for Mediterranean regions with traditional olive agroforestry systems is the work of Mantzanas et al. (2021), which advances our understanding of intercropping perennial trees with species of cereal crops. According to Bateni et al. (2021), agroforestry has the potential to restore and improve soil health while reversing the effects of climate change in a variety of ways. One of the most important resources for the wellbeing of natural and agro-ecosystems is undoubtedly healthy soil, which allows them to continue producing food and providing ecosystem services.

Agroforestry promotes eco-intensification based on a more effective use of the land resources while offering a variety of provisioning, regulating, cultural, and supporting ecosystem services and environmental advantages. The impact of agroforestry on the environment in general and on climate change, carbon sequestration, and forest fires in particular, however, has not received much attention in recent years. Several articles that discuss the various environmental advantages that agroforestry offers are included in this special edition. This special issue's addition to our understanding of how agroforestry methods will become a means of managing agricultural land sustainably and the multifaceted benefits that agroforestry offers to the environment and people in the study region is what makes it distinctive. Although agroforestry's potential advantages are becoming more widely acknowledged, there isn't much thorough research that focuses on the Dollo Watershed and its particular environmental and socioeconomic circumstances.

2. Materials and Methods

2.1. Study setting

The Dollo watershed in Southern Ethiopia's Kamba Zuria area served as the study's site. The watershed under study is located between 39° 37" E and 9° 41" N. 607 kilometers southwest of Addis Ababa, the capital. The watershed is a portion of Ethiopia's Gamo highlands, which are part of the Omo basin. The elevation and topography of the watershed vary greatly, ranging from 1647 to 2180 meters above sea level. The region experiences 19.7 °C of annual average temperature and 1470 mm of yearly average precipitation. The farming system is reliant on rainfall.

2.2. Sample size determination and sampling technique

A household sample size was determined (Eq. 1) based on Yamane developed method (Yemane, 1967).

$$n = \frac{N}{1+N(e^2)} = 547/6.47 = \mathbf{231} \qquad (1)$$

Where, N is total household, n is number of sample size and 'e' is precision level for this case 5%. Systematic random sampling was used for selecting the participants from the total households as the total list of households was available.

2.3. Data collections

Data were collected from January 2022 to April 2023. Primary data for the study were collected using close-ended and open-ended questionnaire. The watershed had a total population of 547 household farmers of which 231 were selected systematically from household. Household socio- economic characteristics, farmers' species preferences, and agroforestry contribution to income diversification and environmental benefit were collected through questionnaire, focus group discussion and key informant interviews.

2.3.1. Key informant interviews

Key informant interviews were conducted to get their opinions on how agroforestry contributes to household income diversification. Key informants include agriculture development agents, elders, young farmers, model farmers, and the head of the kebele government. Forty key informants were chosen for interviews from five villages.

2.3.2. Focus group discussions

Members of the kebele administration were chosen at random to participate in two focus groups. Gender group separation gave both men and women an equal chance to express and verify their views on how agroforestry contributes to household income diversification. Every interviewee was made aware of the goals, topics, and rationale behind the study. Their involvement was entirely voluntary. Discussions and communication between researchers and respondents were made easier by the participation of local agricultural development agents and kebele managers. The duration of each focus group session was one hour.

2.3.3. Questionnaire

The data were collected using a standard close-ended and open-ended questionnaire administered through face-to-face interviews. This questionnaire was filled for the same rural respondents who adopted agroforestry activities.

2.4. Data analysis

The data collected from the survey were first checked for completeness. The quantitative data was analyzed through descriptive statistical analysis such as frequency, mean and percentage. The qualitative data were summarized by using narrative analyses. Simple majority/Relative score was used to calculate species preference in the study area.

3. Results and Discussion

3.1. Socio-economic characteristics of the household

During household surveys, data on age, family size, land holding size, and educational status were collected. The mean age of the respondents was between 25 and 35 years. Most respondents were males (84.5%), and the majority of the respondents (77.38%) were married. Most of the respondents (62%) had undergone formal education, with the majority (23.81%) having completed primary education, few (21.43%) had attended secondary education. Majority of the respondents (66.67%) had land size between 0 and 0.5 hector (Table 1).

3.2. Agroforestry practice

According to the survey on agroforestry practices, the majority (95.2%) of the population engaged in home gardens, followed by parkland (64.3%), woodlots (60.7%), and grazing systems (36.9%), respectively (Figure 1).These findings are consistent with Berihanu et al. (2020), who found that in northern Ethiopia, parkland agroforestry (90%) was practiced alongside woodlots

(7%), home gardens (3%), and other land uses. The majority of the crops integrated with multipurpose trees, included *Zea mays* (maize) and *Eragrostis teff* (teff). Key informants explained that home garden agroforestry practices are the most dominant in the study area since they are simple to manage. Similarly, key informants raised that parkland agroforestry is next highly adopted practice because of providing extra yield and services to human and animals.

Table 1. Socio-demographic characteristics of the households

Households data	Variables	Frequency	Percentage
Sex	Male	195	84.5
	Female	36	15.5
Family size	4	44	19.04
	5	50	21.43
	6	41	17.85
	7	36	15.47
	8	22	9.52
	9	25	10.71
	10	14	5.95
Age	Below 25	52	22.62
	Between 25-35	83	35.73
	Between 35-45	55	23.8
	Above 45	41	17.85
Marital status	Single	25	11.92
	Married	179	77.38
	Divorce	11	4.76
	Widowed	17	7.14
Land holding size (hector)	Below 0.5	154	66.67
	Between 0.5-0.1	52	22.62
	Between 1-1.5	17	7.14
	Above 1.5	8	3.57
Educational status	Not read and write	88	38.09
	Read and write	39	16.67
	1-8th grade	55	23.81
	8-12th grade	50	21.43

3.3. Species preference among farmers

A total of 32 different tree species were identified as suitable candidates for agroforestry, with 21% categorized as exotic species and 79% classified as native species. From highest to lowest, these were the top 10 that a significant percentage of farmers preferred: *Persea americana* (93%), *Coffee arabica* (87%), *Cordia africana* (83%), *Croton macrostachyus* (73%), *Combretum molle* (57%), *Casuarina equisetifolia* (45%), *Olea africana* (43%), *Terminalia brownii* (39%), *Eucalyptus globulus* (38%) and *Eucalyptus grandis* (38%) from highest to lowest (Figure 2). This study is consistent with studies of Alao and Shuaibu, (2013) and Adewusi, (2006), which showed that fruit trees both native and exotic are the most preferred. This suggests that food is considered the most important resource, and the fire wood species are also the second critical resources for human existence.

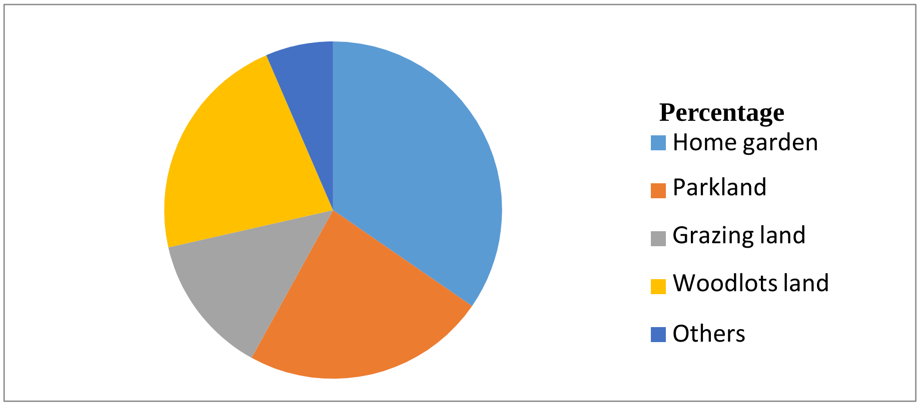

Figure 1. The dominant agroforestry practices in the study area

The results of the study also align with those of Nkurikiye et al. (2024), who discovered that farmers preferred growing trees that increase maize yields through agroforestry. Calliandra calothyrsus, Gliricidia sepium, and Senna spectabilis are being researched for their capacity to preserve natural resources, protect the environment, and yield excellent fuel wood in addition to their contribution to agricultural production (Kuyah et al., 2020). These findings also aligned with those of Tazebew and Asfaw (2018), who discovered that, in the context of coffee-focused agroforestry methods, farmers' decisions to plant native multipurpose trees on their properties influence the species' ecological and economic value.

A relative score was used to determine the preference rating for woody species. Among the species they plant and maintain, respondents were asked to rank the top nine woody species from most preferred to list preferred. The following woody-species were preferred in order of significance: *Persea americana* (93%), *Coffee arabica* (87%), *Cordia africana* (83%), *Croton macrostachyus* (73%), *Combretum molle* (57%). Their preference was were ordered based the species ability to serve multiple purposes, such as providing food, generating income, providing firewood, being used as building materials, serving to shed from sunlight, providing fodder, and enhancing soil fertility (Table 2). Woody plants, both native and alien, are valuable assets on farms because of their significance to farmers' daily life. In the study area, *Cordia africana* and *Terminalia brownii* were the first and second species to integrate with crops. For example, species of trees that benefit agricultural crops, such as *Cordia africana* and *Terminalia brownii*, are planted widely throughout agriculture fields, but species of trees that compete with crops are planted individually to lessen their impact. Farmers set a variety of requirements for integrating trees on farmlands, such as the trees' ability to decompose quickly, their compatibility with crops, their multipurpose use value, their ability to promote soil fertility, and their low branch volume. In the Lemo district of Southern Ethiopia, similar results were observed in crop livestock tree mixed systems (Kuria et al., 2014).

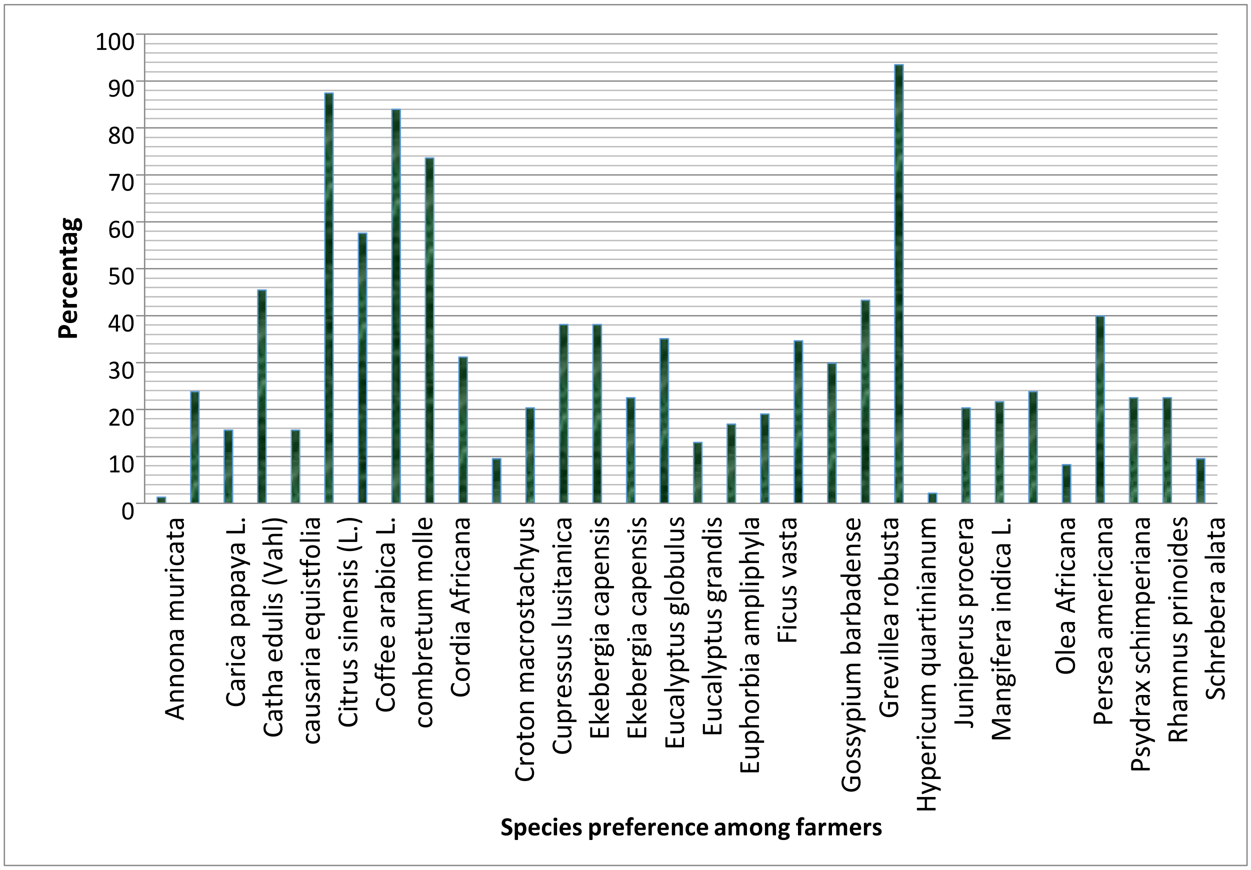

Figure 2. Species preference among farmers in the study area

The tree species found on grazing forms of agroforestry are incredibly large and dispersed, according to information from key informants. Based on information from key informants, field observations, and household interviews, the common tree species found in grazing land are Terminalia schimperiana, Cordia Africana, Terminalia brownii, Ficus vasta, Croton macrostachyus, and Terminalia laxiflora. According to data acquired from interviews with households, the types of trees recognized in agroforestry woodlots are large and densely populated. According to field observation and home interviews, the common tree species in woodlot agroforestry types are Cupressus lusitanica, Eucalyptus grandis, Eucalyptus globulus, Combretum molle, Terminalia brownii, and Croton macrostachyus. Agroforestry tree species that are found in woodlots are also listed.

Table 2. Respondents' species preference ranking according to their benefit in the study area

Species Scientific name	Respondents					Relative score					Total score	Rank	Reason of preference
	1st	2nd	3rd	4th	5th	1st	2nd	3rd	4th	5th			
Persea americana	143	55	30	25	-	88.5	13.1	3.9	2.7	-	108.2	1st	2, 1 and 5
Coffee arabica	55	55	25	74	14	13.1	13.1	2.7	23.7	0.85	53.65	2nd	2,5 and 7
Cordia Africana	-	83	22	14	-	-	29.8	2.1	0.85	-	32.75	3rd	2, 3 and 4
Croton macrostachyus	-	8	17	25	80	-	0.28	1.25	2.71	27.71	31.95	4th	2, 3, 4 and 7
combretum molle	11	-	83	14	3	0.52	-	29.8	0.85	0.04	31.21	5th	2, 4, 5 and 7
causaria equistfolia	-	8	28	22	28	-	0.28	3.39	2.09	3.39	9.15	6th	3, 4, 6 and 7
Olea Africana	22	14	11	11	-	2.1	0.85	0.52	0.52	-	3.99	7th	7, 2 and 1
terminalia brownie	-	-	-	22	3	-	-	-	2.09	0.04	2.13	8th	5 and 7
Eucalyptus globulus	-	-	6	8	-	-	-	0.16	0.28	-	0.44	9th	3 and 4
Total	231	223	222	215	128								

Footnote: relative score was calculated by multiplying the number of respondents in each ranks by its proportion (e.g. 143*143/231=88.52). Reason of preference, 1= food, 2=income generation, 3= fire wood, 4= construction materials, 5= shade benefit, 6= animal fodder 7= soil fertility improvement

(n=231)

The results of FGD, key informant interviews, and household surveys indicate that farmers' choices for particular species rely on the significance of those species within each type of agroforestry practice and how those components interact with one another. This conclusion is consistent with that of López-Sampson and Andrade (2024), who found that farmers placed a high value on animal temperature regulation and that providing environmental services can make agroforestry species more appealing. Furthermore, the findings of Hailu *et al*. (2024) investigation showed that farmers' choices for woody species differed across the nation and that they planted various woody species according to their respective advantages.

3.5. Role of agroforestry to livelihoods diversification

The farmers in the study area generate household income from both agroforestry and monoculture farms. Out of the farmers surveyed, 90% practice both agroforestry and monocropping. Meanwhile, 9% of the farmers engage in non-agroforestry farming activities, and the remaining 1% is involved in non-agricultural pursuits. Additionally, 91% of households reported that their primary source of income comes from agroforestry operations, while 9% indicated that their main source of income stems from non-agroforestry farming activities. These indicate that the agroforestry significantly increases farm income compared to non-agroforestry farm activities.

Table 3. Preferred tree species for different types of agroforestry in the Dollo watershed

Species scientific name	Home garden	Parkland	Grazing land	Woodlots	Percentage
Annona muricata	2	-	-	-	0.21645
Carica papaya	70	-	-	-	30.303
Catha edulis	12	-	-	-	5.19481
Casuarina equisetifolia	-	50	-	-	21.645
Citrus sinensis	13	-	-	-	5.62771
Coffee Arabica	110	-	-	-	47.619
Combretum molle	-	-	11	21	6.92641
Cordia Africana	0	0	36	23	6.38528
Croton macrostachyus	20	41	43	46	16.2338
Cupressus lusitanica	-	-	-	16	6.92641
Ekebergia capensis	-	12	-	-	5.19481
Eucalyptus globulus	-	-	-	34	14.7186
Eucalyptus grandis	-	-	-	31	13.4199
Euphorbia ampliphyla	-	-	-	19	8.22511
Ficus vasta	-	-	70	-	30.303
Gossypium barbadense	8	-	-	-	3.4632
Grevillea robusta	30	-	-	-	12.987
Hypericum quartinianum	-	-	-	14	6.06061
Juniperus procera	20	-	-	13	7.14286
Mangifera indica	60	23	-	-	17.9654
Olea Africana	-	32	7	-	8.44156
Persea Americana	120	98	-	-	47.1861
Psydrax schimperiana	-	-	-	18	7.79221
Rhamnus prinoides	60	-	-	-	25.974
Schrebera alata	-	-	9	-	3.8961
Syzygium guineense	-	-	-	19	8.22511
Tamaranus indicus	-	8	-	-	3.4632
Terminalia brownie	10	102	30	43	20.0216
Terminalia laxiflora	-	-	17	-	7.35931
Terminalia schimperiana	-	-	12	-	5.19481
Vernonia amygdalina	-	9	-	15	5.19481

Agroforestry can diversify Farmers' income in a number of ways. These include fruits, coffee, fodder crops, fire wood and dairy products. More than 93% of respondents use fruits from home garden agroforestry, such as banana, *Carica papaya*, *Persea americana*, and *Mangifera indica;90% use crops from parkland, such as Zea mays (Maize), Eragrostis teff (teff),* *haricot bean*, and groundnuts; and 88% use woodlots, parkland, and home garden agroforestry for fuel and other wood products for construction. 83 % of the respondents declared that their primary source of income comes from coffee plantations, which are a significant cash crop in the region. 67% of all respondets employed home gardens, parklands, and agroforestry to produce fodder for animals (Figure 3). Fruit was the most popular product harvested from agroforestry trees, demonstrating how dependent farmers were on these items for their primary source of revenue. This outcome was consistent with findings from related studies which looked into the roles of agroforestry in increasing farmers' income (Mabel *et al*., 2017; Tharlakson, 2012; Quinon *et al*., 2010). This outcome was consistent with reports from other academics (Kalaba, 2010; Maroyi, 2009) that said that agroforestry's various productions have enabled people to build sustainable lives.

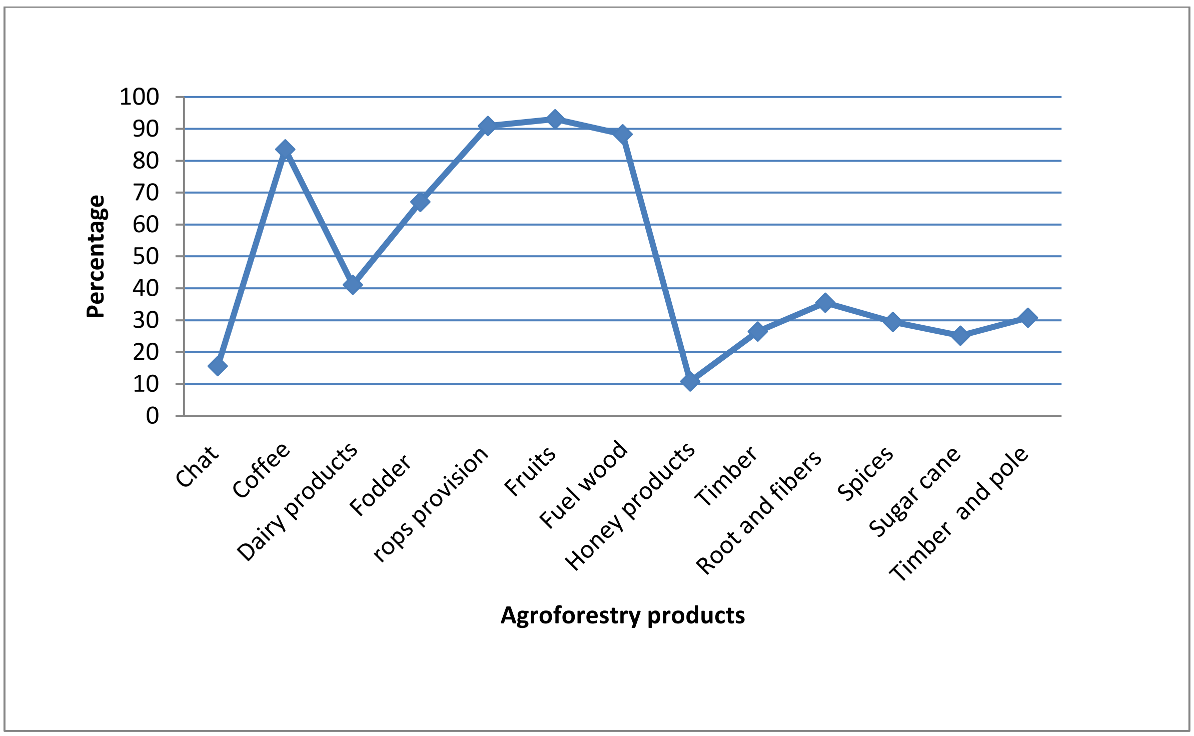

Figure 3. List of products to livelihoods diversification from agroforestry practices

3.6. Role of agroforestry to environmental sustainability

Based on the results of the poll, farmers concur that agroforestry contributes to environmental sustainability by making more nutrients available to the soil, which helps to preserve and restore soil fertility. Out of all the households surveyed, 51% thought that agroforestry offered superior woody biodiversity than mono cropping farming, while 66.67% thought that the main advantage of agroforestry techniques was an increase in crop yield. Out of all the respondents, 46% claimed that agroforestry could improve soil nutrient availability and decrease soil erosion, while 36% claimed that it could provide shade for cattle and control the microclimate (Figure 4). Additionally, by increasing soil organic matter through leaf litter, agroforestry practices improve soil fertility. Traditional land use practices like agroforestry could help find a solution of environmental problems in agriculture (Pantera *et al.*, 2021).

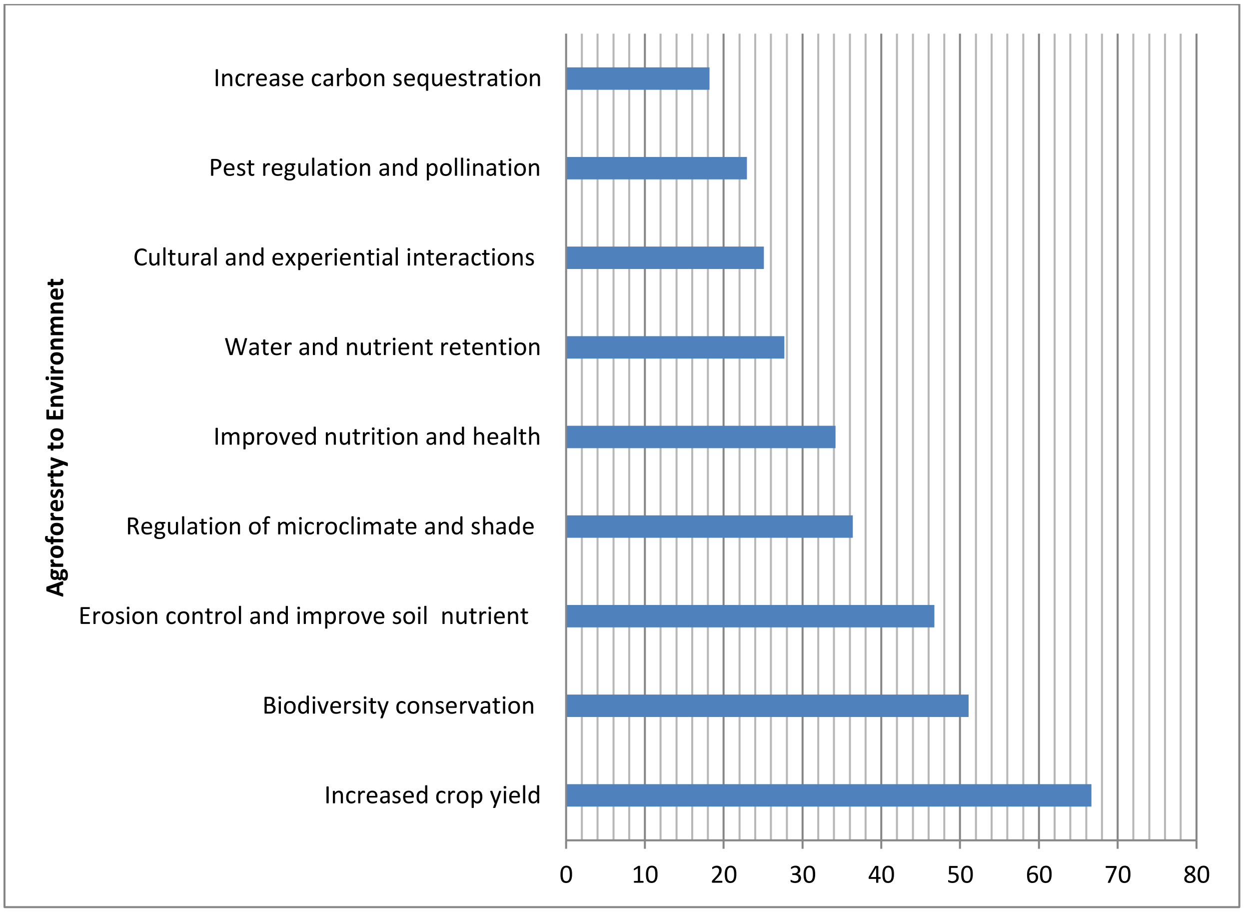

Figure 4. Contribution of agroforestry practices to environmental sustainability

One acknowledged effect of agroforestry practices was increased crop yield. This results from enhanced soil characteristics, microclimate, and nutrient levels (Fahad et al., 2022). The current findings in lined with (Akinnifesi *et al.*, 2006; Castle, 2021), who found that agroforestry techniques can raise crop yields in many regions of the world. Agroforestry in the Umbria area of Italy improved soil health and counteracted the negative impacts of soil erosion in a variety of ways (Bateni *et al.*, 2021; Pantera *et al.*, 2021). This result is consistent with that of Ndalama *et al*. (2015), who found that the primary ecosystem services received from agroforestry were soil improvement, water and nutrient retention and conservation, and biodiversity conservation. Increased agroforestry adoption, according to Khanal (2011), lessens the strain on forests and protected conservation areas. Furthermore, the present findings are consistent with the reviews conducted by Rolo *et al.* (2021) and Rosati *et al.* (2021), which suggested that implementing agroforestry techniques might enhance the sustainability of organic farming and augment soil fertility. Additionally, Tsegaye's (2023) study result shows that agroforestry practices provide protective services such soil improvement, climate regulation, biological conservation, and recreational value in addition to their productive role.

4. Conclusions

The study demonstrates that agroforestry significantly enhances the livelihoods and environmental sustainability of farmers. Practices such as home gardens, parklands, woodlots, and grazing systems are common, with a preference for multipurpose tree species like *Persea americana*, *Coffee arabica*, and *Cordia africana*. Agroforestry contributes to household income through products like fruits, coffee, and firewood, and improves soil quality, crop yields, and reduces soil erosion, aligning with previous research on its benefits for economic stability, biodiversity, and environmental resilience. To maximize agroforestry benefits, further research on species selection, management practices, and innovations is encouraged. Knowledge sharing platforms should be established to disseminate best practices. Integrating agroforestry into national and local agricultural policies can promote food security and income generation, especially in rural areas, through technical support, subsidies, and incentives. Agroforestry is vital for sustainable land management, enhancing soil fertility, and reducing soil erosion. It supports biodiversity conservation by promoting native, multipurpose species, contributing to ecosystem resilience. By providing diverse income sources, agroforestry reduces dependency on single crops and enhances resilience to market fluctuations and climate change, mitigating its impacts through improved soil health and carbon sequestration. Policymakers should consider agroforestry in climate adaptation and mitigation strategies, particularly in vulnerable regions.

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Conflict of Interest

The authors declare no conflict of interest.

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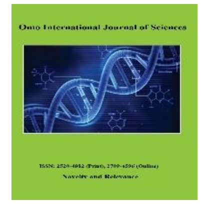

Research Article

Molecular investigation of *Enterocytozoon bieneusi* in calves in Oromia special zone, Central Ethiopia

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Abstract

Enterocytozoon bieneusi, the most frequently diagnosed microsporidian species in humans, is also identified in a wide range of animals. The aim of this study, therefore, was to determine the prevalence and genotypes of *E. bieneusi* in calves and to assess its public health implications in Central Ethiopia. A total of 449 fecal samples were examined by a nested PCR targeting the internal transcribed spacer (ITS) of the rRNA gene. All positive PCR products were sequenced to determine the genotypes. *Enterocytozoon bieneusi* was found in 7.1% (32/449) of the calves. Difference in the infection rate was statistically significant ($P < 0.05$) among age groups. Out of the 10 ITS genotypes, nine belonging to the known genotypes BEB8, BEB4, BEB17, I, KIN-1, Peru11, PigEBITS5, H, and ET-L2; and one novel genotype (named as ET-C1) were identified. Four of the genotypes (KIN-1, Peru11, PigEBITS5, and H) were clustered to a member of a major phylogenetic group with zoonotic potential. This study constituted the first molecular characterization of *E. bieneusi* in Ethiopia, and it suggested a potential risk of zoonotic transmission. Studies in humans and further studies in animals are necessary to assess the public health significance of *E. bieneusi*.

Keywords: *Enterocytozoon bieneusi; G*enotypes; Internal transcribed spacer; Nested PCR

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1. Introduction

Microsporidia are obligate intracellular parasites with worldwide distribution in humans and major groups of animals (Santin and Fayer, 2011). Among the seventeen microsporidian species infecting humans, *Enterocytozoon bieneusi* is the most frequently diagnosed species in humans. It has also been reported in a variety of wild, farm, and companion mammals and in birds (Santín and Fayer, 2011; Li et al., 2019a; Li et al., 2019b). *E. bieneusi* primarily infects the enterocytes of the small intestine and it is mainly associated with chronic diarrhea and wasting syndrome (Desportes et al., 1985; Matos et al., 2012). Enormous genetic diversity within *E. bieneusi* has been observed based on sequence polymorphism in the internal transcribed spacer (ITS) of rRNA (Santin and Fayer, 2009; Santin and Fayer, 2011) that reported ~500 ITS genotypes of the parasite in humans, animals and environment (Gui et al., 2020; Tao et al., 2020; Karim et al., 2020). Phylogenetic analysis of the ITS genotype sequences revealed the presence of eleven genotypic groups (Li et al., 2019a; Li et al., 2019b). A large cluster of genetically linked ITS genotypes named Group 1 are frequently found in both humans and animals, and they are considered to be zoonotic (Li et al., 2019b). Group 2, consisting of mainly ruminant specific genotypes (Thellier and Breton, 2008), also contains some genotypes that occur both in humans and animals having zoonotic potential. The remaining genotypes represent largely host-adapted groups (Groups 3 to 11) associated with specific animals and probably have no significant public health importance (Li et al., 2019b).

Except few works in humans and sheep using microscopy and Polymerase Chain Reaction (PCR), *E. bienusi* has not been studied and characterized in calves in Ethiopia (Adamu et al., 2005; Endeshaw et al., 2006; Wegayehu et al., 2020). As a result, the aim of this study was to determine the prevalence of *E. bieneusi* and the circulating genotypes in calves in Oromia Special Zone, Central Ethiopia with a perspose of assessing the public health potential.

2. Materials and Methods

2.1. Study area

This study was conducted in Oromia Special Zone, Central Ethiopia. The Special Zone has an estimated total area of 4,800 km2 which accounts for 1.5% of the total area of the Oromia Regional State. The zone borders with Eastern Shewa zone in the east, North Shewa zone in the North East and South-west Shewa Zone in the South West. The mean annual temperature of the Zone is between 20-25 ºc in the low lands and 10-15 ºc in the central high lands. Based on the available meteorological data, the mean annual rainfall varies from 700mms to 1400mms in low lands and high lands, respectively. The Special Zone has six districts and eight major towns of which, this study included Holeta, Sendafa and Chancho areas because of the high population of cattle and sheep (Figure 1).

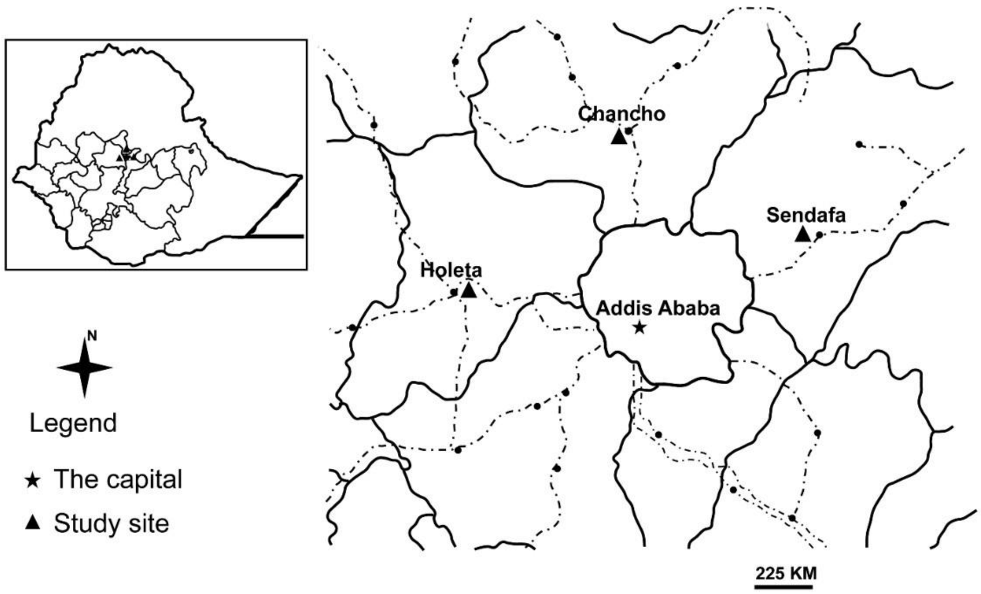

Figure 1. Locations of the study area in Oromia special zone, Central Ethiopia. The special zone has six districts and eight major towns of which, this study included Holeta, Sendafa and Chancho areas because of the high population of cattle (Adapted from Wegayehu et al., 2020).

2.2. Study design and period

A community-based cross-sectional study was conducted between January and June 2014 to evaluate the circulating genotypes of *E. bieneusi* in calves in Oromia Special Zone, Central Ethiopia.

2.3. Sample Population and Sampling

Calves younger than three months were the study population. The owners of these animals who consent to allow us to take fecal samples from their animals were included in this study. A total of 449 fresh fecal samples were collected from calves in separate and labeled stool containers. The samples were taken directly from the rectum of each animal or immediately after defecation using sterile disposable gloves. Identification number, animal species, age and sex were recorded during sample collection. The samples were preserved in 2.5% potassium dichromate solution, transported to Parasitology Laboratory of Aklilu Lemma Institute of Pathobiology in icebox and stored at 4°C before deoxyribonucleic acid (DNA) extraction.

2.4. DNA extraction

The preserved fecal samples were washed with deionized water until the potassium dichromate was removed. Genomic DNA was extracted from each fecal sample using the E.Z.N.A.® Stool DNA kit (Omega Biotek Inc., Norcross, USA). Briefly, about 50-100 mg of fecal sample was added in a 2ml centrifuge tube containing 200 mg of glass beads and placed on ice. Following, 300µl buffer SP1 and proteinase K were added and incubated at 70ºC for 10 minutes. Subsequently, all the procedures outlined in the product manual were performed according to the manufacturer's protocol. Finally, DNA was eluted in 200 µL of elution buffer and the extract was stored at -20°C until used in PCR.

2.5. PCR and sequence analysis

A nested PCR targeting the internal transcribed spacer (ITS) region of the rRNA gene was used to detect *E. bieneusi* (Sulaiman et al., 2003). The PCR was performed in 25µl reaction volume that includes 23µl mixes and 2µl DNA template. The PCR amplifications were performed with rTaq DNA polymerase (Takara Bio Inc, Shiga, Japan) in Applied Biosystems Thermal Cycler version 2.09. The primary PCR program was involved enzyme activation at 94ºC for 5 minutes, followed by denaturation at 94ºC for 30 seconds, annealing at 57ºC for 30 seconds and primer extension at 72ºC for 40 seconds for 35 cycles. A seven- minute final extension at 72ºC was done after 35 cycles followed by cooling at 4ºC. The second PCR was run under the same conditions as the first except the annealing temperature which was reduced from 57ºC to 55ºC for 30 seconds; and the cycle which was again reduced from 35 to 30 cycles. To validate the PCR amplification, positive and negative controls were included in each batch of PCR. The amplified products were separated by electrophoresis on 1% agarose gel and visualized under a trans- illuminator after staining with ethidiumbromide. The PCR was conducted in International Joint Research Laboratory for Zoonotic Diseases at Henan Agricultural University, China.

The secondary PCR products were purified using Montage PCR filters (Millipore, Bedford, MA) and sequenced using an ABI BigDye Terminator v. 3.1 cycle sequencing kit (Applied Biosystems, Foster City, CA) on an ABI 3100 automated sequencer (Applied Biosystems). The nucleotide sequences obtained were aligned with reference *E. bieneusi* sequences using ClustalX software (ftp://ftp-igbmc.u-strasbg.fr/pub/ClustalX/). The genotype determination was based on polymorphism in 243 bp ITS region of the rRNA gene as previously proposed (Santín and Fayer, 2009). The established and reputable nomenclature system was used in naming *E. bieneusi* ITS genotypes. Bayesian inference (BI) and Monte Carlo Markov chain methods were used to construct the phylogenetic trees in MrBayes program (version 3.2.6). The posterior probability values were calculated by running 1,000,000 generations. A 50% majority rule consensus tree was constructed from the final 75% of the trees generated via BI. Analyses were run three times to ensure convergence and intensity to priors. The representative nucleotide sequences of the ten *E. bieneusi* ITS genotypes obtained in the present study were deposited in the GenBank database under the accession numbers: KT922241.

2.6. Ethical Considerations

Ethical clearance was obtained from the National Health Research Ethics Review Committee, Ministry of Science and Technology. Support letters were obtained from concerned health and agricultural offices and administrative authorities at the community level. The objectives of the project were explained to the owners of the animals and informed consent was obtained before inclusion to the study.

2.7. Data Analysis

Data were entered using EpiData version 3.1 and transferred to STATA Software for analysis. Chi square test was used to verify the possible association of *E. bieneusi* infections in different study groups. Values were considered to be statistically significant when the P-value was less than 0.05.

3. Results and Discussion

3.1. *E. bieneusi* infection in calves

Of the 449 fecal samples investigated by the nested PCR at ITS region (392 bp) of the rRNA gene, *E. bieneusi* was found in 32 (7.1%) calves' fecal samples (Table 1). The prevalence of *E. bieneusi* varied across the study areas. A relatively higher prevalence of 8.5% (13/153) was found in Holeta followed by 7.5% (9/120) in Chancho and 5.7% (10/176) in Sendafa. The prevalence showed statistically no significant difference (P = 0.602) among study sites (Table 1).

To investigate the distribution of *E. bieneusi* among calves in relation to sex, age and breed groups, data were arranged and summarized in Table 1. The prevalence of *E. bieneusi* was 7.0% (14/200) and 7.2% (18/249) in male and female calves, respectively. The difference in the prevalence of *E. bieneusi* infection was not statistically significant between male and female calves. There was an age-associated difference in the occurrence of *E. bieneusi* infections. Calves less than 5 weeks had the highest infection rate of *E. bieneusi* (12.0%, 15/125), followed by those of 5-8 weeks (6.6%, 8/121), and greater than 8 weeks (4.43%, 9/203). The age-associated difference in *E. bieneusi* infection rates was statistically significant (P = 0.034) among different age groups (Table 1). Likewise, the infection rate of *E. bieneusi* in the exotic breed (10.9%) was higher than that of the local calves (3.5%) and the difference was statistically significant (P = 0.002) (Table 1).

Table 1**.** Prevalence of *E. bieneusi* in calves by study area, sex, age and breed in Oromia Special Zone, Central Ethiopia

Demographic characteristics	No. of samples examined	No. of samples positives %)	$\chi 2$	P-value	Genotypes (no. of isolates)
Study areas					
Holeta	153	13 (8.5)	1.0143	0.602	BEB8 (6), I (2), BEB4 (1), BEB17 (1), H (1), Peru11 (1), ET-C1 (1)
Sendafa	176	10 (5.7)			BEB8 (7), BEB4 (1), KIN-1 (1), PigEBITS5 (1)
Chancho	120	9 (7.5)			BEB8 (5), I (2), BEB17 (1), ET-L2 (1)
Sex					
Male	200	14 (7.0)	0.0088	0.925	BEB8 (10), I (1), PigEBITS5 (1), Peru11 (1), ET-L2 (1)
Female	249	18 (7.2)			BEB8 (8), I (3), BEB4 (2), BEB17 (2), KIN-1 (1), H (1), ET-C1 (1)
Age group					
< 5 weeks	125	15 (12.0)	6.758	0.034*	BEB8 (9), KIN-1 (1), H (1), Peru11 (1), ET-C1 (1), ET-L2 (1)
5-8weeks	121	8 (6.6)			BEB8 (5), I (3), BEB17 (1), PigEBITS5 (1)
> 8weeks	203	9 (4.4)			BEB8 (4), I (1), BEB4 (2), BEB17 (1)
Breed group					
Local	229	8 (3.5)	9.322	0.002*	BEB8 (5), I (1), ET-C1 (1), KIN-1 (1)
Exotic breed	220	24 (10.9)			BEB8 (13), I (3), BEB4 (2), BEB17 (2), H (1), PigEBITS5 (1), Peru11 (1), ET-L2 (1)
Total	449	32 (7.13)			BEB8 (18), I (4), BEB4 (2), BEB17 (2), KIN-1 (1), H (1), PigEBITS5 (1), Peru11 (1), ET-C1 (1), ET-L2 (1)

$\chi 2$ and P- values compare the prevalence among study areas, male and female, age and breed groups in calves
* Represent statistically significant difference (P < 0.05).

3.2. Genotype of *E. bieneusi*

The sequence analysis revealed the presence of ten different genotypes in calves (Table 2). Among these genotypes, BEB8, BEB4, BEB17, I, KIN-1, Peru11, PigEBITS5, H and ET-L2 were previously described in cattle, humans, macaques, swine and sheep. One new genotype, named ET-C1 was identified for the first time from Ethiopia. It had a 99% sequence similarity to genotype J (Genbank accession number JF776170). Among the genotypes, BEB8 was the most prevalent genotype being detected in 18 (56.3%) isolates followed by genotype I in 4

(12.5%) isolates, and BEB4 and BEB17 each in 2 (6.3%) isolates. The other genotypes KIN-1, H, PigEBITS5, Peru11, ET-C1 and ET-L2 were identified in 1 (3.12%) isolate each.

Table 2. Distribution the genotype of *E. bieneusi* in calves in Oromia special zone, Central Ethiopia

Study areas	Positive samples (Number & %)	Genotypes (Number of isolates)
Holeta	13 (8.5)	BEB8 (6), I (2), BEB4 (1), BEB17 (1), H (1), Peru11 (1), ET-C1 (1)
Sendafa	10 (5.7)	BEB8 (7), BEB4 (1), KIN-1 (1), PigEBITS5 (1)
Chancho	9 (7.5)	BEB8 (5), I (2), BEB17 (1), ET-L2 (1)

3.3. Phylogenetic analysis

The phylogenetic tree was constructed to demonstrate the genetic relationship of previously described genotypes and the new genotypes recorded. Four known genotypes (Peru11, KIN-1, H and PigEBITS5) verified from calves were clustered to the members of a major phylogenetic group with zoonotic potential (Group 1). The remaining five known genotypes (BEB8, BEB4, BEB17, I and ET-L2) and the new genotype ET-C1 identified in this study from claves were placed in the cluster with genotypes that were most commonly isolated from cattle (Figure 2).

4. Discussion

The results of the present study showed that *E. bieneusi* is a common enteric parasite in claves in the study area. The prevalence of *E. bieneusi* infection in calves (7.1%) in the present study was lower than 18.0% prevalence found in calves in South Africa (Samra et al., 2012) and most published studies conducted elsewhere in dairy cattle (Wang et al., 2019; Zhang et al., 2019; Tao et al., 2020). Although a significant difference was not recorded among the study areas, *E. bieneusi* infection was slightly higher in Holeta site than the other study areas among calves (8.5%). The possible reason for the absence of statistically significant difference among the three study areas is that, in addition to the similarity in environmental conditions, there are relatively similar animal management systems. The prevalence of *E. bineusi* varied with the age of the calves. The lower age group, especially less than 5 weeks, had a significantly higher prevalence of infection than the other age groups. This contrasts with a longitudinal study reported by Santin and Fayer (2009) in dairy cattle in which post-weaned calves had the highest prevalence of infection than the pre-weaned calves. This might be because as the age of cattle increases, immunity might play a role in reducing the burden of *E. bieneusi*. No sex-associated prevalence was observed in the present study in calves.

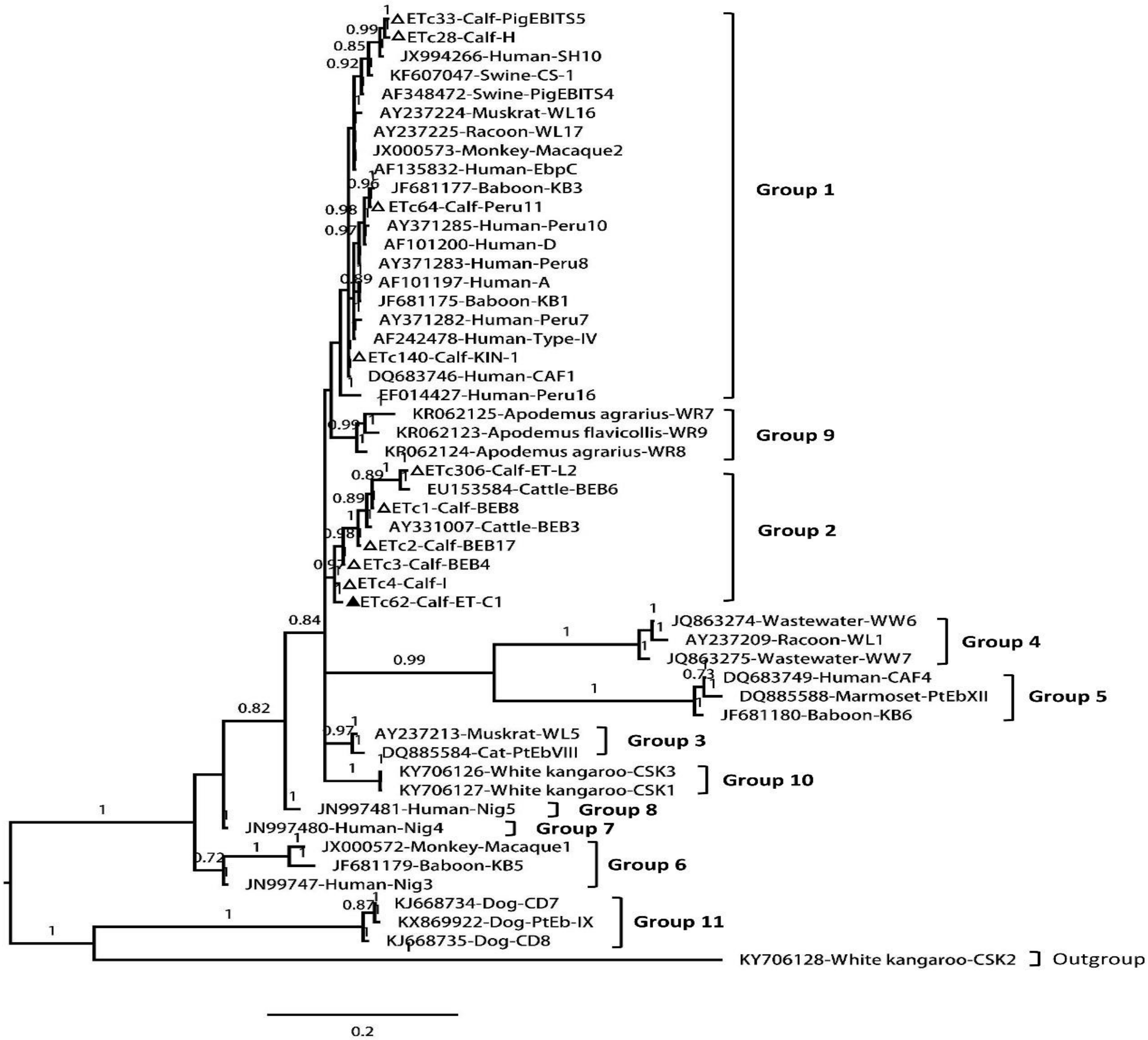

Figure 2. Phylogenetic tree based on Bayesian inference (BI) analysis of the *Enterocytozoon bieneusi* ITS sequences. Statistically significant posterior probabilities are indicated on the branches. Known and novel *E. bieneusi* ITS genotypes identified in the present study are indicated by empty and filled triangles, respectively.

The possible reasons for the absence of sex-related differences in the prevalence among the calves could be explained by lack of sex-related resistance to infection of *E. bineusi*. In this study, a higher prevalence of *E. bieneusi* was detected in exotic breeds than native calves. This might be due to differences in management systems. It might be associated with host immunity that exotic is more susceptible than the native ones. Based on the sequence data from the ITS region, 88% of *E. bieneusi* isolates found in calves in this study appear to be so-called cattle-specific genotypes. This finding is consistent with the situation in South Africa as reported by Samra et al. (2012) where the cattle-specific genotypic infection was 89%. The result was also comparable to previous observations in the Eastern United States where 98% of *E. bieneusi* genotypes were identified as cattle-specific (J, I, BEB3 and BEB4) (Santin et al., 2005). Sulaiman et al. (2004) also found a high proportion (96.5%) of cattle-specific *E. bieneusi* isolates (J, I, BEB3 and -BEB4) from seven states in North America and Portugal. In South Korea, cattle-specific genotypes of *E. bieneusi* were isolated in 90% of the positive animals: CEbA, I, J, and CEbF (with 99% similarity to J) (Lee, 2007). In China also, so-called cattle- specific genotypes have predominantly been detected in cattle fecal samples (Wang et al., 2019; Zhang et al., 2019; Tao et al., 2020). Of the ten genotypes identified in calves in this study, genotype BEB8 was the most prevalent followed by genotype I. However, some of the cattle-specific genotypes, such as BEB4, I, and J have also been reported in other animals and humans, indicating their low host specificity and zoonotic significance (Li et al., 2019b).

The new genotype ET-C1 found in a calf was clustered to a member of genotypes isolated from cattle in Group 2. The genotype differed from genotype J (JF776170) at nucleotide positions 87 (G-to-A substitution) and 188 (G-to-T substitution). *E. bieneusi* has been identified in water sources as well as in wild, domestic, and food-producing farm animals, raising concerns of water-borne, food-borne, and zoonotic transmission. The identification of four common human pathogenic genotypes of *E. bieneusi* (Peru11, KIN-1, H and PigEBITS5) (Li et al., 2019a; Li et al., 2019b) in this study highlights the possible role of calves as a source of environmental contamination with genotypes of zoonotic potential. In addition, the identification of the two most common genotypes of cattle (I and BEB4) (Thellier and Breton, 2008), now found in humans, changes the paradigm from genotypes thought to be cattle-specific to genotypes with zoonotic potential (Li et al., 2019b). This indicates the public health importance of *E. bieneusi*.

5. Conclusion

The results of this study suggest that *E. bieneusi* is prevalent in calves in Central Ethiopia and there is extensive genetic diversity, as was reported in other parts of the world. Although most of the genotypes recorded in this study were found to be cattle- specific, four genotypes were clustered to members of a major phylogenetic group with zoonotic potential. To the best of our knowledge, this constitutes the first molecular characterization of *E. bieneusi* in Ethiopia. Therefore, studies in humans and further studies in animals are necessary using molecular techniques to assess the genetic diversity and the public health significance of *E. bieneusi.*

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Author Contributions

LZ and TW conceived the idea for this study. TW, MRK and JL conducted the experiments and analysed the data. TW, MRK, JL and LZ wrote and revised the manuscript.

Conflict of Interest

The authors declare that they have no conflict of interest.

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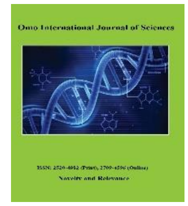

Research Article

Identification, characterization and diversity of cultivated *Ensete ventricosum* landraces in Gamo highlands, South Ethiopia

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Abstract

Enset-based indigenous knowledge and associated agro-ecological niche is often confined within cultural groups of enset growing regions, limiting further expansion of cultivation and development. This study aimed to identify and characterize enset landraces using farmers' knowledge and assess extent of diversity at two of enset growing districts in Gamo zone, South Ethiopia. Six localities encompassing 1530 to 3000 m.a.s.l were sampled at Chencha and Kogota districts. Observations, semi-structured interviews and focus group discussions were employed on 204 households. Names and quantities of enset landraces in the home gardens were recorded at a 10x10 m^2 quadrant laid out per household. Totally, 38 enset landraces were recorded and grouped as processing (kocho, bulla) and cooking (amicho) types on the basis of characteristics described by farmers. These were locally distinguished as 'Wodala Uhthi' or 'Macca' 'Uuthi' in Gamo language. The Shannon index ranged from 2.75 at high altitude of Chencha to 0.75 at low altitude of Kogota suggesting diversity and altitude were directly proportional. The indigenous knowledge associated with enset landraces needs to be enhanced to ensure food security and resilience of the smallholder livelihood. Conservation initiatives such as Dorze Enset Field Gene Bank and around by Arba Minch University are highly encouraged.

Keywords: Amicho; Diversity; Enset; Kocho; Landrace

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1. Introduction

Enset (*Ensete ventricosum, (Welw.) Cheesman)* is an essential food security crop serving over 20 million people in Ethiopia (Zerihun et al., 2013; Dereje, 2012). Indigenous to Ethiopia, enset is predominantly cultivated in the southern and southwestern highlands. The pseudostem and/or corm are processed into kocho and bulla or amicho - the three edible products of enset. Kocho is a fermented starch derived from scrapped leaf sheaths and milled corms. Bulla is a dehydrated product obtained from liquid extracted of the processed leaf sheaths and corm mass before fermentation. Amicho refers to boiled pieces of young enset corm, consumed similarly to other root and tuber crops (Admasu, 2002). Enset grows across various agroecological zones, with product characteristics influenced by different cultivars (Endale *et al.,* 2013; Brandt et al., 1997). Enset thrives best at altitudes between 2000 to 2750 m.a.s.l., 1100-1500 mm of rainfall, 10-21 ºC temperature and a relative humidity of 63-80% (Brandt et al., 1997).

Enset production system lacks standards in agronomic management practices and is affected by biotic constraints, mainly of enset bacterial wilt (Sabura *et al.,* 2021; Zerihun et al., 2017; Admasu and Struik, 2002). On the other hand, Enset is rich in genetic and phenotypic diversity (Tobiaw, 2011; Admasu, 2002) and adapts to wide range of agro-ecologies. Few studies elsewhere indicated evidence of site-specific clone suitability, suggesting strong relationship between enset clone diversity and different growing environments, and farmers' preferences (Zerihun *et al.,* 2013; Endale *et al.,* 2003). However, data is yet scanty on site-specific adaptation of different landraces growing in potential enset belts in Ethiopia. To this end, agro-ecological potentials suitable for production of specific landraces and products are not exploited due to lack of demand oriented agronomic improvement studies in enset.

The various enset landraces possess high production potential and management systems, bolstered by farmers' traditional knowledge (Awol *et al.*, 2014). Farmers and scholars identify and categorize enset in different ways. Melesse *et al.* (2014) reported that farmers identify and categorize enset based on use values such as human and animal medicine. Others classify enset on the basis of different food values such as for bulla, kocho, and fiber (Temesgen et al., 2014). However, use values stated in most literature represent only limited regions and lack detail grouping of the diverse enset landraces in the country (Mengesha et al., 2022; Tesfaye et al., 2023; Zerihun et al., 2012). For example, over 600 enset landraces maintained at Areka field gene bank (Zerihun et al., 2017) have not been fully characterized for the different use values, agronomic and environmental adaptation on the one hand and lack traceable data of their original collection sites, on the other hand.

However, identification of different enset genotypes (or local varieties or landraces) is somewhat complex as most of them are only locally recognized and whose extent of diversity has not been exhaustively assesed and documented over the entire enset growing regions in Ethiopia. The perceived characteristics of different enset genotypes such as maturity, tolerance to biotic and abiotic stresses, yield and product quality by farmers are believed to be influenced by the growing environment and farm management. Those characteristics may vary from region to region and less known to the scientific world as knowledge related to specific landrace is confined to local conditions. This limits further improvement and expansion of its cultivation and utilization across the country and beyond (Koch et al., 2021). Using on-farm observation approach, this study therefore aimed to identify, classify and assess the diversity of enset landraces at two districts of the Gamo highlands, South Ethiopia. This would contribute to the knowledge base required to utilize the full potential of enset landraces and to improve the food security and resilience of enset-dependent farm households, besides conservation of genetic resources for sustainable use. The specific objectives this study were to: (i) identify and document locally recognized enset landraces and characterize them in terms of perceived characteristics and morpho-gronomic features, (ii) classify each enset landraces into specific use value, and (iii) determine on-farm diversity of enset landraces in the study area.

2. Materials and Methods

2.1. Description of the study area

The study was carried out in two of the major enset growing districts of Gamo zone: Chencha Zuria and Kogota. The geographic locations of the two districts are 6°9'30''N- 6°26'00''N latitude and 37° 31'30''E-37°42'30''E longitude (Figure 1). Total population numbers for Chencha and Kogota are 94,149 and 74,258, respectively.

2.2 Sampling strategies

The two districts were stratified into three elevation zones (Figure1): High altitude (>2733 m.a.s.l.), middle altitude (2573-2732 m.a.s.l.) and low altitude (<2572 m.a.s.l.), which represent major enset production belt. Three representative kebeles/localities were selected from each district, each two localities belonging to two districts falling within each of the three-altitude range.

Total household size at each locality was obtained from the list of locality agriculture office. From the total of 2098 households at the six localities, 204 enset farms/respondents were determined for the entire study (Table 1) using sample size determination formula (Yamane, 1967) in Equation 1.

$$n = \frac{N}{1 + N} \text{ x } (e^2) \qquad (1)$$

Where n is number of required samples or enset growing households interviewed, and N = Total number of households of the districts obtained from list of households in each locality agriculture office and 'e' stands for the marginal error, i.e., 0.07 (93% confidence interval).

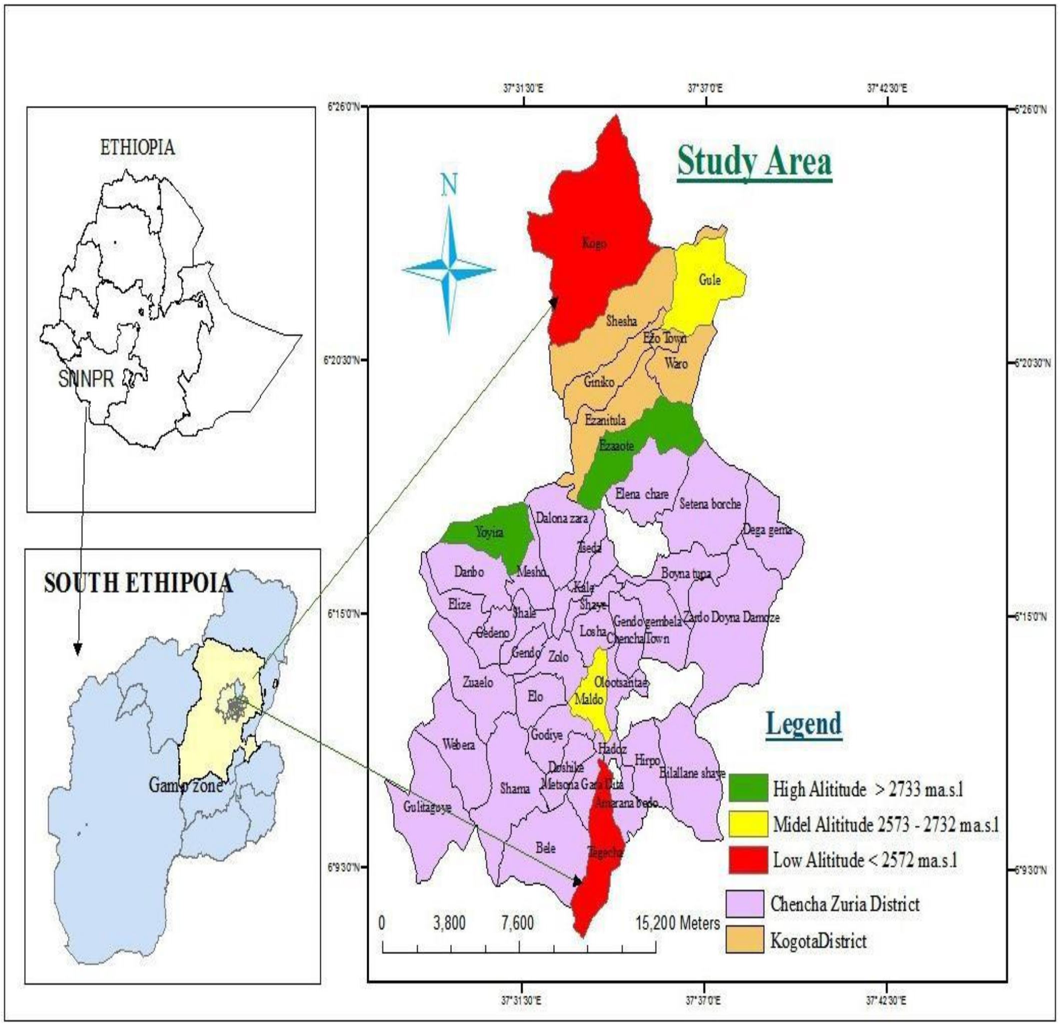

Figure 1. Map of the study area showing selected kebeles from the higher, middle, and lower altitude range

Table 1. Selected localities, altitude ranges and sample size used for the study

District	Kebele/locality	Altitude class	Altitude range (m)	Household size	Sample size
	Yoyira	High	2733-2909	429	44
Chencha	Lakana Maldo	Mid	2573-2597	224	28
	Tegecha	Low	1788-2320	365	30
	Ote	High	2750-3000	350	38
Kogota	Gule	Mid	2620-2732	370	35
	Kogo Ayira	Low	2500-2572	360	29
Total				2098	204

2.3. Data collection

Field surveys were conducted in the sampled households during mid-September to November 2022. Data collection employed interviews using semi-structured questionnaire designed for this purpose and administered to each household, focus group discussion and observations. Farmers were asked to tell the names of the landraces cultivated in their farms and distinct names were recorded. Information on the use values: Kocho, bulla, amicho, and medicinal of each recorded landraces were obtained from farmers. In addition, information on adaptation areas, maturity status and general plant size of each landrace were collected. Furthermore, names and quantities of enset landraces were enumerated per farm using a 10x10 m^2 quadrant laid out along a transect representative of enset home garden (one quadrat per household). Key informant interviews and focus group discussions were also held especially to cross-check landraces names, use values and if duplicate names exist for certain landraces at different districts and localities. Handheld GPS (Garmin 72) was used to record the geographic coordinates of each sampled household farm.

2.4. Data analysis

Shannon-Wiener diversity (H') and evenness (E) indices were first computed using the formula (Eq. 2) suggested by Hennink & Zeven (1990).

$$H' = -\sum pi \ln p \tag{2}$$

Where, pi represents the proportional abundance of the i^{th} landrace; lnpi is the natural logarithm of pi.

Evenness was calculated as a measure of the observed diversity to the maximum diversity (H'max) and defined by the function (Eq. 3):

$$E = H' \ln S \tag{3}$$

Where H′ is the Shannon index and S refers to the number of landraces described in each locality.

Richness was determined by counting the total number of respective landraces occurred in a district or locality. The similarity or variation of enset clones' composition between the districts and localities were determined using Sorenson's similarity coefficient (Sorensen, 1948) per the equation (Eq. 4) below:

$$C_s = \frac{2c}{a + b} \tag{4}$$

Where C_s represents Sorenson's coefficient, 'a' is the number of landraces at locality A, 'b' is the number of landraces at locality B, and 'c' is the number of landraces common to both localities.

The values obtained from the above calculations were analyzed using SPSS version 20. Diversity, richness and evenness values among locations and altitude groups were determined using analysis of variance and statistical significance was tested using LSD at 5% level of significance.

The uses of enset landraces were grouped into three main categories based on their similarity in use value: Kocho, bulla, and amicho medicinal value and associated characteristics and frequency and percentages were computed.

3. Results and Discussion

3.1. Naming and characterization of enset landraces in Gamo Highlands

In the study area, 38 distinctly named enset landraces were recorded and explanations were associated with each named landrace (Table 2). The names of landraces were recorded in Gamo language, which is dominantly spoken by the Gamo ethnic group in the study area. Physical characteristics of the specific landraces, suitability for food uses/quality, resemblance of landraces characteristics to names/nature of other objects, original location of a landrace were used in naming of specific landraces. Furthermore, other characteristics such as the plant's ecological adaptation (high, middle and low altitude), maturity and plant size especially height were used to distinguish one landrace from the other (Table 2). This study agrees with Bizuayehu (2008), who reported that names of enset landraces were related to plan characteristics, locality, names of objects, persons, social groups, etc. per the knowledge of farmers in that region.

Names for most of the cultivated enset landraces in literature from different regions have been only locally recognized as there have been only six released cultivars (Zerihun et al., 2012). In this study, farmers reported that most of the landraces (25; 66.8%) adapt in the highlands and the rest (13; 37 %) to have adapted in the mid and lowlands. Other sort of classification was based on maturity and plant size, 25 landraces (65.8%) and 13 landraces (34.2%) were grouped under early and late maturing, respectively. It was also reported that early maturing landraces were generally said to be smaller whereas late maturing landraces were perceived to be vigorous. Farmers' preferences for cultivating most of the early maturing landraces suggest their role in closing the food gaps which may occur due to changing climate. However, such categorization by farmers may vary from place to place as farmers and often based on long-years of practical experience over generations. As empirical evidence is very limited on agronomic characteristics of the available enset landraces in the farmers' fields and at Areka field gene bank (Zerihun et al., 2012; Zerihun et al., 2017), more field trials are needed to prove

Table 2. Naming of enset landraces and their perceived characteristics in Chencha and Kogota districts, Gamo zone

No	Vernacular	Explanations about naming	Agro-ecology	Maturity	Plant height
1	Beshera	Sweet and soft corm when boiled	High	Early	Smaller
2	Bodha	Sweet and soft corm when boiled, bigger corm	High	Late	Vigorous
3	Bora	Thicker landrace	High	Early	Smaller
4	Boroda Maze	Named after original location (Boroda area)	High	Late	Vigorous
5	Botha Zinke	Named after pale green pseudostem, not other colorations	Mid & low	Early	Smaller
6	Botha	White pseudostem	High	Early	Smaller
7	Bundo	Remains plentiful when eaten	Mid & low	Early	Smaller
8	Chamise/chamo	Bitter amicho when eaten	High	Late	Vigorous
9	Checho	After distinctive brownish-spotted appearance	High	Early	Smaller
10	Dokaze	Derived from "Doko" area, where it was originated	High	Late	Vigorous
11	Gena	Highly values for kocho preparation may also be related to plant size	High	Late	Vigorous
12	Godare	Named after skin color of hyena as the pseudostem resembles	Mid & Low	Late	Vigorous
13	Halako	Crispy and sweet corm, especially in dry season	High	Ealy	Vigorous
14	Halanga/Alang	Known for long and strong fibre	High	Early	Vigorous
15	Haliee	Not explained	Mid & low	Early	Smaller
16	Haranbo	Not explained	Mid & low	Early	Smaller
17	Hoe	Not explained	High	Late	Vigorous
18	Karga/charga	Its corm is hard	Mid & low	Early	Smaller
19	Katane	Is fast growing	High	Early	Smaller
20	Katise	Stress tolerant	High	Early	Smaller
21	Kelo	Not explained	Mid & low	Early	Smaller
22	Kunka	Used during periods of food scarcity	High	Early	Smaller
23	Loffe	Pink appearance, also used as a medicinal, ornamental	Mid & low	Early	Smaller
24	Loza	Not explained	Mid & low	Early	Smaller
25	Masa Maze	After 'Massa", a person who brought, has also a laxative property	High	Late	Vigorous
26	Maze	Bitter amicho, originated from Doko Mesho area	High	Late	Vigorous
27	Orgozo	Thick and large plant	High	Late	Vigorous
28	Pallake	Can feed more people	High	Late	Smaller
29	Patate	Not explained	High	Early	Smaller
30	Phello	Sought after for Amicho	High	Early	Smaller
31	Shina	Named after a cursed place, name also associated with its taste	Mid & low	Early	Smaller
32	Sorghe	Its Kocho ferments and spoils quickly	High	Late	Vigorous
33	Suite	Named after blood like fluid (sap) that comes out of midrib	High	Early	Smaller
34	Tadesa- Utha	Named after Tadese, a person who brought the plant to the area	Mid & low	Late	Vigorous
35	Wosayife	Narrow leaves resembling banana leaf, has medicinal value	High	Early	Smaller
36	Yila	Not explained	Mid & low	Early	Smaller
37	Zinkie	Delicious corm with crispy mouthfeel	High	Early	Smaller
38	Zoo Zinke	Deep red midrib and pseudostem	Mid & low	Early	Smaller

the perceived characteristics for efficient utilization of enset genetic resources under different environmental contexts.

3.2. Farmers' classification of enset landraces

3.2.1. Classification on the basis of use values

The cultivated enset landraces studied were classified as processing types (kocho and bulla) and cooking types (amicho), but also grouped as those used for both kocho and amicho and medicinal purposes (Table 3). This means farmers cultivate different landraces for various purposes, but kocho and amicho were the main food products as most landraces were grouped under these two products. However, among the 38 enset landraces identified in this study, majority (60.5%) belong to processing types, most common ones include Maze, Tadesa-Utha, Bodha, Falake, Sorghe, Gena, Beshera and Katise (Table 3). It was also perceived that high yield and good quality kocho would be obtained from matured plants. Since bulla is obtained via squeezing the processed enset mass to be fermented for kocho, landraces said to be used for kocho can also yield bulla, although which landraces were not separately identified for bulla in this study. On the other hand, 23.7% of landraces were known as cooking or amicho types and the most preferred ones in this group were Katane, Zoo Zinke, Halako, Bundo, Phello and Botha Zinkie in the study area (Table 3). The best amicho types were distinguished by their delicious corm with crispy mouth feel (neither too moist nor too hard) after cooking. The processing and cooking types were also distinguished by their perceived characteristics, the processing types being late maturating and having larger biomass while the amicho types being faster maturity and smaller biomass. This implies that processing and cooking type landraces would interact differently with environment, as there is high phenotypic plasticity in enset with implication on yield (Sabura, 2022; Admasu and Struik, 2003).

There were also enset landraces, which can serve both for kocho processing and amicho cooking. However, the suitability of the landraces for amicho in this group depends on plant age with good amicho cooking and sensory quality achieved at later age compared to common amicho types, which are often harvested at younger ages. Therefore, the harvestability of enset at any time when needed ensures the uniqueness of enset crop for household food security especially during food shortage. However, farmers in the study area perceive that the sensory qualities of amicho depends not only on type of landrace, but also on farm management (Sabura et al., 2021) which necessitates further agronomic and nutritional study to prove such hypothesis and to promote diversified enset-based foods to a larger community.

Table 3. Characterization and classification of enset landraces based on use values according to indigenous knowledge at Chencha and Kogota districts, Gamo zone

No	Uses	Characteristics	# landraces (%)	Landrace within the use group
1	Kocho & Bulla	high yield; large, thick pseudostem, big corm, late maturing	23 (60.5)	Maze, Tadesa-Utha, Sorghe, Palake, Karga, Origozo, Halango, Haranbo, Haliee, Bora, Boroda Maze, Patate, Botta, Godare, Kunke, Shina, Yila, Hoe, Loza, Kelo, Katise, Masa, Maze, Chamise
2	Amicho	Tasty and crispy corm, Fast corm, cooking, small short in stature, early maturing	9 (23.7)	Bundo, Phello, Zinkie, Botha Zinkie, Checho, Dokaze, Katane, Zoo Zinke, Halako
3	Kocho & Amicho	Can be processed & boiled	4 (10.5)	Beshera , Bodha, Gena, Wosaiye
4	Medicinal	Treatment of disorders	2 (5.3)	Suite, Loffe

In line with our finding, studies in other enset regions in Ethiopia showed that some landraces are best for Kocho and bulla while others were preferred for amicho (Kedir, 2016; Tesfaye et al., 2023; Zerihun et al., 2013). Moreover, the study by Tesfaye et al. (2023) showed that some amicho types were superior in proximate and minerals contents, which may highlight their role in repairing bone fractures. Therefore, similar nutritional profile studies are needed on the enset landraces identified in the study area to support their use values with scientific evidence.

The enset plant and its parts contribute to indigenous ethno-medicinal values in the study area district. According to respondents, the part of enset corm, leaves, and pseudo stem of Loffe and Suite enset landraces were used to treat both animals and humans' aliments (Table 3). Similarly, studies by Kedir (2016) described that "Astara" and Qibnar" enset landraces in Gurage were used to cure both human and animal diseases. More information on ethnno-medicinal values of enset landraces were also described in literature (Gizachew et al., 2022). Further research should give attentions to the biochemistry and clinical tests to prove/disprove this hypothesis and help provide homegrown solutions for health and nutrition, for e.g., research on role of enset for orthopedics is recently initiated at Armauer Hansen Research Institute, Ethiopia (personal communication, Prof. Milkias Endale).

3.2.2. Characteristics of 'male' and 'female' enset landraces

In the study area, enset landraces preferred for kocho and bulla products were easily distinguished as 'male' clones while those for amicho were called 'female' clones as characterized in Table 4. ‘Male’ and ‘female’ landraces were respectively known as ‘*Wodala Uuthi’* or ‘*Macca Uuthi’* in Gamo language. It should not be misleading that such distinction as 'male' and 'female' is not related to the biological reproductive behavior rather based on suitability for kocho processing and corm cooking, maturity period, yield and product quality as well as level of stress tolerance.

Of the total 38 landraces identified, 23 processing types (Table 3) were classified as 'male' and 11 (9 amicho types +2 medicinal types) were identified as 'female' landraces, while the rest four landraces were perceived to share the characteristics of both ‘sex’ groups. Similarly, enset clones sharing ‘male’ and female’ characteristics as in our study were classified as soft and hard in Guji area of Oromia region (Wendawek et al., 2022). Bizuayehu (2008) reported similar mode of classification of enset landraces as female (Meyate) and male (Labbaahu) depending on criteria such as maturation time, plant size, and its hardness to process by Sidama people. More such like reports from other regions is also available in literature (Temesgen et al., 2014), although empirical evidence on such characteristics is scanty and needs agronomic research and testing enset-based products quality (sensory, nutritional profiles, medicinal and bioavailability) among landraces to satisfy growing consumer need and markets.

Moreover, future research should focus on fast maturing amicho types which may perform at mid and low altitudes to enhance food security and resilience.

Table 4. Perceived characteristics of male and female enset landraces based on farmers’ indigenous knowledge in Gamo highlands.

Characteristics	‘Male’	‘Female’
Maturity	Late maturing	Early maturing
Amicho	Hard & not suitable for amicho	Suitable for amicho (loose textured corm falls apart into small pieces after cooked
Kocho & bulla	High yield & slow fermentation	Low kocho yield, ferments quickly
Fibre	Strong, high in quality & quantity	Low strength, low quality & quantity
Plant size	Bigger	Smaller
Reaction to biotic stress	Tolerant	Susceptible
Leaves	Hard and stiff	Soft
Leaf sheath	Hard and stiff	Soft
Average yield	Higher	Lower

3.2.3. Diversity and abundance of enset landraces at different altitude categories

In this study total of 38 locally named enset landraces were recorded (Table 5). Admasu (2002) described 52, 55 and 59 enset landraces from Sidama, Wolaita, and Hadiya, respectively.

Thus, landraces in our study area seem fewer compared to other regions. Less number of landraces in the present study may be due to inclusion of limited geographies (i.e., only two districts) compared to other regions. Table 5 indicated that the diversity indices, Shannon (H') index, richness and abundance decreased with decreasing altitude. 'H' ranged from 0.75 at Kogota lowland to 2.75 or 2.55 at Chencha or Kogota highland (Table 5). The result also revealed significance difference in 'H' among the three altitude ranges.

Table 5. Diversity indices of enset landraces across different altitudes of chencha and kogata districts, Gamo zone

No.	Altitude	Districts	Shannon index	Richness	Evenness	# of unique clones
1	High	Chencha	2.75^{a}	18^{ns}	0.8^{a}	2
		Kogota	2.55^{a}	23^{ns}	0.9^{a}	6
2	Mid	Chencha	1.95^{ab}	14^{ns}	0.7^{b}	1
		Kogota	1.65^{b}	15^{ns}	0.8^{b}	0
3	Low	Chencha	1.15^{b}	19^{ns}	0.7^{b}	0
		Kogota	0.75^{c}	5^{ns}	0.8^{b}	0

Values in small letters within columns show significant differences ($P < 0.05$) according to F- test between altitudes and between districts.

The higher enset clonal diversity with increasing altitudes may be related to the agro-ecological suitability as precipitation and hum idity increases with rising latitudes in the study area. Moreover, it indicates higher dependence of highland communities on enset as major source for household food security. In addition, highlanders had better knowledge about the uses of different enset landraces so they maintain diverse landraces in their farms. On the other hand, less Shannon index in farms of low-lying communities suggest less contribution of enset to food security and livelihood at present. This may be associated with the fact that enset farms shift to annuals at middle/lower altitudes. Increasing enset diversity at highlands is in line with literature (Admasu, 2002; Awol et al., 2014; Melesse et al., 2014). Lower diversity indices with decreasing altitude in our study may also be linked to lack of own clean planting materials as communities at lower elevation ranges in this area often rely on passing sellers from highlands due to poor extension efforts on enset (Vantyghem, 2018). Relationship between species diversity and altitude gradient in vegetation may vary with type of vegetation and altitude levels, but species diversity increases from highland to midland in trees and shrubs (Fikadu et al., 2019) as opposed to enset.

Table 6 summarizes Sorenson's similarity coefficient for pair of localities. The result showed similarities in landraces between localities but with different intensities. The similarity index ranged from 0.2 (between Ote and Kogo-Ayira) and 0.9 (between Yoira and Lakana Maldo). The similarities in landraces between pairs of locations were attributed to proximity and/or similarity in altitude category (Fig. 1, Table 1). For instance, both pairs of locations: Ote and Kogo-Ayira; and Yoira and Lakana-Maldo were located close to each other, but fall under different altitude ranges. For par of locations under similar altitude, the Sorenson's coefficient ranged from 0.5 (Kogo Ayira vs Lakana-maldo) to 0.8 (Yoyira and Ote). This indicates nearby locations share similar landraces suggesting that farmers obtain planting materials within their neigbourhoods or obtain from local markets. Common landraces observed for locations under similar altitude range may indicate adaptation of similar landraces to certain altitude range, with implications on genotype - environment suitability in enset. Less similarity of landraces between pair of locations in a close distance may be due to the fact that preference for landraces may differ from farmer to farmer perhaps depending on soil type and access to type of planting materials. Enset is said to adapt to wide range of environments and adaptation is often mentioned in literature as one of the criteria for selection of landraces. Our data show proximity and environment influences diversity and composition of enset landraces. However, literature dealing with agro-ecological adaptation of specific enset landraces is scanty; hence, further research to identify genotypes more performing in a certain environment is crucial to ensure sustainable intensification of enset cultivation, particularly in the era of climate changing.

4. Conclusions

Indigenous knowledge about enset accumulated over generations can contribute to advancing enset farming and efficient utilization of its genetic resources in Ethiopia and beyond. This study provided first-hand information generated from farmers' experiences from Gamo highlands. Enset is recently attracting national and global attentions in terms of research, food security, commercialization and environmental resilience. In this regard, documentation of the available genetic resources and associated indigenous technical knowledge is essential for sustainable intensification of enset cultivation for various use values and applications. Accordingly, our study showed that enset landraces in Gamo highland were classified into different categories such as product use value (processing in to kocho or for direct use as cooked amicho, for both kocho and amicho, or medicinal purposes). Moreover, agro-ecological suitability of landraces, maturity period and plant vigor (size) were considered by farmers as important criteria to classify enset landraces. We conclude that this accumulated indigenous knowledge played a significant role in mainiating enset landraces diversity and food system. Therefore, it is recommended that designing systematic field experimentations, enset-based products development and commercialization need to account for such knowledge base to ensure sustainable intensification of enset farming system in the region. In this context, conservation efforts such as Dorze Enset Field Gene Bank initiatives by Arba Minch University are duly appreciated.

Acknowledgements

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Conflict of Interest

The authors declare that they have no conflict of interest.

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Research Article

Ethnobotanical study of traditional medicinal plants in Boreda woreda, Southern Ethiopia

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Abstract
Plants are the major and cheap sources of traditional medicine. Countries like Ethiopia with ethnic and cultural diversity own a vast treasure of indigenous knowledge of medicinal plants. However, much of this knowledge remained undiscovered for generations. The objective of this study was to investigate the traditional knowledge of medicinal values of plants in Boreda woreda in two kebeles. A survey was conducted on purposively selected five key informants of healers and 25 elders who provide traditional healing service in the locality. An informant consensus factor and preference matrix analysis was employed to analyze the data. Identification of taxonomic class of plants was carried out using expert methods and Flora of Ethiopia and Eritrea. Overall, 35 medicinal plant species belonging to 22 families were recorded. About 63% of the plants found to be herbs and 20% of them were trees, and the remaining were shrubs. About 75% of the plants were used for treatment of human ailment. Leaves of herbs were the most widely used part of the plants followed by root and stem. According to preference matrix analysis *Citrus* x *limon* (L.) Osbeck, *Nigella sativa* L. and *Ocimum forskolei* Benth., were the first three priority plants by the indigenous people for internal pain treatment. There is high level (0.78) of consensus of using medicinal plants for various diseases treatment among the community. Therefore, such high value indigenous knowledge should be conserved and the medicinal plants need to be protected.

Keywords: Biodiversity; Boreda; Ethnobotany, Hambissa; Medicinal plant

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1. Introduction

Plant as primary food producers plays an irreplaceable role in balancing ecological life cycle. Besides this vital role, plant have been used for treating various diseases (Fabricant and Farnsworth, 2001; Michael, 2006). Several studies showed that around the world people are still highly dependent on plant-derived medicines (Dawit, 1986; Mengistu, 2010; Belayneh et al., 2012; Mirutse and Tilahun, 2013; Tilahun, and Moa, 2018). Over 80% of the world's population gets treatment directly from plant product medicines (Tilahun, and Moa, 2018). According to

Zao et al. (2019), traditional medicines from plant roots, stems, leaves and fruits or seed parts were used for treating several diseases in China. Similar practice of using different plant parts for healing of different diseases also reported in Turkey (Polat, 2019). Traditional preparation of medicine from the tissues of plants may vary from place to place. Most of the time crude extraction with water is used.

Indigenous communities in several Asian and African nations have a strong cultural tradition of using medicinal herbs (Subramanyam et al., 2008). In particular, the rural population uses traditional herbal medicine as their main source of healthcare (Haile and Delenasaw, 2007; Mohammed and Berhanu, 2011). Additionally, according to WHO (2019), 60–70% of Ethiopians practice traditional medicine. Due to Ethiopia's many languages, cultures, and beliefs, as well as its great geoclimatic diversity, which has facilitated the establishment of various habitats for medicinal plants, there is a high anticipation of extensive traditional knowledge and use of medicinal plant species (Cunningham, 2001).

Only few members of the communities are allowed to practice healing. The healing skills are transferred to generations through inheritance from family members. These are made through verbal communication and demonstration. As the last successor (the old person) who owned the knowledge is about to die, the training begins and usually ends with the death of the elder. This results in the loss of most of the knowledge before it is completely transferred. Beside such specific people, the larger community has some commonly held knowledge about plants. Therefore, this study aimed at assessing some commonly used medicinal plants by Boreda indigenous people. The study also tried to discover how much of the traditional knowledge is owned by ordinary people. Boreda is located in remote area. There is no direct highway or sub-way road that links the area to main cities. Hence, investigation of an original traditional knowledge from such remote area has great value for ongoing science in the field of ethno-biology.

2. Materials and Methods

2.1. Study area

This study was conducted from mid of April to end of June 2021 in Boreda area, Gamo zone, Ethiopia. Boreda woreda is located in between 6^{o} 22′ 0″ N to 6^{o} 42′ 30″ N longitude and 37^{o}31′ 15″ E to 37^{o} 48′ 45″ E (Fig.1) at average altitude of 2185masl. It is just at the upper shaft of East African Rift Valley with beautiful undulating landscape. Indigenous ethnic group (Gamo) inhabited the area for more than five hundred years (Freeman, 1999). According to the CSA's 2007 census, there are 67,960 people living in the region, with 34,460 men and 33,500 women. Of these, 2,761 (4.06%) are urban dwellers. The people of Boreda are settled farmers. They harvest crop like maize (*Zea mays*), teff (*Eragrostis tef*), coffee (*Coffea arabica*), and enset (*Ensete ventricosum*). Some people are engaged with cattle husbandry. The study was conducted particularly in two adjacent kebeles known as Hamibisa and Meteka mele. According to CSA (2007) census, both kebeles have total population of 4625 (2308 men and 2317 women). The climate of the area is predominantly characterized by moist lowland and with mosaic dry lowland and moist mid highlands (Azene, 2007). The hottest and coldest months of the year are March and December, respectively. Average annual precipitation is 1180.5 mm (year 2025).

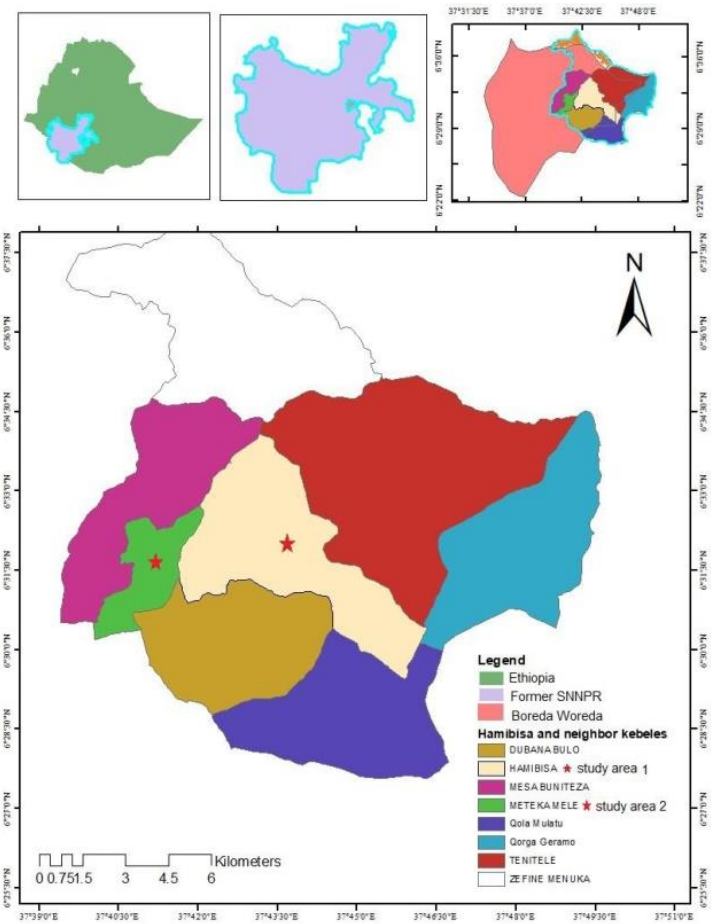

Figure 1. Map of the study areas with other neighboring kebeles (ArcGIS 10.1).

2.2. Data collection methods

To get relevant data, 30 informants with the age of 30 to 45 (8 female and 22 male) were identified and divided into two groups. Five (two from Meteka mele and three from Hamibisa) of the informants were traditional healers and the remaining (10 from Metekamele and 15 from Hamibisa) were other community members. The elites of traditional healers were purposively selected. Elder informants were selected from the community randomly. Two separated questionnaires were prepared in the local language (Gaammoththo doona); one for traditional healers and the other for the community elders who used the traditional medicinal plants for human and animal ailments. Informal interview method has been used by which plant specimen were demonstrated following Bernard (1988). Informants were asked to give information for local name of traditional medicinal plants, parts used, disease treated, and methods of preparation. Besides this, the limitations of traditional medicine and its side effects were discussed. Guided field walk method was used for some community members. Plant samples were collected from randomly selected gardens of farmer's house. Plants were, then, pressed and preserved following appropriate herbarium techniques following Lucilene et al. (2013). Plant taxonomic identification was made through expert methods and crosschecked with Flora of Ethiopia and Eritrea.

2.3. Data analysis

2.3.1. Quantitative analysis

Microsoft Excel 2010 was used for sorting plant names for quantitative analysis based on informant's response and field observations.

2.3.2. ICF analysis

To find out whether the informants agreed with the reported plant remedies for the group of illnesses, an ICF analysis was conducted. It also gauges the informants' level of awareness. In accordance with Troter and Logan (1986), the ICF was computed as follows (Eq. 1).

$$\mathrm{ICF} = \frac{n_{ur} - n_t}{n_{ur} - 1} \tag{1}$$

Where ICF = Informants Consensus Factor, *nur* = number of use citation in each category, *nt* = number of species used

2.3.3. Preference ranking

Following Martin (1995), a preference ranking was carried out for five significant medicinal herbs that are used to treat internal parasites that cause sickness in humans and livestock. In order to determine the most popular medicinal herbs for treating internal parasites, five randomly chosen informants took part in the study. After being handed the plants, the informants were asked to rank the medicinal plants according to how often they were used. They were to provide the greatest number (5) to the most favored plant species, the lowest number (0) to the least preferred plant, and a value in between for the remaining plants. The findings were then compiled for each respondent and arranged according to the sum of the ratings for every medicinal plant.

3. Results and Discussion

3.1. Medicinal plant diversity

Overall, 35 plants belonging to 22 families were identified as Traditional medicinal plants (TMP) used by the people in the study area (Table 1). A similar study in Northern Ethiopia showed that more than 80 species of medicinal plants records (Seyoum and Zerihun, 2014) and more than 130 species in Delanta in Northern Ethiopia (Misganaw et al., 2015). This might not be surprising because in the former studies, data were collected from geographically larger areas.

The agro-climatic condition variation among the study locations can be the factors that might account for the species richness of the traditional medicinal plants in those areas. Mirutse et al. (2003) has also speculated that reduction of medicinal plant diversity induced could be driven by deforestation. In the present study, five plant species belong to Solanaceae, four to Euphorbiaceae and three to Lamiaceae families. Lamiaceae and Euphorbiacea were also reported to be among the first three top plant families for medicinal plants sources elsewhere (Ermias et al., 2008; Seyoum & Zerihun, 2014). Nearly 63% of the TMP collected were herbs and only 20% were found to be trees (Fig.3). The present findings agree with the work of others (e.g., Mirutse et al., 2003; Misganaw et al., 2015), where herbs are found to be the most frequently used plants in traditional medicine. This high proportion of herbs in traditional medicine is due to relatively higher abundance, easy adaptability and mulifunctionality (Guo et al., 2023). About 75% of the plant samples were used to treat human ailments and about 17% of the plants were used to treat livestock ailments (Table 1).

The indigenous people has also learnt and classified the medicinal plants based on route of administration and target organ for treatment as plant for eye; plant for abdomen and plant for skin. Over 70% of the plants were administered orally to treat intestinal (internal organ) diseases. Plants like *Withania somnifora, Geranium maculatum, Ocimum lamiifolium* were used in diluted form to treat various type internal pains. About 20% of medicinal plants were also mentioned as they were used for skin care and related problems. Such plants were used for skin wound, lesion, tumor, and even as disinfectants for body and household equipment. Some of the plants used for dermal treatment were *Commelina diffusa*, *Croton macrostachyus* and *Euphorbia tirucalli. C. diffusa* has been identified as plant with anti-fungal properties (Prima et al., 2019). The later species were also reported for similar function in other places (Dawit et al., 2003).

Table 1. Medicinal Plants and physiognomic features with their use parts and administration route in Hamibisa kebele Gamo zone, Ethiopia

Taxonomic Name of the plant	Family	LN	HB	PU	Disease treated	TO	RA
Allium cepa (L.)	Alliaceae	Qeyshinkurt	H	Root	Coughing	Hu	Oral
Allium sativum (L.)	Alliaceae	Nech-shinkurt	H	Root	Comman cold	Hu	Oral
Aloe vera (L.) Burm.f.	Aspodelaceae	Godere-uta/rett	H	Stem	Eye disease	Hu	Ocular
Amaranthus caudatus (L.)	Amaranthaceae	Gagabsa	H	Seed	Internal organ broken	Hu	Oral
Asparagus scaberulus (A. Rich)	Asparagaceae	Sereta	S	Leaf	Diarrhea	Hu & L	Oral
Capsicum annuum (L.)	Solanaceae	Qarya	H	Fruit	Rumen disease	Hu	Oral
Citrus x limon (L.) Osbeck	Rutaceae	Lome	T	Fruit	Internal	Hu	Oral
Clinopodium nepeta (L) Kuntze	Lamiaceae	Gulo	S	Leaf	Wart	Hu	Dermal
Combretum molle R.Br. ex G. Don	Combertaceae	Ambe	T	bark	Tonsil	Hu	oral
Commelina diffusa Burm.f.	Commelinaceae	Dal'aso	H	stem	Lesion on head	Hu	dermal
Croton macrostachyus Hochst. ex Delile	Euphorbiaceae	Bisana	T	leaf	Wound	Hu	Dermal
Datura stramonium (L.)	Solanaceae	Machara	H	leaf	External parasite	L	Dermal
Dirichletia glaucescens (Hiern) verdc.	Sapindaceaae	Tora-tuko	S	Leaf	Internal pain	Hu	Oral
Ehretia cymosa Wild. exRoem.&Schult.	Boraginaceae	Esirwanja	T	leaf	Tumor	L	Oral
Eragrostis tef subsp. red (Zucc.) Trotter	Poaceae	Zo'ogashe	H	seed	Internal pain	Hu	Oral
Euphorbia tirucalli (L.)	Euphorbiaceae	Qinchib	T	Stem	Wart	Hu	dermal
*Foeniculum vulgare*Mill.	Apiaceae	Caticala/ensilal	H	leaf Stem	Stomach discomfort	Hu	Oral
Jatropha curcas (L.)	Euphorbiaceae	Jatropha	MT	leaf	Cut and wound	Hu	Dermal
Linum usitatissimum (L.)	Linaceae	Telba	H	Seed	Bone brake	Hu	Oral
Manihot esculenta (Crantz*)*	Euphorbiaceae	Mithaboye	H	Tip of stem	cholera	L(hen)	Oral
Moringa stenopetala (Baker f.) Cufod.	Moringaceae	Halako	T	Root	malaria	Hu	Oral
Nigella sativa (L.)	Ranunculaceae	Tikurazmud	H	Seed	Internal parasite	Hu	Oral
Ocimum forskolei Benth	Lamiaceae	Shasha	S	root	Internal parasite	L	Oral
Ocimum lamiifolium Hochst. ex-Benth	Lamiaceae	Waselo/damakesse	H	leaf	Anemia	Hu &L	Oral
Oxalis radicosa Tent. Fl. Abyss.	Oxalidaceae	Zil'emata	H	leaf	Tumor	Hu	Dermal
Pelargonium whytei Baker	Geraniaceae	Ayin-fiqir	H	leaf	Lesion	Hu	Dermal
Ruta chalepensis(L.)	Rutaceae	Tena'adam	H	leaf	Internal parasite	Hu	Oral
Solanum coagulans Forssk.	Solanaceae	Yegomen	H	leaf	Coughing	Hu	Oral
Solanum incanum (L.)	Solanaceae	Embway	H	root	Stomach disease	Hu	Oral
Spilanthes costata Benth.	Asteraceae	Aydame	H	Leaf	Tonsil	Hu	Oral
Vachellia nilotica sbsp. nilotica (L) Del.	Fabaceae	Girar(chacha)	T	Stem tip	Eye disease	L	Ocular
Vernonia amygdalina Delile	Asteraceae	Girawa	MT	leaf	Internal parasite	L	Oral
Withania somnifera (L.) Dunal	Solanaceae	Girosana	H	root	Internal parasite	L	oral
Zingiber officinale Roscoe	Zingeberaceae	Zingibil	H	Stem	Common cold and [illegible]	Hu	Oral

H= Herb, T=Tree, S=Shrub, MT= Medium Tree, Hu= Human, L=Livestock, TO=Target organism, RA=Root of administration, LN=Local name, HB=Habit, PU=Plant part use

Twenty-two plant families with their relative abundance of species is presented in Figure 2. Solanaceae family with five species leads while Amaranthaceae and other 14 families were at the bottom, each with one representative species in the study area.

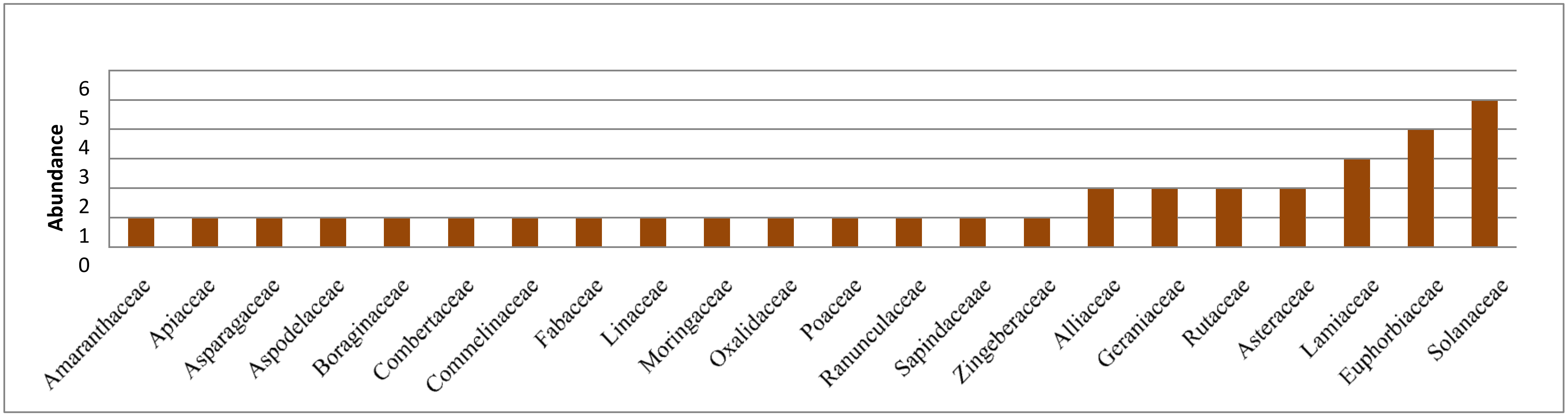

Figure 2. Medicinal plants with respect to their taxonomic family group distribution

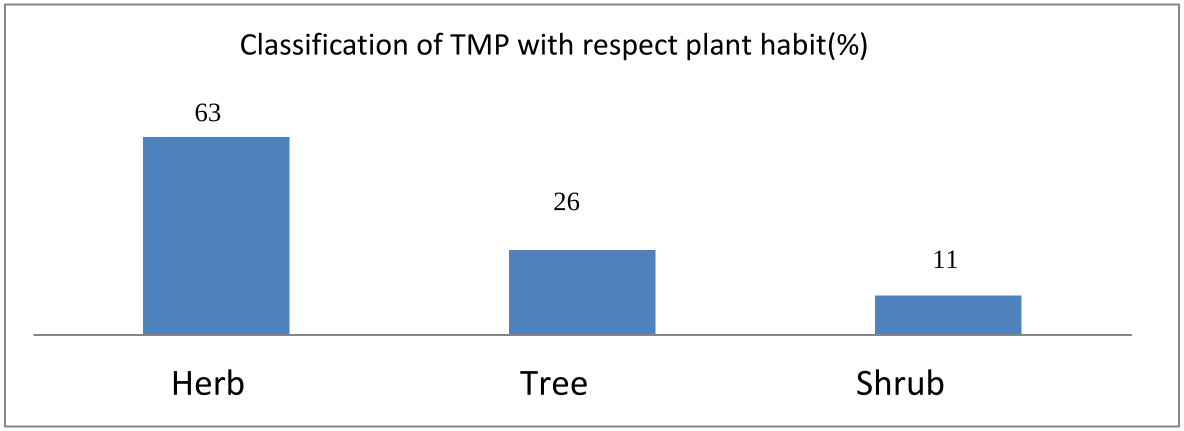

Figure 3 Medicinal plant comparisons with respect to plant habit

Traditional Medicinal Plant were highly out sourced from herbs (Fig. 3). This might be because the trees and shrubs are being used extensively for fuel and other destructive uses (Helmut, 2023).

Almost in all plant habit, the leaf parts have been used as medicine (Fig. 4). Debela et al. (2006) and Tilahun and Moa (2018) reported that root as major part of the plant used as medicine followed by leaf and shoot. Higher score observed in herbaceous plant. Surprisingly utilization of fruit as medicine was observed only in herbaceous plants. This might be due to the target sampling area which was only restricted to plants in the garden holdings.

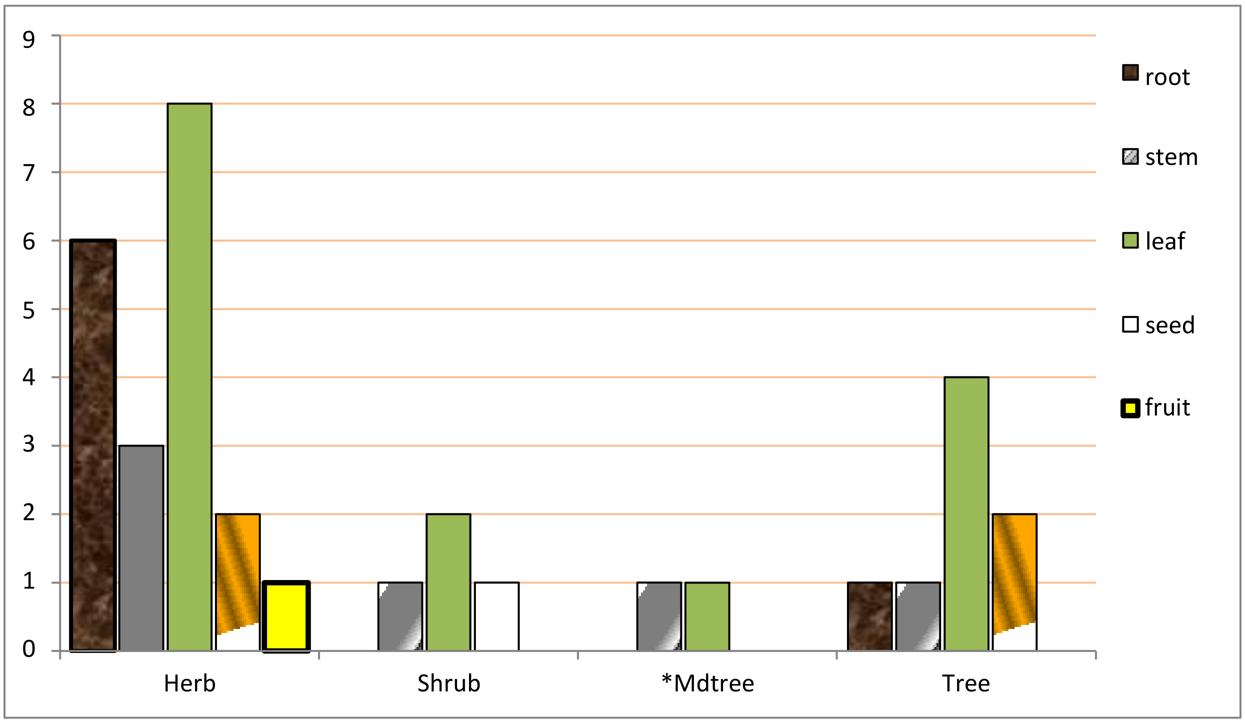

Figure 4. Plant habit and their tissue parts used for treatment (* Mdtree = medium tree)

3.2. Preference ranking of medicinal plants

In this study, five key informants (A-E) were selected to conduct ranking on medicinal plant based on priority to treat internal parasite and related pin (Table 2). *Citrus x limon* was prioritized first followed by *Nigella sativa* and *Ocimum forskolei*.

Table 2. Preference ranking of top five medicinal plants for internal parasite and related pain treatment

Plant species	Respondents(A-E)score for the plant						
	A	B	C	D	F	Total	Rank
Nigella sativa	5	4	5	4	3	21	2nd
Ocimum forskolei	2	4	4	1	4	15	3rd
Carphalea glaucescens	0	1	3	1	0	5	5th
Citrus x limon	5	3	5	4	5	22	1st
Ruta chalepenses	3	5	3	3	2	16	4th

3.3. Knowledge level of the community towards uses of 10 selected plants

Analyses on homogeneity of knowledge level for 10 randomly selected medicinal plants were carried out on randomly selected respondents. The results are presented in Table 3.

Table 3. ICF analysis for common uses of top 10 randomly selected medicinal plants

Treatment use category	Nt	%nt(sp)	ur	%(Ur)	ICF
Internal parasite	8	80	47	23.74	0.847826
Common cold	8	80	40	20.20	0.820513
Wound healing	10	100	42	21.21	0.780488
Lesion	10	100	39	19.70	0.763158
Tumor	10	100	30	15.15	0.689655
Total					0.780328

The informant consensus for the various diseases treated by the traditional medicinal plants in the study region was displayed in Table 3's ICF analysis result. For the majority of use categories, informants' agreement was strong (mean ICf = 0.780328). This suggests that the informants have the most uniform understanding of how to use various TMP species for various human and animal foods. Internal parasites had the highest degree of consensus (ICF=0.847826), followed by the common cold (ICF=0.820513). Knowledge about utilizing TMP to treat tumors and lesions had comparatively low levels of consensus (ICF=0.689655) and 0.763158, respectively.

4. Conclusions

Despite the spatial advantages that help shield indigenous knowledge from the pressures of modernization and the presence of a favorable agro-ecological climate, the number of medicinal plants recorded in this study is comparatively lower than in previous research. While there is general awareness among local communities regarding the use of traditional medicinal practices (TMP), this knowledge remains heavily reliant on herbaceous species and is gradually diminishing, particularly in relation to livestock treatment. Encouragingly, remnants of this valuable knowledge still persist, underscoring the urgent need for a comprehensive conservation strategy. Such efforts should include the protection and encouragement of traditional medicine practitioners, active governmental involvement in preserving medicinal plant species, systematic documentation and manual preparation to safeguard local knowledge, and the identification, cultivation, and propagation of key medicinal plants. Additionally, training traditional healers on standardized dosages to minimize adverse effects and conducting phytochemical and pharmacological studies on frequently used species are essential steps to ensure the sustainability and scientific validation of traditional medicine for future generations.

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Conflict of interest

Authors declare no conflict of interest.

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Research Article

Assessment of dairy cattle breeding practices and reproduction performances in Derashe district, Southern Ethiopia

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Abstract

This study was conducted in Derashe District, Southern Ethiopia with the aim of assessing the breeding practices and the reproductive performance of crossbred and local cows in the district. Field observations, key informant discussion and structured questionnaire were used to generate data. The district was stratified in to three agro-ecologies namely highland (2301-2622 m.a.s.l), mid-altitude (1501-2300 m.a.s.l) and lowland (below1500 m.a.s.l) with a total of 149 respondents. The number of respondents was determined by using probability proportional to size-sampling technique. The overall average cattle herd size in the study areas was 9.5 of local cows and crossbreds. However, the average cattle herd size of crossbred and local cows was 9.5 heads per household. Age at first services, age at first calving, days open, calving intervals and number of services per conception of HF in the mid-altitude were 19.85±1.101months, 28.519±1.354 months, 141.111±6.435 days, 22.815±0.912 months and 1.781±0.102, respectively. Age at first services, age at first calving, days open, calving intervals and number of services per conception of Jersey crosses were 24.09±0.513 months, 33.09±0.5 month, 152.273±3.835 days, 24.455±0.312 months and 1.982±0.018, respectively. Age at first service, age at first calving, days open, calving intervals and number of services per conception rate of local cows were 39.414±0.552 months, 48.483±0.558 months, 170.624±0.882 days, 26.559±0.321 months and 2.009±0.005, respectively. The overall daily milk yield of HF crosses, Jersey crosses and local cows in the study areas was 8.344±0.576, 4.06±0.248, and 1.971±0.052 liters, respectively($P<0.05$). The mean lactation length of HF crosses, Jersey crosses and local cows was 8.62±0.233, 7.51±0.552 and 7.40±0.076 months, respectively ($P<0.05$). Poor extension and shortage of AI services were the major problems in the study area. The opportunities for improving dairying are suitable climatic condition, road access, AI services and increased demand of dairy products by increasing human population. Generally, dairy cattle production in the study district was subsistent type of production. Except for mid-altitude dairy producers, the highland and lowland farmers did not focus on dairy production. The local Zebu, Boran and unknown breed types are dominant cattle population in highland and lowland areas of the district which were associated with low productivity. In order to alleviate these problems, farmers should be halped to have awareness to use AI services.

Keywords: Agro-ecologies; Dairy cattle; Derashe district; Productive,;Reproductive

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1. Introduction

Ethiopia has the largest livestock population in Africa (Metaferia *et al.,* 2011). This Livestock sub-Sector contributes an estimated 16 % of the total Gross Domestic Product (GDP) and over 30 % of the agricultural GDP in Ethiopia although the sector ranks second in foreign exchanges of the country (Alazar, 2015). The total cattle population for the country is estimated at about 59.5 million. Out of this the female cattle constitute 55.5% and the remaining 44.5 % are male cattle. It is estimated that 98.20% of the total cattle in the country are local breeds. The remaining are hybrid and exotic breeds that account for about 1.62% and 0.18%, respectively (CSA, 2016/2017).

In Ethiopia, different types of dairy production systems are identified based on various criteria. It can broadly be categorized in to urban, peri-urban and rural milk production systems based on location (Redda, 2001), while based on market orientation, scale and production intensity, dairy cattle production system can categorize as traditional small holders, privatized state farms and urban and peri-urban system (Kumsa, 2002; Ahmed, 2004; Ketema, 2008).Even if it has the largest cattle population in Africa, reproductive and productive performances of cattle are very low in Ethiopia.

The per capita milk consumption of the country is estimated to be about 19.2 kg per year, which is far below the average per capita consumption of Africa and the world per capita which averages 37.2 kg/year and 100 kg/year, respectively (FAOSTAT, 2011). A recent report indicated that, the average lactation period per cow during the reference period at country level is estimated to be about *six* months, and average milk yield per cow per day is about 1.37 liters. The average lactation period is about *nine* months whereas the average daily milk yield is about 3.59 liters in the sedentary areas of the country (CSA, 2016/2017).

Furthermore, the annual rate of increase in milk yield (estimated to be 1.2%) lags behind the increment in human population (estimated to be about 2.7% per annum) (CSA, 2008) and this resulted in large supply–demand variance for fresh milk (MoARD, 2004). Azage (2003) estimated that if the current level of milk production would be maintained, then about 6 million tons of additional milk (4% increment in total milk production) is required per annum to feed the increasing human population and narrow the gap in milk supply and demand. Thus, the country has been spending foreign currency to import dairy products from abroad to meet domestic demand. For instance, the country spent about 3.1 million USD in 2001 for same purpose, and this number increased to 9.3 million USD in 2008 (Haile, 2009).

The level of foreign exchange earnings from livestock and livestock products are also much lower than would be expected, given the size of the livestock population (Gebremedhin *et al*., 2007). Therefore, dairy production in Ethiopia is anticipated to increase rapidly in response to the fast-growing demand for livestock products resulting from increasing human population, especially in urban areas, and rising consumer income, provided that appropriate interventions are made along the dairy value chain (Azage *et al*., 2013).

Ethiopia has a huge potential for dairy development in Africa. The large and diverse livestock genetic resources, the existence of diverse agro-ecologies suitable for dairy production, the increasing domestic demand for milk and milk products. However, dairy development has been hampered by multi-faceted, production system-specific constraints related to genotype, feed resources and feeding systems, access to services and inputs, low adoption of improved technologies, marketing and absence of clear policy support to the sector (Azage et al., 2013).In order to improve the low productivity of local cattle, selection as well as cross breeding of indigenous breed with high producing exotic breed has been considered as practical solution (Tadesse, 2010). Cross breeding work in Ethiopia was initiated to cross indigenous zebu with Holstein- Friesian or Jersey cattle to improve milk production in the early (1950s) Aynalem et al. (2011). Unfortunately, the activities were not based on clearly defined breeding policy with regard to the level of exotic inheritance and the breed types to be used (Aynalem et al,. 2011).

Although efforts were made to develop breeding program for various livestock species in the country, all were not materialized due to lack of commitment and consultation with various stakeholders (Aynalem et al., 2011). Success of dairy production in general and crossbreeding program in particular needs to be monitored regularly by assessing the reproductive and productive performance under the existing management systems. Reproduction and productivity of crossbred dairy cattle are believed to be higher than that of local zebu, but the performance status of different exotic blood level crossbred and local dairy cows in different farming system of Ethiopia highland both in production and reproductive traits are little understood, therefore, the present study is planned to undertake to assess production, breeding practice, breeds and reproductive performance of dairy cattle in the study area.

2. Materials and Methods

2.1. Description of study areas

The common agricultural practice of the district is mixed crop-livestock production system. The major growing crops in the study area are maize, sorghum, teff and wheat. Livestock production system are characterized by minimal management of inputs in terms of production and breeding management, disease control and nutrition and are mainly traditional and subsistence oriented.

The study site was selected from the districts based on dairy cattle potential of both local and crosses, farmers' motivation and preferences to improve local cows through crossbreeding, farmers' long experience of keeping crossbred and local dairy cattle among the five districts of Segen area peoples' zone. Stratified sampling technique was applied to select agro-ecologies whereas the study farmers associations were selected using simple random sampling technique. Households having crosses of HF and Jersey cows and local cows were selected for the study following systematic random sampling technique. One hundred forty- nine (149) households were selected from the districts. The agro-ecological Zone of the district comprised of 17.27% (2301-2622 m.a.s.l) highlands, 35% (1501-2300 m.a.s.l) mid altitude and 48.0 % (Below 1500 m.a.s.l) lowlands. The proportionality of respondents across each agro-ecology was obtained by using probability proportional to sample size determination formula. The selected farmers are interviewed using a structured questionnaire which was pre-tested with 5 farmers in each agro-ecology.

The total sample size for household interview was determined (Eq. 1) using probability proportional to sample size-sampling technique of Cochran's (1977).

$$n = \frac{Z^2 * (p)(q)}{d^2} \quad \rightarrow n1 = \frac{No}{(1+\frac{N}{No})} \tag{1}$$

Where no= desired sample size according to Cochran's (1977) when population greater than 10,000 n1 = finite population correction factors (Cochran's formula, 1977) population less than10, 000, Z = standard normal deviation (1.96 for 95% confidence level), P = 0.11 (proportion of population to be included in sample i.e., 11%), q= 1-0.11 i.e. (0.89), d = is degree of accuracy desired (0.05), 5% error term.

Based on the first formula, the total number of households were 149 from three agro-ecologies of the district i.e. (26 HH highland (17.27%), 52 HH mid-altitude (35%) and 71HH lowland (48.0%)).

2. Data and data collection tools

Data on socio-economic characteristics of the respondents, dairy cow holding of households, dairy cattle feeds and feeding, health care and common diseases, breeding practices and farmer's trait preferences, housing and routine farm managing activities were collected. Milk production traits (average daily milk yield, lactation length and lactation milk yield) was collected.

Economically important reproductive traits age at first calving, calving interval, gestation length, number of services per conception and days open were considered for evaluating the reproductive performances of cows. Opportunities and constraints of dairy cattle husbandry was also assessed using structured questionnaire. The researcher's own observation, interview using structured questionnaire, focus group discussions and keeping records on performance parameters was also used for data gathering.

Besides performance records recalled indicative information was also incorporated. Researcher's own observation, questionnaire survey, records on reproductive and productive performances, focus group discussion with model or experienced farmers and communication with livestock production experts at different levels were used as data collection tools.

2.3. Data analysis

All the data was analyzed using Statistical Package for Social Sciences (SPSS) version 20. Statistical variations for categorical data were tested by means of cross tabs/Chi-square Tests. Significant differences were considered at $P < 0.05$ whereas the other numerical data were subjected to one way analysis of variance (one-way ANOVA).

Mean comparisons was carried out using Turkey's honestly significant difference test and levels of significance was also considered at $P<0.05$. The analyzed data was presented using table, figures, percentages, means, and standard error of means. The appropriate statistical model used for characterization of the dairy cattle production and feeding system is as follows (Eq. 2):

$$Y_{ijk} = \mu + \alpha_i + \Sigma_{ij} \qquad (2)$$

Where $yijk$ = total observation due to i^{th}, agro ecology effect μ = is overall mean

α_i = the i^{th} effect of location (agro-ecology), Σ_{ij} = random error

3. Results and Discussion

3.1. Purpose of keeping dairy cattle in the study area

The purposes of keeping dairy cattle in the study area were varied between agro-ecologies as presented in Table 1. Highland farmers preferred to keep dairy cattle to often male calves to assist draught power than milk productions, mid-altitude dairy cattle producers kept to produce milk for either household consumption or daily income from sale of raw milk. Moreover, male calves were grown for fattening whereas culling of heifers or cows were practiced due to lack of space. Whereas lowland farmers kept cattle to produce milk for household consumption, source of income from sour butter milk and butter sale, income from sale of animals, to assist draught power and to use them as asset. On the other hand, income from sale of animals and manures used as bio gas were non-significant (P>0.05). The present study agrees with Asrat et al. (2016) in and around Wolaita Sodo town. The role of animal dung in study area was not that much used to the crop production system, especially at highland and lowland districts because of lack of awareness and lack of extension services.

Table 1. Purpose of keeping dairy cattle in the study area

Purpose of keeping	Agro-ecology (%)			Overall (n=149)	p-value
	Highland (n=26	Mid altitude (n=52)	Lowland (n=71)		
For milk consumption	0	100	100	82.6	***
Produce raw milk for daily income	0	61.5	0	21.5	***
Income from sour milk & butter	0	38.5	100	61.1	***
Growing male calves for ploughing	100	38.5	50.7	55	***
For asset	0	0		24.2	***
Income from sale of animals	100	100	100	100	NS
Manure for bio-gas	0	3.8	0	1.3	NS
Manure for fertilizer	0	78.8	0	27.5	***

n= number of the respondents, NS= not significant, ***=P<0.001 significant

3.2. Cattle herd size holding and composition in study area

Cattle holdings and herd structure in the three agro-ecologies are presented in Table 2. The overall average local cattle holding per household where 9.5 heads per household was varied between agro-ecologies, being highest in Lowland 19.18 followed by highland 7.04 and mid-altitude 2.27 heads per household, respectively. The overall average of unidentified blood level group of HF and Jersey crosses holding per household were 2.6 and 0.72, respectively. The current result agrees with the finding of Yayeh et al.(2014) for Debremarkos district where cattle heads per household reported was 10.60,Yohannes(2015 reported for Borena and Guji zones Shakiso, 9.8) heads per household and Philimon (2012) for East Shewa Zone which was 10.39 cattle heads per households. The current finding is much lower than Yabello area, which were 25.7. This is because in the present study area low number of cattle founded in mid-altitude and highland than lowland area. The highland and lowland agro-ecologies of the district were occupied by 100% of indigenous or local cows. In mid-altitude of the district 60.28% were cross breeds and 39.72% were local cows. This was due to the fact that mid-altitude was located around the district town and the dairy cattle producers had well organized awareness to dairy cattle production, feeding and solely used to AI services to improve their own local cows.

Table 2. Average cattle herd size and compositions in the study area

Types breeds	Agro-ecology			
	Highland (N=26)	Mid-altitude (N=52)	Lowland (N=71)	P-value
HF cross breed				
Milking cows	-	0.94	-	0.14
Pregnant cows	-	0.12	-	0.05
Dry cows	-	0.48	-	0.08
Heifers	-	0.31	-	0.09
Male calves	-	0.35	-	0.09
Female calves	-	0.40	-	0.07
Bulls/oxen	-	0	-	0
Total		2.6	-	0.52
Jersey cross breed				
Milking cows	-	0.25	-	0.07
Pregnant cows	-	0.14	-	0.07
Dry cows	-	0.04	-	0.02
Heifers	-	0.06	-	0.04
Male calves	-	0.23	-	0.07
Female calves	-	0	-	0
Bulls/oxen	-	0		0
Total		0.72		0.27
Local cows/zebu breed				
Pregnant cows	0.62^{b}	0.17^{c}	1.55^{a}	0.46
Dry cows	0.62^{b}	0.0^{c}	3.14^{a}	0.72
Heifers	0.88^{b}	0.02^{c}	2.89^{a}	0.66
Calves	1.73^{b}	0.81^{c}	3.66^{a}	0.77
Bulls/oxen	1.69^{b}	0.06^{c}	4.73^{a}	0.82
Total	7.04	2.27	19.18	4.04

Regarding herd composition, the overall average number of local cattle between agro-ecologies oxen/bulls (6.48 heads per household) was used for breeding and ploughing purposes, milking cows (5.92 heads per household), pregnant cows(2.34 heads per household), dry cows (3.76 heads per household), Heifers (3.79 heads per household) was used to stock replacement purposes and Calves (6.2 heads per household). The average number of HF crosses only in mid-altitude area was milking cows(0.94 heads per households), pregnant cows(0.12 heads per household), dry cows (0.48 heads per households), heifers(0.31 heads per household) , female calves(0.40 heads per household) were used for stock replacement while 0.35 male head calves per households were used for fattening purposes. The average number of Jersey crosses only in mid-altitude area was milking cows (0.25 heads per households), pregnant cows (0.14 heads per household), dry cows (0.04 heads per households) and heifers (0.06 heads per household) and male calves (0.23 heads per households) were used for fattening purposes.

3.3 Breeding Practices

The overall breeding practices of dairy cattle production in study areas was 78.5% natural mating with local bulls and 21.5% Artificial insemination (AI). According to the respondents, the reason for the limited use of AI especially in highland, lowland and partial part of mid-altitude dairy cattle producers were lack of awareness, lack of provision of extension services and unavailability of road access. The majority of mid-altitude (61.5%) of the households used AI as a sole source of genetic improvement while 38.5% used solely local bulls. Whereas highland and lowland dairy cattle producers used 100% local bulls for breeding practices. The breeding practice was different in mid-altitude than highland and lowland areas. The present study agrees with Asrat et al. (2015) for Humbo Woreda, Wolaita Zone, Southern Ethiopia.

3.3.1. Criteria to select dairy cows in the study area

Selection criteria of dairy cows were differed between agro-ecologies of the study area. The most widely used selection criteria were milk yield, availability and fat content of the breed in the study area as presented in Figure 1. When agro-ecologies were compared, the mid-altitude dairy producers were better in the selection of dairy cows than highland and lowland areas.

3.3.2. Calf rearing practices

Calf rearing practices varied between agro- ecologies of the study area. Almost all highland farmers focused on calf rearing because of calves are grown to assist draught power. As a result, they feed colostrum and common milk freely up to lactation length. Among Mid-altitude dairy producers 61.53% have crossbred and feed colostrum averagely for one week because they focus on milk production for income sources while 38.47% have local cows and focus on calves and milk used for household consumption and they feed milk freely for the calves. Lowland farmers have large number of local cows, so they were focus on calves other than milk production and feed their calves colostrum freely. Overall, of the households were feed colostrum averagely for 6.3 days. The average weaning age of calves 7.19 months highland, 5.28-month mid-altitude and 7.40-month lowland, this figure showed that at mid-altitude area wean age of calves was lower than highland and lowland, because in mid- altitude area the households reared cross breed cows and they focus prior to milk production than calves, even though cross breed calves grow faster than local calves genetically. This result line with the reported by Asaminew and Eyassu (2009) in Bahar Dar Zuria and Mecha areas and Asrat et al. (2015) for Humbo Woreda. All of the respondent supplement after birth the new born animals with soft green local grass between the range 15 and 20 days.

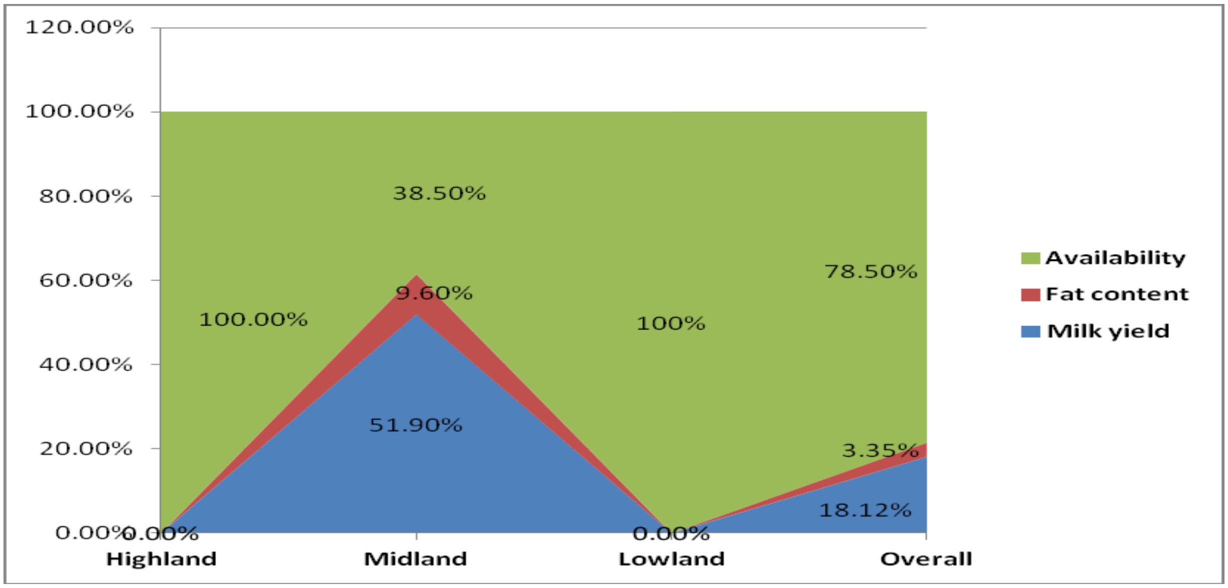

Figure 1. Selection criteria of dairy cows in the study area

3.3.3. Culling of dairy cattle in the study area

Culling of dairy animal in the study areas varied between agro-ecologies as presented in Table 3. The overall culling of animals in the study areas were based on production problems, feed shortage, disease (mastitis), space problems and to get financial requirement. The current finding agreed with reported by Philimon (2012) for Selected Woredas of east Shewa Zone, Oromia region. In comparison between agro-ecologies culling of dairy cows due to space problems was observed in more percentage in mid-altitude (town) area than highland and lowland areas. Production problems was higher in lowland area followed by highland than mid-altitude area.

Table 3. Culling of dairy in cattle in study area

Purpose of keeping	Agro-ecology (%)			Overall	p-value
	Highland (n=26)	Mid altitude (n=52)	Lowland (n=71)	(n=149)	
Production problems	15.4	0	54.9	28.9	***
Disease problems(mastitis)	0	11.5	0	4	**
Space problems	0	69.2	0	24.2	***
To get financial requirement	92.3	0	52.1	35.5	***
Feed shortage	67	79	7	61.35	***

N= number of the respondents, **=<0.01, significant, ***=p<0.001 significant

3.4 Features of dairy cattle production system in Derashe area: A focus group discussion

Focus group discussion was held in the study areas with 33 (29 male and 4 female) household headed. Highland (13 males only), mid-altitude 11 (7 males and 4 females) and lowland area (9 males only). According to the focus group discussion results, cows were not specialized for milk production at highland. Similarly lowland farmers were rearing the dairy cattle for multipurpose such as for milk consumption, calf rearing, income from sale of animals and milk products and for useas asset.

The feeding system of highland farmers in the study area was tethering on their own backyard, road sides and supplementing crop residues, enset and palatable trees/shrubs. The mid-altitude dairy cattle producers feeding systems were intensive/stall feeding or zero grazing by green and dry grass (standing hay), crop residues, enset and non-conventional feeds, like katikala, tella and cheka residues respectively, tethering and free grazing for a few times on private grazing land. In lowland area the feeding systems of dairy cattle producers were dominated by free grazing on natural pastures, supplementing crop residues only at morning time before free grazing. Tuber crop such as enset is also commonly used in the study area of highland and mid-altitude. Crop residues are commonly used as animal feeds sources in three agro- ecologies of the study area. There is little practice (tradition) of developing improved forages in the highland area like, elephant grass and Desho. Even though there was lack of industrial by- product feed sources in three agro-ecologies of the district. Because the study district was far from the sources. Generally dairy cattle production and management practices were poor and it should be requiring many training and extension services in the study area. The present study agrees with Misgana et al. (2015 in Selected Districts of East Wollega Zone, Ethiopia.

3.5 Reproductive and productive performance of dairy cows in study area

The mean (±SEM) age at first service (AFS), age at first calving (AFC), Days open (DO), calving interval (CI), and number of services per conception (NSPC) in three agro-ecologies of the study area is summarized in Table 3.

3.5.1 Age at first service (AFS)

The mean (±SEM) age at first service in the mid-altitude area was for Holstein Friesian (HF) and Jersey cross which were 19.85±1.1 and 24.09±0.51 months, respectively. The overall mean (±SEM) age at first service for local breeds were 39.41±0.55 months. Local breeds mean of (AFS) was significantly varied between agro-ecologies (P<0.001) in highland, mid-altitude and lowland areas were 41.08±1.05,40.87±1.15 and 36.29±0.63 months, respectively. Lowland area mean age at first service of local breeds were lower than in highland and mid-altitude areas.

The current finding of mean AFS of HF cross in the study area was 19.85±1.1 months. This result is higher than the value reported by Nibret (2012) in and around Gondar town and Dessalegn et al. (2016) in Bishoftu and Akaki town with the values of 15.4 and 18.7±3.7 months, respectively on the same HF crossbred because of the better dairy cattle managements practices applied in in the study area. However, lower than the value reported by Embet and Zeleke (2007), Nuraddis et al. (2011), Belay et al. (2012), Hunduma (2012), and Kumar and and Alemshet (2014) in Dire-Dawa, in Gondar towns, Debre-Birhan, Jimma town, Asella, Eastern Zone of Tigray, in Mekele and in and around Adigrat town, respectively with the values of 25.6, 27.5, 24.30±8.01, 25.2±1.1and 25.5±0.21 months, respectively. The current results recorded for AFS of Jersey crossbred was 24.09±0.51 months. This result is similar to the value reported by Habitamu et al. (2010) in Wolaita Sodo with the value of 24.07 month. It is lower than the finding of Demissu et al. (2014) in and around Horro- Guduru who reported that 33.3±10.9 month. The current result of the mean AFS of local cows was 39.414±0.552 months. This finding is lower than the value reported by Debir (2016) in Sidama zone with the values of 44.1±5.9 months.

3.5.2 Age at First Calving (AFC)

The mean(±SEM) age at first calving in mid-altitude area of cross breed of HF and Jersey were 28.52±1.35 and 33.09±0.5months respectively. Overall mean(±se) number of age at first calving of local breeds were 48.48±0. 56months.The mean(±se) age of first calving of local breed in highland, mid-altitude and lowland were significantly varied between agro-ecologies(P<0.001) of 50.02±1.6, 50.09±1.13 and 45.32±0.64 months, respectively.The current finding of mean of HF crossbred of AFC was 28.519±1.354months.This result is higher than the value reported by Nuraddis et al.(2011) in Gondar town and Dessalegn et al. (2016) in Bishoftu and Akaki town with the values of 23.1 and 26.9±5.4 months respectively, but lower than the value reported by Embet and Zeleke (2007), Nibret (2012), Alemshet (2014) and Debir (2016) in Selale and Addis Ababa, in North Gondar Zone, Dire-Dawa, in and around Gondar town, in North Shewa Zone, Eastern Zone of Tigray, in and around Adigrat town and Sidama Zone , Southern Ethiopia respectively with the values of 30.14, 36.41±0.0.9, 36.2±1.03, 32.4, 39.83±0.18, 39.6±0.4, 34.8±0.21 and 39.3±3.25 months respectively. The current result of mean of AFC of Jersey cross was 33.09±0. 5months.This result line with the value reported by Habitamu et al. (2010) in Wolaita Sodo with value of 34.5 months and lower than the value reported by Demissu et al. (2014) in and around Horro- Guduru, with the value of 42.2±11.45 months. The current finding of mean of AFC of local cows was 48.483±0.558 months. Debir (2016) in Sidama Zone Southern Ethiopia with the values of 59.90±0.83 and 51.9±5.9 months, respectively.

3.5.3 Days Open (DO)

The mean(±se) number of days open (DO) in mid-altitude(town) areas was of cross breeds of HF and Jersey were 141.11±6.44 and 152.27±3.84 days, respectively. Over all mean(±sem) number of days open of local cows were 170.62±0.88 days. The mean (±sem) number of days open of local cows were significantly varied between agro-ecologies ($P<0.001$) in highland, mid-altitude and lowland areas were 168.96±1.674, 169.78±1.78 and 173.13±1.01days, respectively. The current finding of mean of (DO) of HF crossbreds were 141.11±6.44 days. This result higher than the value reported by Hunduma (2012), Nibret et al. (2012) and Nuraj et al. (2014) in Asella town, in and around Gondar and in Gondar, Ethiopia with the values of 85.6±5.6, 87and 104.23±28.81 days respectively and lower than the value reported by Nuraddis et al. (2011) and Belay et al. (2012) in Gondar town and Jimma town with the value of 171 and 155 days respectively at the same HF crossbred. The day's open of local cows in current study was 170.624±0.882 days. This result higher than the value reported by Nuraj et al. (2014) in Gondar, Ethiopia with the value of 148.33±38.44 days.

3.5.4 Calving Intervals (CI)

The calving interval is a period between two consecutive parturitions. The mean(±se) number of months of calving interval in mid-altitude area of HF and jersey crosses were 22.82±0.91and 24.46±0.31 months respectively. The overall mean(±se) of calving interval of local cows were 26.54±0.32months. The mean(±se) of calving interval of local breeds were significantly varied between agro-ecologies($P<0.001$) in highland, mid-altitude and lowland areas were 25.62±0.61, 28.61±0.65 and 25.39±0.37 months respectively. The current finding of mean CI of HF crossbred was 22.82±0.91 months. This result line with the value reported by Mulugeta and Belayneh (2013) in Chacha town and nearby selected kebeles, North Shoa Zone, Amhara Region, Ethiopia with the value of 22±4.4 month. However, it is lower than the value reported by Nuraddis et al. (2011), Hunduma (2012), Debir (2016), Dessalegn et al. (2016) and

Zereu and Lijalem (2016) in Gondar town, Asella town, Sidama zone and Bishoftu and Akaki town respectively with the value of 13.9, 12.42, 17.1±4.5 and13.0±2.1 months respectively. Even though it is lower than the finding of Alemshet (2014) in and around Adigrat town, North Ethiopia with the value of 26.5±0.32 month. The current finding of mean calving interval (CI) of local cows was 26.54±0.32 months. This result agreement with the value reported by Mulugeta and Belayneh (2013), Damitie et al. (2015) and Debir (2016) in Chacha town and nearby selected kebeles, North Shoa Zone, Lake Tana Watershed, North Western Amhara, Ethiopia and Sidama Zone, Southern Ethiopia respectively, with the value of 24.94±4.1, 25.5±0.52 and 23.6±4.4 months respectively. However, the current result is higher than the value reported by Zereu and Lijalem (2016) in Wolaita Zone, Southern Ethiopia with the value of 19.91±0.83 month. Number of Services Per Conception (NSPC)

The mean(±se) number of services per conception (NSC) of HF and Jersey cross breeds were 1.78±0.1 and 1.98±0.02respectively. The overall mean(±se) of number of services per conception of local breeds were 2.01±0.01. The mean(±se) of number of services per conception of local breeds was significantly varied between agro-ecologies($P<0.001$) in highland, mid-altitude and lowland areas were 2.03±0.01, 2.00±0.01 and 1.99±0.01 respectively. The current finding of mean NSPC of HF Crossbred was 1.781±0. 102.The current result agreement with Shiferaw et al. (2003), Yifat et al. (2009), Alemshet (2014) and Debir (2016) in Central Highland, Ethiopia, in and around Zeway, North Shoa Zone, in and around Adigrat and Sidama Zone, Southern Ethiopia, they were reported that 1.62, 1.67, 1.6, 1.73±0.04 and 1.8 respectively. But higher than the finding of Nuraddis et al. (2011), Hunduma (2012), Belay et al. (2012), Nibret et al. (2012) and Niraj et al. (2014) in Gondar town, Asella town, Jimma town, in and around Gondar town and in Gondar, Ethiopia respectively with they were reported that 1.29, 1.52±0.9, 1.56, 1.3 and 1.5±0.3 respectively. Mean of NSPC of Jersey cross in current study was 1.982±0. 018.The current result agreement with the finding of Gizaw et al. (2011) in Ethiopia, Habitamu et al. (2010) in Wolaita Sodo and Demissu et al. (2014) in and around Horro-Guduru, they were reported that 1.92, 1.79 and 1.8 respectively. The current mean of NSPC of local cows was 2.01±0.01. This result agrees with that reported by Niraj et al. (2014) in Gondar, Ethiopia and Debir (2016) in Sidama Zone, Southern Ethiopia with the value that 2.2±0.2 and 2.4, respectively.

Table 4. Mean(±SE) reproductive performance of HF and Jersey crosses and local cows in the study district

Independent variable	Agro-ecology (Mean ± SEM)			Overall	P-value
	Highland (n=26)	Midland (n=52)	Lowland (n=71)	(n=149)	
HF cross breed					
Age at first services		19.85±1.10		19.85±1.10	
Age at first calving		28.52±1.35		28.52±1.10	
Days open		141.11±6.43		141.11±6.43	
Calving intervals		22.82±0.91		22.82±0.91	
Number of services per conception		1.78±0.10		1.78±0.10	
Jersey cross breed					
Age at first services		24.09±0.51		24.09±0.51	
Age at first calving		33.09±0.51		33.09±0.51	
Days open		152.27±3.84		152.27±3.84	
Calving intervals		24.46±0.31		24.46±0.31	
Number of services per conception		1.98±0.02		1.98±0.02	
Local cows					
Age at first calving	50.04±1.06[a]	50.09±1.126[a]	45.32±0.64[b]	48.48±0.56	***
Days open	168.96±1.67	169.78±1.78[b]	173.13±1.01[a]	170.62±0.88	***
Calving intervals	25.62±0.61[b]	28.61±0.648[a]	25.39±0.37[b]	26.54±0.32	***
Number of services per conception	2.03±0.01[a]	2±0.010[a]	1.997±0.01[b]	2.01±0.01	***

n= number of respondents, se± standard error, HF= Holstein Friesian, ***= P<0.001 significant

3.6 Milk yield of cross breed and local cows in the study area

Milk yield is one of the most important outputs of dairy cattle production. According to breed type, management and season of the year in Table 5, the mean (±sem) daily milk yield of HF cross in mid-altitude area was 8.34±0.58 liters/day/cow and mean (±se) daily milk yield of Jersey cross breed in mid-altitude area was 5.07±0.25 liters/day. The overall mean (±se) of daily milk yield of local was 1.97±0.05 liters/day/cow. Mean (±SEM) daily milk yield of local cows were significantly varied between agro- ecologies ($P<0.01$) in highland, Mid-altitude and lowland areas were 1.93±0.1,2.31±0.1 and1.68±0.06 liters/day/cow, respectively. High daily milk yield was observed of local cows in mid-altitude and highland than the lowland area because better management practices in both agro-ecologies than lowland area. The mean daily milk yield (DMY) of HF crossbred was 8.34±0.58 liters/day.

The current result line with the finding of Belay et al. (2012) in Jimma town that reported 8.4 liters. Even though higher than the finding of Amasaib et al. (2008), Niraj et al. (2014) and Ketema (2014) in Sudan, Debremarkos, in Gondar and Kersa Malima Woreda,Oromiya, respectively with the values that reported 6.8, 7.3±4.65, 6.5 and 4.73±3.2 liters/day/cow, respectively. Although the current result is lower than the finding of Dessalegn et al. (2016) in Bishoftu and Akaki town 11.6±3.1 and 10.8±2.4 liters/day/cow, respectively. The overall mean daily milk yield (DMY) of local cows was 1.97±0.1liters. Current finding similar with the finding of Nuraj et al. (2014) in Gondar, Ethiopia and Zereu and Lijalem (2016) in Wolaita Zone, Southern Ethiopia, they reported that 1.97 and1.99±0.06 liters/day respectively. However, higher than Ketema (2014) in Kersa Malima Woreda, Oromiya with value that reported 1.15±0.39 liter.

Table 5. The average Mean± SE of daily milk yield of cross breed and local cows in the study district

Independent variable	Agro-ecology (Mean ± SEM) Highland (n=26)	Midland (n=52)	Lowland (n=71)	Overall (n=149)	P-value
HF cross breed-Milk yield per day in liter		8.34±0.58		8.34±0.58	
Jersey cross breed-Milk yield per day in liter		5.07±0.25		5.07±0.25	
Local cows-Milk yield per dairy in liter	1.93±0.10^{b}	2.308±0.10^{a}	1.68±0.10^{b}	1.97±0.05^{b}	**

n= Number of respondents, SE± standard error, HF= Holstein Friesian, **= P<0.01significant

3.7 Lactation length of cross breed and local cows in the study area

The mean (±SE) number of lactation length of HF crosses, Jersey crosses and local cows were 8.62±0.23, 7.51±0.55 and 7.40±0.08 months respectively as presented in Table 6. The overall mean (±SE) of lactation length of local cows were non-significantly varied (P>0.05) across three ago-ecologies. The mean(±se) of lactation length of mid-altitude area HF cross breed was longer than both highland and lowland areas of local breeds because the mid-altitude dairy producers were rearing more cross breed and their most interest focuses on dairy production than the highland and lowland areas. The mean lactation length of HF cross was 8.62±0.23 months.

The current result is disagreed with the finding of Amasaib et al. (2008) in Sudan, Belay et al. (2012) in Jimma town, Ketema (2014) in Kersa Malima Woreda, Nuraj et al. (2014) in Gondar, Ethiopia and Dessalegn et al. (2016) in Bishoftu and Akaki town, where the value reported by 12.5, 9.1, 10.1, 10.8 and 9.22±1.17 months respectively. The overall lactation length of local cows in current study area was 7.40±0.076 months. The current result agreement with the value reported by Niraj et al. (2014) in Gondar Ethiopia with the value of 6.8 month and lower than the value reported by Ketema (2014) in Kersa Malima Woreda, Zereu and Lijalem (2016) in Wolaita Zone, Southern Ethiopia, with the values of 9.8, 10.5 and 10.802±0.503 months respectively.

Table 6. Mean (±SEM) of lactation length (in months) of cross breed and local cows

Independent variable	Agro-ecology (Mean ± SEM)			Overall	P-value
	Highland (n=26)	Midland (n=52)	Lowland (n=71)	(n=149)	
HF cross		8.62±0.22		8.62±0.23	
Jersey cross		7.51±0.55		7.51±0.55	
Local cows	7.5±0.17	7.35±0.18	7.38±0.097	7.40±0.08	0.1335

SEM=Standard error of means, HF=Holstein Friesian

Since dairy production and productivity was very low in highland and lowland areas due to large number of genetically poor local cows. In order to alleviate this problem, creating awareness for the farmers to use AI services to improve their own local cows. Extension services will give due attention for innovators and early adopter farmers.

4. Conclusions

Generally, dairy cattle production in Derashe district is a subsistence type of production system except mid-altitude (town) area. Indigenous local zebu cattle Boran and uncharacterized local breeds are dominate cattle population in highland and lowland areas with low milk production potential. Improving such low milk production potential of local cows via Artificial Insemination is challenged by many factors, such as lack of awareness among farmers, lack of extension services, lack of training and lack of infrastructures. Dairy cattle production in the study area constrained by provision of extension services, Genotypic problems, lack of AI services in highland and lowland. Despite of the many problems and constraints that might slow down or reduce the development of the dairy cattle production in the study area, there were also suitable condition to improve dairy cattle production and productivity for the future times. These are climatic condition/ agro-ecology, cereal crop production, road access, human population increment and AI services specially in mid-altitude (town) area.

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Conflict of Interest

The authors state that they do not have any conflicts of interest.

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