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TABLE OF CONTENTS

Farmers' Finger Millet [*Eleusine coracana* (L.) Gaertn] Seed Management Practices in West Gojjam Zone, Northwestern Ethiopia

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Abstract: *Finger millet is one of the major growing crops in Amhara region particularly in West Gojjam Zone in maintaining food and nutrition security. However, the quality of finger millet seeds, agronomic packages and the productivity of the crop is very low as well as maintaining of genetic diversity is not documented. The present study was carried out in Yilmana-Densa and Mecha districts of Northwestern Ethiopia to document farmers' knowledge and experiences on finger millet seed management practices. Data were collected from 120 households using a structured questionnaire and focus group discussion. The results showed that 72.5% of the respondents explained that seed selection is made by both husband and wife; and the seed was selected soon after threshing 58.3% of the respondents replied that the seeding materials are selected soon after threshing while 37.5% did during planting time. Almost all respondents used locale made materials to clean seed and 97.5% of them didn't use storage chemicals as finger millet do have a long shelf life like teff. Nowadays farmers used improved varieties of finger millet as its productivity is better than the local varieties. Therefore, the existing finger millet seed management practices has been contributing for maintaining genetic diversity, however, the system is insufficient to hold and enhance the existing function of the extension organization, farmer cooperative union, NGO and government organization to meet the seed quality thereby seed security. Hence, establishing and strengthening linkages among stakeholders to use indigenous knowledge on seed management practices, seed selection, diversity conservation and seed security for a bad time.*

Keywords: Genetic diversity, Indigenous knowledge, Seed cleaning, Seed security

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1. Introduction

Agriculture is the mainstay of the Ethiopian economy and the primary source of livelihood for the majority of its population. In view of this, the supply of high-quality seed of well-adapted crops could be considered crucial among the other agricultural inputs. This is because seed is the most vital and crucial input for crop production, one of the ways to increase productivity without adding appreciably to the extent of land now under cultivation by planting quality seed (https://www.agriquest.info/quality). Even if, seed consider as a major agricultural input, its quality declined due to poor postharvest handling technics like physical damage during threshing, transportation, improper moisture content, poor storage, insect/disease attach, or prolonged shelf life and others, all these will affect the productivity of finger millet. However, it is one of the most important crops to achieve both food and feed security, especially in drought-prone areas. Millets are grown and can give reasonable yield even under harsh growing conditions with low-input agricultural situations in which major cereal crops often produce low yields in areas of Africa and Asia (Adekunle, 2012; Amadou et al., 2013; Changmei and Dorothy, 2014). However, research effort on varietal development as well as in seed multiplication and supply is very limited. As a result, finger millet producers traditionally developed a number of cultivars and have been selecting their own seed for the next season.

Finger millet seed management practice has been undertaken from the time of domestication until now. It was exercised through selecting landraces, which are adaptable to the existing environmental condition and having the most preferred traits. The seed management activities have been played their own role in seed quality, on-time availability, productivity and diversification of varieties. However, finger millets seed management practices of farmers are not studied well and well documented. Therefore, this study was initiated to assess and document farmers' knowledge and experiences on finger millet seed management practices in West Gojjam Zone, Northwestern Ethiopia.

2. Materials and Methods

2.1. Description of the study area

The study was carried out in Yilmana-Densa and Mecha Districts (*Woredas*) in West Gojam Zone of Northwestern Ethiopia. Yilmana-Densa and Mecha Districts are found between 11^o 16'19" N and 11^o 25'20" N latitudes, and 37^o 28'38" E and 37^o 10'20" E longitudes; with an altitude of 2240 and 1960 meters above sea level (m.a.s.l.). The soil type of the study area is characterized as Luvisol and Nitosol with pH setting of 5.38 to 5.48 and 5.09 to 5.3, respectively (NSRC, 2006; Berhanu, 2014). The temperature of Yilmana-Densa (Adet) varies between 10.9 (Min) and 26.9°C (Max) with a mean annual rainfall of 1164.1 mm. On the other hand, Mecha District experienced an annual temperature that ranges from 9.4 to 28.1^{O}C with an annual rainfall of 1454.5 mm (WAMSC, 2013). The farming system of these districts is mainly mixed crop-livestock production. Most farmers in the district undertake both crop and livestock production activities. Agriculture is mainly characterized by rain-fed production system. The major crops grown in the study areas include maize, finger millet, tef, wheat, barley, green peas, fava bean and vegetables.

2.2. Sampling procedures and participants selection

The study population comprised of a researcher in a public agricultural research organization, extension personnel in extension offices and bureaus of agriculture and rural development, seed supplier organizations and farmers who produce finger millet. The survey was undertaken with a multi-stage sampling technique having three stages that involve the selection of (1) sample zone and districts, (2) Peasant associations and (3) smallholder farmers. In the first stage, West Gojam Zone and two Districts, namely Yilmana-Densa and Mecha were selected purposively from all the finger millet growing zones and districts based on larger area coverage and production potential. In the second stage, the study included four total finger millet growing Peasant associations; two PA from each district based on their area coverage and production potential of finger millet. In the third stage, 120 farm households were randomly selected from lists of names of household head in the peasant association. The sample size was determined proportionally to the population size of farmers.

2.3. Data collection and analysis

The information was collected on farmers' seed management practices: perception of seed cleaning, seed sorting, seed storage, varietal obsolete and seed security. Both qualitative and quantitative primary data were collected from extension staffs, researchers, farmers and key informant. Respondents were interviewed independently with a structured questionnaire. Further, additional information was collected using Focus Group Discussions (FGDs) and individual interviews on socioeconomic and demographic characteristics of sample farmers, seed selection, seed cleaning, seed storage and seed security. In addition, an open-ended questionnaire was used to capture information during the focus group discussion from key informants, who have knowledge and experience about the management practice of finger millet.

Descriptive statistics was employed to analyze the seed management practice of finger millet. The qualitative data generated using FGDs and key informants were analyzed thematically. The quantitative data analysis was performed using SPSS (Version 21) computer package (IBM, 2012); and results are presented in the form of frequency distribution and percentage.

3. Results and Discussion

3.1. Socioeconomic and demographic characteristics of sample farmers

Of the 120 sample households about 113 were male-headed and seven were female-headed. Mecha and Yilmana-Densa had 54 and 59 male-headed households, respectively. Of the seven female-headed households, five were in Mecha and two were in Yilmana-Densa. The mean number of male and female family members above 15 years was 1.75 and 1.54, respectively. This group of people is economically active workforce, which helps farmers during crop production. On the other hand, the mean number of male and female family member less than 15 years old was 1.34 and 1.12, respectively, which are participated mainly in cattle herding (Table 1).

Table 1: Mean family size and number of family members in sample households

Item	Yilmana-Densa District		Mecha District	
	Mean	Std.	Mean	Std.
Family size	5.75	1.73	6.58	1.66
Male family member (>15 years)	1.75	1.07	1.76	1.07
Male family member (<15 years)	1.34	1.05	1.48	1.18
Female family member (>15 years)	1.54	0.87	1.78	0.74
Female family member (<15 years)	1.12	0.82	1.56	1.12

Std. = Standard deviation

Table 2: Age of farmer and level of education in sample household (n= 120)

Item	Yilmana-Densa district		Mecha District	
	Mean	Std.	Mean	Std.
Age MHH	43.9	10.5	45.04	8.6
Age FHH	37.5	3.5	46.4	4.2
Level of education	Number of farmer	Percent of farmer	Number of farmer	Percent of farmer
Illiterate	22	36.1	31	52.5
Read and write	3	5	2	3.4
Adult education	24	39.3	14	23.7
Grade (1-4)	10	16.4	10	17.0
Grade (5-8)	1	1.6	1	1.7
Above	1	1.6	1	1.7

Std. = Standard deviation; MHH = Male household head; FHH = Female household head

About 52.5% the sample respondents in Mecha and 36.1% in Yilmana-Densa district were illiterate. About 63.9% of the respondents in Yilmana-Densa district were literate where 19.6% had got a formal education. In Mecha District, about 47.5% were literate where 20.4% had exposure to formal education. These results showed that more than 50% of the respondent were literate with different level of education, that bring good opportunity for agriculture extension service, which allows farmers to make better decision and choice for improvement of seed management practice. These findings agree with that of Reimers and Klasen (2012) and Oduro-Ofori *et al*. (2014) who also discovered that the technology adoption of farmers increases in relation to the level of education to obtain maximum output.

The average age was 43.9 (Std. = 10.5) and 37.5 (Std =3.5) for male and female sample farmers in Yilmana-Densa. The average age in Mecha was 45.04 (Std. = 8.6) and 46.4 (Std. = 4.2) for male-female sample farmers, respectively (Table 2).

3.2. Farm and household resources

The results of the survey indicate that the average farmlands owned by the farmers were 1.24 ha in Mecha and 1.2 ha in Yilmana-Densa districts. From interviewed farmers, 25.5% of Mecha and 31.1% for Yilmana-Densa farmers' have owned less than 1 ha of land. On the other hand, 8.5% of Mecha and 6.4% of Yilmana-Densa farmers' own more than 2 ha of land (Table 3).

During the assessment of oxen, the result depicted that 18.7%, 54.2%, 18.6% and 8.5% of Mecha, owned more than two oxen, two oxen, single ox and have no ox; similarly, 16.4%, 59%, 23% and 1.6% of Yilmana-Densa owned more than two oxen, two oxen, single ox and have no ox, respectively (Table 3). Farmers gave comparatively large area coverage for finger millet production from available cultivation of land. Finger millet is among the highest labor demanding crops, farmers said that it was the crop that most required mechanization, particularly for threshing. Hence, farmers have two and above two oxen, which enables them to thresh timely by sharing their oxen with relatives and neighbors (which is known as *wonfel*) before deteriorating the seed quality through high rainfall and sun damages.

Table 3: Farm and household resources of sample households (n=120)

Farm and household resource	Yilmana-Densa district		Mecha district	
	Mean	Std.	Mean	Std.
Number of oxen	1.9	0.7	1.93	1.03
Number of cattle	9.0	4.6	7.6	7.1
2012 amount of land cultivated (ha)	1.77	0.63	1.73	0.72
2012 rent farm size (ha)	0.57	0.54	0.49	0.5
2012 own land (ha)	1.2	0.57	1.24	0.62
Maize (ha)	0.32	0.13	0.51	0.27
Finger millet (ha)	0.26	0.098	0.54	0.25
Tef (ha)	0.62	0.25	0.13	0.24
Wheat (ha)	0.098	0.12	0.004	0.033
Barley (ha)	0.2	0.16	0.04	0.11
Green peas	0.08	0.24	0.0	0.0
Bean	0.08	0.19	0.17	0.06
Noug	0.0	0.0	0.04	0.14
Eucalyptus farm land (ha)	0.11	0.09	0.3	0.21

Std. = Standard deviation

3.3. Seed selection

Farmers are exercising several seed management activities. One of them was seed sorting. About 72.5% of the respondents reported that both husband and wife are responsible for seed sorting while about 20.0% reported that women/wives alone are responsible for seed sorting (Table 4). About 58.3% of the respondents sorted their seeds on the threshing ground after threshing while 37.5% of the respondents sorted the seeds during planting. Only 4.2% of the respondents sorted the seeds before harvesting (Table 4). Characteristics of seeds such as size and weight are important selection criteria.

The results of the present study showed generally most farmers sort the seeds after threshing on the threshing ground and in the store. These practices help to maintain genetic diversity within the cultivar and to contribute to the conservation of finger millet genetic resources. However, during the interview period, the respondents said that, as compared to other cereal crops like teff, finger millet seed and/or variety selection at harvesting stage is low; which is because farmers did not give more care to the crop due to its low productivity and market demand. This kind of activity ascribed how the crop gets low emphasis even by farmers. In contrary to th**ese** result**s**, Baniya *et al.* (2005) reported that many farmers followed seed selection during the harvesting of finger millet, while some did this activity before harvest. The farmers either select the better ears from the whole field or first select a better area and select the better ears from the fixed area only.

Table 4: Finger millet seed selection responsibility and seed selection stages

Seed selection practice	Number of respondents	Percentage
Responsible for selection		
Both husband & wife	87	72.5
Women only	24	20.0
Men only	7	5.8
All family members	2	1.7
Total	120	100
Time of selection		
On the field before harvesting	5	4.2
On threshing ground after threshing	70	58.3
On the store before planting	45	37.5
Total	**120**	**100**

3.4. Seed cleaning

One of the practice exercised by farmers on finger millet seed management is seed cleaning. All respondent farmers used to clean seed during threshing by winnowing using locally made wooden material called "*mankia/lamieda"*. Moreover, farmers also cleaned sorted and cleaned seeds at planting using weight and size based separating materials called "*sefed"*. The seeds are cleaned usually two times using locally made materials. Its main purpose is to improve the physical quality of the seed by removing inert matter, weeds and other crop seeds, and broken or diseased/insect damaged seeds. These locally made seed cleaning materials are also used by farmers in different parts of the country and for different crop species (Bishaw, 2004; Brikti *et al.,* 2011; Birhanu *et al*. 2016).

However, these cleaning methods that were used by the respondent households in this study are inadequate to ensure seed quality. Mechanical devices, called separators, should have to get emphasis for future to be established by farmers' cooperative union and /or projects work on seed sector. Cleaning separate unwanted seeds from wanted ones and thus reduces the bulk to be handled and stored, reduces potential vectors for pathogens and pests, removes moist material to maintain viability (Guzzomi *et al*., 2016).

3.5. Seed storage practice

According to the respondents, finger millet seed does not have a storage problem. Accordingly, 97.5% of the respondents did not apply fungicide or insecticide in the storage to prevent finger millet seed from diseases and insect pest damages. Only 2.5% of respondents use zinc phosphide chemical to control rodents. They did not use specialized or airtight seed storage structures. About 14.2% and 85.8% of the respondents use sack and "*Gushgusha /Gota"*, respectively to store finger millet seeds (Table 5).

The grain storage structure "*Gushgusha or Gota"* is locally made from a mixture of mud and teff or barley straw. Both are kept in house and did not have a mechanism to regulate the relative humidity and the temperature. Hence, the existing finger millet seed storage structures cannot ensure seed quality and cause shorten seed longevity. Therefore, farmers use fresh seeds the production of finger millet. Regular replacement of seed may contribute to maintain genetic diversity through gene recombination as well as to improve the existing landraces through natural selection. Farmers in various countries use various storage materials or structures for storage of finger millet seed including small earthen pots, wooden vessel, bamboo container, tin vessel and small plastic bags (Baniya *et al*., 2005).

Farmers appreciate the long storability of finger millet seed. It is not susceptible to major insect pests such as weevil. This quality of finger millet guaranteed farmers to save seed for bad times that cause total crop failure due to unfavorable weather condition such as drought. This peculiar feature of finger millet makes it a priority crop in most drought-prone areas of Africa and Asia. A similar feature has been reported on another neglected crop teff, which has an absence of serious storage pests (Melkam and Mekbib, 2013).

Table 5: Farmers' finger millet seed storage structures/materials

Storage structure and	Seed		Grain		Mix		Yilmana Densa	Mecha	Total	
Measurement taken	N	%	N	%	N	%			N	%
Sacks	14	11.667	-	-	3	2.5			-	-
Gota/Gushgusha	50	41.67	62	51.67	62	51.67			-	-
No chemical use	-	-	-	-	-	-	61	56	117	97.5
Chemical use	-	-	-	-	-	-	0	3	3	2.5

N = Number of farmers

3.6. Varietal status

Results showed that some farmers have terminated growing different finger millet cultivars, which were widely grown before in the districts (Table 6). From 2002-2007 cropping season, 41.7% of the respondents in Yilmana-Densa District stopped growing a finger millet cultivar called *Angedie*. Similarly, about 58.1% of the respondents from Mecha District terminated *Abate tikur* from the production system. During the period of 2008 to 2013, farmers in Yilmana-Densa District continued with the termination of *Angedie variety* and started withdraw *Abate tikur* from the system. Similarly, in Mecha District farmers continued with the termination of *Abate tikur*, *Angedie* and *Abate necho* from the system (Table 6). These obsoleting of finger millet landraces might be due to small landholdings and availability of high yielding improved variety like *Necho*, *Mecha* and *Degu* which may reduce the competitiveness of land races.

Interviewed farmers were illustrated that norms of self-reliance and social value by the community forced the farmers to keep their own seed in priority from other problems and these make reluctant to admit receiving freely gifted seeds. The finding on side location seed or other side sources, such as exchange and purchasing seed of local variety is considered as second seed source when their own seed is not selected for sowing. This is because of an absence of improved variety and quality seed in the market.

Seed security is vital for food and nutrition security. Reliability and availability of seeds at the right time and in the right price, as well as easy access, are crucial for poor smallholder farmers, but such hallmarks might not be universal in all systems. Farmers' seed systems are often considered good traditional practices for seed security and therefore, for ensuring food sovereignty. The present findings showed that 100% of seed was obtained from the farmer seed system. Similarly, Louwaars (2007) reported that over 60 to 85% of the seed was found from farmer seed system depending upon the crops and countries. Sthapit and Padulosi (2011) also reported that close to 99% seeds of neglected and underutilized crop species sourced from farmer's seed system. According to Wekundah (2012), the informal seed supply system also provides about 80-100% of the seed used in the African states.

The farmers' practice indicated that formal seed multiplication, certification and supply systems do not exist for finger millet and are not sufficiently available for other crops in the study areas. But, it ensured the survival of landraces to obtain the seed they need and enables them to produce for their own consumption, sale and for their social relations within the villages. However, the presence of seed for sowing cannot assure the existence of sufficient food to eat. This trend continues till now because of the absence of improved seed supply in the market.

Table 6: Status of finger millet varieties in the study area

Finger millet withdraw from production system	Yilmana-Densa district (n=12) N	%	Mecha district (n=31) N	%
Between 2002— 2007				
Abate necho	2	16.7	7	22.6
Angedie	5	41.7	7	22.6
Abate tikur	_	_	18	58.1
Total*	7	58.4	32	103.3
Between 2008— 2013				
Abate necho	1	8.3	11	35.5
Angedie	4	33.3	13	41.9
Abate tikur	7	58.3	17	54.8
Nech dekie	_	_	1	3.2
Total	12	100	42	135.4

N = Number of farmers, *the same farmer practiced repeated response

3.7. Household seed security and relation to wealth category

All the respondents in Yilmana-Densa District and 98.3% of the respondents in Mecha District save their own finger millet seed for their next cropping season (Table 7). The wealth category of the respondents was identified on the basis of the following characteristics, which includes hectare of farmland, plantation, livestock and constructed houses. The result showed that, about 21.3% rich farmers; 47.5% medium farmers; 29.5% poor farmers and 1.6% very poor farmers in Yilmana-Densa. In correspondence to the above figures, 28.8%, 54.2%, 17% and 0% of the respondents found to be in Mecha District, respectively (Table 7). Differences in wealth category have been documented in this study. Wealthier households were produce higher production and more self-sufficient in food than poor households. But, seed self-sufficiency have priority in all wealth groups rather than eating or selling a large portion of their harvest. The community norms and social values attributed to retain and store their own seed for the next season or for unfavorable weather condition; and surprisingly the poor farmers can assure their own seed through side location seed sources by off-farm incomes and selling sheep and goats.

Table 7: Farmers' perception for reasons of seed security in the study area

Seed security	Yilmana-Densa District (n = 61)		Mecha District (n = 59)	
	N	%	N	%
Secured farmer	61	100	59	100
In secured farmer	0	0	0	0
Own seed	61	100	58	98.3
Purchase seed	29	47.5	17	28.8
Exchange seed	29	47.5	25	42.4
Wealth category for seed security				
Secured farmer	61	100	59	100
Rich	13	21.3	17	28.8
Medium	29	47.6	32	54.2
Poor	18	29.5	10	17
Very poor	1	1.6	0	0

N = Number of farmers, same farmers practiced more than one criterion

4. Conclusions and Recommendations

Finger millet is a multipurpose staple crop in the study areas. Farmers save and use seeds of local cultivars, due to the unavailability of improved varieties. Quality of the farmer saved seeds is relatively poor since it is not produced and processed as per certified seed production and processing procedures. The existing farmers' seed management practices found to be useful in maintaining genetic diversity and seed security in the study areas. However, high yielding crops threaten diversity of finger millet varieties and farmers started withdrawing the production of some landraces. Therefore, it is critical to collect, conserve and improve the existing finger millet landraces. Establishing and strengthening linkages between stakeholders such as cooperative union, NGOs and government organizations for indigenous knowledge management practices in seed selection, conservation and seed security is necessary.

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Determinants of Technical Efficiency in Agricultural Production among Sub Saharan African Countries

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Abstract: *Climate change has led to a decline in agricultural production due to erratic weather patterns, compromised crop yields and population pressure on arable land. Sub-Saharan Africa is most vulnerable to climate change due to its geographical location, increase in population, destruction of the forests and other agricultural malpractices. This is a threat to livelihoods, food systems, and increase in malnutrition and shocks in food prices. This study examines the influence of climatic factors on the technical efficiency of agricultural production in Sub Saharan Africa using time series data for 25 years from 1991 to 2015 selected from nine countries. The data envelopment analysis estimates technical efficiency with input variable as agricultural land and output variable as agricultural value-added. The panel data analysis response variable is the technical efficiency scores. Predictor variables were population, forest area, temperature, rainfall, and greenhouse gases. In the last 25 years, there has been an increase in population, agricultural land, temperature, and greenhouse gases with a decrease in forest area and rainfall. Temperature, forest area, and greenhouse gases showed significant influences on the technical efficiency of agricultural production. The intricate nature of climate change requires significant efforts to reverse the trend being observed and boost agricultural production efficiency.*

Keywords: Climate change, greenhouse gases, panel analysis, Sub-Saharan Africa, technical efficiency

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1. Introduction

The last two decades have witnessed a drastic change in climatic conditions that have led to a decline in food production. Climate change is taunted to increase the frequency and intensity of disasters, disruption of food production and livestock rearing. This has raised concern among public policymakers and interest groups due to uncertainty in food security and agricultural sustainability (Eniko *et al*., 2018). Climate change is one of the several changes affecting food systems and this varies between regions and the different social groups within a region. The threat of global food shortage is evident due to a number of factors: population pressure, water scarcity, land degradation, frequent droughts, declining soil fertility, lack of credit facilities, poor agronomic practices, poor seed quality, pests, weeds and incidence of diseases (Abera *et. al*., 2018; Nsiah and Fayissa, 2019; Popp *et. al*., 2019). African is already overburdened with food insecurity, poverty and low adaptive capacity but climate change is projected to increase the vulnerability and burden (Muller *et. al*., 2011). The models that derive the relationship between environmental conditions and production systems project a continued decline in crop yields due to climate change (Ray *et. al*., 2019) with traditional rain-fed agriculture facing more climate-related risks (Eniko *et al*., 2018).

Smallholder systems in Africa will be the most compromised in agriculture production due to little adaptive capacity to climate change (Muller *et. al*., 2011). In Asia and Latin-America, there is improved food security that has also reduced the prevalence of undernourishment (Popp *et. al*., 2019). Smallholder farmers account for 80% of all the farms in SSA employing 175 million directly and 70% of the smallholder farmers being women. Subsistence farming is a key employer with 76 % of the population in Botswana, 85% in Kenya and 90% in Malawi depending on agriculture (AGRA, 2014). The future impacts and exposure to climate variability and extremes are expected to increase with time (FAO, 2018). Food systems are changing rapidly due to globalization and urbanization with an increasing population (Gregory *et al*., 2005; Nsiah and Fayissa, 2019). This is compounded by the expected growth of 22% in the SSA population by the year 2050 projected to be 1.5 billion (Nsiah and Fayissa, 2019) and an additional of 2.4 billion people in the world by 2050 (Islam and Wong, 2017). The rate of population growth exceeds the agricultural production due to declining land size, climate change and other vulnerabilities facing farmers (Nsiah and Fayissa, 2019). Worldwide, 821 million people are undernourished, with 237 million in SSA and 257 million are in Africa (Islam and Wong, 2017; FAO, 2018).

The risks for African agriculture and food production are due to anthropogenic climate change with statistical, process-based and econometric models indicating negative and positive impacts on agriculture. The underlying assumptions in the climate change projections and its impact on food production are greenhouse gas emissions, biophysical and socio-economic conditions. Climate change has increased the global mean annual air temperature by 0.74 °C and atmospheric greenhouse gases during the last 100 years (Tokunaga, *et al*., 2015). The vulnerability of the African continent to the effects of climate change are already evident, with predictions indicating that Africa is warmer compared to the global average. Temperature and rainfall are two key determinants of agricultural production and food security (Abera *et. al*., 2018). Climate change is worsening agricultural production in Africa due to erratic weather patterns and extreme weather events that decrease the average yields (AGRA, 2014).

The agricultural production technical efficiency (TE) study found that agricultural land, arable land, rural population, average precipitation, land under cereal production and economically active population working in the agricultural sector, access to credit and agricultural research influence TE (Nsiah and Fayissa, 2019). An estimated 2.7 million hectares can be irrigated, but only 11% was equipped for irrigation in 2001 (FAO, 2018). A survey from 28 among 47 countries in SSA indicated that 75% of the labour force worked in household enterprises and the agricultural sector (FAO, 2018) with households that are food secure being TE and productive (Oyetunde-Usman and Olagunju, 2017). The future maize yields in Ethiopia are either increasing or decreasing based on the region (Abera *et. al*., 2018) while Ngango and Kim (2019) noted that coffee production TE in Rwanda depends on technological adoption.

An input-oriented Data Envelopment Analysis (DEA) employed to examine the TE of maize production in northern Ghana noted that efficiency can further be boosted through formal and informal educational platforms to educate the farmers on improved cultivation practices. The DEA employed various variables, fertilizer consumption, household size, household labor, maize plot size, age of respondent, among other variables (Abdulai *et. al*., 2018). The mean difference between food secure and insecure households TE is 0.035 and was found to be statistically significant among the agriculture households in Nigeria (Oyetunde-Usman and Olagunju, 2017). A study on the African agriculture and food production TE found that it has decreased significantly over time (Ogundari, 2014). The employment of the right combination of productive resources to achieve food sustainability is important for African countries (Abdulai *et. al*., 2018). The technically efficient food producers are more food secure to non-technically significant producers. African countries need to continue making agriculture a critical component as it’s the principal source of food, livelihood and a channel to reduce poverty and attain food security (Ogundari, 2014).

A panel data analysis model was used to estimate the impact of global warming-induced climate change on agricultural production in Japan. The results indicated that rising precipitation and temperature and decreasing solar radiation reduced rice production in Japan. A dynamic panel analysis on rice, vegetable and potato showed a decline in production. An increase of a degree in mean annual temperature reduces rice production by 5.8% and 3.9%, and potato production by 5% and 8.6% in the short and long term, respectively (Tokunaga *et al*., 2015). In Burkina Faso, an increase in temperature reduced the production of millet, maize and sorghum while an increase in rainfall and precipitation increased the production of the cereals (Nana, 2019).

The goal of this study was to assess and identify the climatic factors that influence technical efficiency of agricultural production in SSA through the DEA model and panel data analysis. Climatic risks are changing the agricultural production landscape in SSA with a reduction in crop yields to cater for the increasing population. An analysis of the relationship between the environmental conditions and production system is important to understand the influence of climatic risks on agricultural production efficiency. The intent is to understand to what extent climatic conditions are influencing the agricultural sustainability and food systems in SSA. We found no similar study that has considered agriculture value-added and agricultural land size in estimating TE among SSA countries and use of forest area as a predictor variable in panel data analysis. Forest cover is key in absorbing greenhouse gases while agricultural value-added is an indicator of the interplay between the inputs and outputs in the agricultural production systems.

2. Materials and Methods

The two-step DEA model was applied to estimate the agricultural production TE among the selected countries in SSA. The first step is to estimate the efficiency scores on agricultural production. The second step performs the panel data analysis to estimate which climate variables have an influence on the agricultural production TE scores. The study covers a period of 25 years from 1991 to the year 2015 with countries sampled from SSA. The DEA input variable is agricultural land and the output variable is the agricultural value-added, with data sourced from FSP (2020). The five climate change variables are forest area from World Bank portal (World Bank (2020)) while rainfall, temperature, population and greenhouse gases are from climate watch data (CWD, 2020). The study has two input/output variables. Therefore at least 8 Decision-Making Units (DMU) were required as indicated by Ntwiga (2020). The study population has 28 SSA countries with an overall food security score of between 34.3 and 67.3% (Economist Intelligent Unit, 2020). A total of top 9 DMUs with no missing data points were selected from the 28 countries to form the study sample. The countries include Benin (BEN), Botswana (BWA), Burkina Faso (BFA), Cameroon (CMR), Ethiopia (ETH), Ghana (GHA), Kenya (KEN), Mali (MLI) and Nigeria (NGA) (Economist Intelligent Unit, 2020).

The efficiency scores were analyzed using DEA. Then, the results were assessed using descriptive statistics and econometrics model. The influence of climatic factors on TE of agricultural production was estimated using regression panel analysis. The efficiency scores summary statistics were grouped into four periods; 1991-2000, 2001-2010, 2011-2015 and 1991-2015. The purpose was to check if any significant changes can be attributed to these time segments compared to the overall period. In the determinant of TE, four models were derived where model M1 was the two-dimensional variables panel analysis. Model M2 and M3 captured one-way effect controlling for the year and country, respectively while M4 captured two-way effects controlling for both year and country.

2.1. Variables definition and measurement

The DEA input and output variables resulted to the TE scores as the output variable. In the panel analysis, the TE scores were the response variable and climate factors were the predictor variables.

The study variables and their descriptions for step one DEA model and the step two-panel analysis are presented in Table 1. In the DEA model, the input and output variables estimate the TE of agricultural production. In the panel data analysis, the efficiency scores are the response variable, while the five climate change variables are the predictor variables. The goal is to assess the influence of the climatic factors on TE of the agricultural production in SSA.

Table 1: Data Envelopment Analysis and panel regression models variables

Variable Name	Description
Agricultural land (AL) – Input variable	Percentage of total land that is arable, used for permanent crops, and used for permanent pastures
Agriculture value-added (AVA) - Output variable	Net output for the agriculture sector, forestry, hunting, cultivation of crops, fishing and livestock production, after adding up all outputs and subtracting intermediate inputs (Value added is outputs minus inputs)
Forest Area (FA)	Land under natural/planted trees (5 meters), whether productive or not
Greenhouse Gases (GHG)	Total including land-use change and forestry/agriculture
Population (POP)	People living in the country as defined by the national statistics office
Rainfall (RN)	Average annual rainfall observed in the country
Temperature (TP)	Average annual temperature observed in the country

2.2 Data envelopment analysis

The non-parametric DEA technique was applied to estimate the efficiency scores of a DMU relative to other DMU. The Charnes, Cooper and Rhodes (CCR) model is the basic DEA technique with the Constant Return to Scale (CRS), which assumes no significant relationship between the scale of operations and efficiency (Charnes, *et al*., 1978). A modification of CRS by (Banker *et al*., 1984) became the Banker, Charnes and Cooper (BCC) model which accommodates the variable return to scale (VRS). The TE entails overall TE estimated by the CRS. In the DEA, an efficient frontier is created that evaluates the efficiency of a DMU and is designed to maximize the relative efficiency of each DMU. The efficiency score is estimated as the ratio of weighted outputs to weighted inputs for each variable of every DMU in order to maximize its efficiency score (Ntwiga, 2020; Abel and Bara, 2017). Weights were determined by solving the following linear programming problem.

$$Maximize \quad h_k = \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} \qquad [1]$$

$$\textbf{Subject to}: \quad \frac{\sum_{r=1}^{s} u_r y_r}{\sum_{i=1}^{m} v_i x_i} \leq \mathbf{1} \qquad [2]$$

$v_i \geq 0;\ u_r \geq 0;\ r = 1 \ldots s;\ \ i = 1..m$

Where,

y_{rk} is the output for the r^{th} country at k^{th} year with weight u_r

x_{ik} is the input for the i^{th} country at k^{th} year with weight v_i

s and m are the number of countries for the output and input variables respectively;

k is the number of years

h_k is the efficiency score to be maximized

The maximal efficiency score is equal to 1 and the lower values indicate relative inefficiency of analyzed objects (Ntwiga, 2020). We apply the output-oriented DEA model to estimate the efficiency scores of agricultural land used to produce agriculture value addition.

2.3 Panel data analysis

The panel regression model response variable is the TE scores with the predictor variables being GHG, FA, POP, RN and TP as explained in Table 1. The panel data comprises of nine countries from SSA, with 25 annual data points for five predictor variables and one response variable. The equation for the panel model is indicated below.

$$TE_{it} = \alpha + \beta_i FA_{it} + \psi_i GHG_{it} + \psi_i Ln(POP_{it}) + \theta_i RN_{it} + \rho_i TP_{it} + \epsilon_{it} \qquad [3]$$

Where,

TE_{it} is the TE scores of country i and time t

FA_{it}, GHG_{it}, POP_{it}, RN_{it} and TP_{it} represent the forest cover, greenhouse gases, population, rainfall and temperature in country i at time t, respectively

3. Results and Discussion

The results were analyzed in two steps. Efficiency scores of two-dimensional variables, individual and time period, were computed using DEA. Then, the panel data of computed efficiency score regressed on the explanatory variables to find the determinants of TE. The descriptive statistics provide the summary statistics for the variables in Table 1. The diagnostic tests for the panel data comprising nine countries, for 25 years with five predictor variables were performed and the data did not exhibit multi-collinearity but heteroscedasticity and autocorrelation were observed. The panel AR package and function (Panel Regression with AR (1) Prais-Winsten correction and panel-corrected standard errors) in R statistical software were used to correct for heteroscedasticity and autocorrelation.

Table 2 presents the summary statistics for the nine countries based on the mean, standard deviation and percentage change of the two DEA variables (AVA and AL) and the five-panel regression model variables (GHG, FA, POP, RN and TP). Nigeria had the highest GHG production on average in the 25 years followed by Cameroon and Ethiopia. The ratio of AVA to AL was an indicator for the TE with Benin having a ratio of one-to-one, Botswana had a ratio of one-to-fourteen and Ethiopia's ratio was one-to-less than one. These ratios indicated the efficiency levels with Ethiopia being more TE based on the selected variables among the nine countries in the sample. The average temperature did not vary much across the nine countries during these 25 years but major variations were observed in mean rainfall amounts. The highest average rainfall was observed in Cameroon, followed by Ethiopia, Nigeria and Benin. Nigeria had the highest population, followed by Ethiopia, Kenya and Ghana. Cameroon had the highest forest area, then Benin and Ghana with Mali having the lowest forest area.

The variables summary for the 25 years among the nine countries indicates a decrease in forest area, rain and agriculture value addition with an increase in population, greenhouse gases, agricultural land and temperature. This is a paradox as population increase requires more food that led to agricultural land increase that increases agricultural production and in the process of reducing forest cover. The increase in greenhouse gases and temperature and reduction of rainfall complicates the agricultural production due to the compound nature of climate change. Nsiah and Fayissa (2019) observed that the SSA population is expected to increase by 22% to 1.5 billion by 2050, to exceed agricultural production and declining agricultural land. This study noted that population increase far exceeds the growth in agricultural land which will further lead to food security vulnerabilities in the short and long term. An increase in temperature by 1.37% is similar to observations by FAO (2018) that Africa is becoming warmer compared to the rest of the globe. On average, among the nine countries between 1991 and 2015, forest cover had reduced by 20.85%, rainfall by 17.49% and agricultural value-added by 23.06% while the population, greenhouse gases, agricultural land, temperature increased by 90.81, 46.94, 14.93, 1.37%, respectively which agrees with the sentiments from Tokunaga *et al*. (2015).

Table 2: Summary statistics of variables in DEA and panel analysis

Variable	Statistic	BEN	BWA	BFA	CMR	ETH	GHA	KEN	MLI	NGA	Mean
FA	Mean	43.87	22.18	21.51	45.39	13.39	39.53	7.21	4.64	13.08	
	SD	3.70	1.61	1.51	3.43	0.89	0.92	0.49	0.48	3.31	
	%	-24.25	-21.17	-20.29	-21.91	-16.52	7.88	-4.22	-28.68	-58.44	-20.85
GHG	Mean	21.89	66.66	29.92	192.47	134.89	40.81	51.24	32.09	402.48	
	SD	1.84	29.48	4.68	21.07	25.95	13.70	41.02	6.00	30.21	
	%	26.59	117.6	59.73	52.13	70.96	46.74	-55.50	87.23	16.97	46.94
POP	Mean	7.65	1.81	13.00	16.88	73.42	20.81	34.74	12.43	134.75	
	SD	1.65	0.23	2.78	3.28	15.21	3.86	7.02	2.74	25.48	
	%	105.4	55.94	100.12	89.33	100.5	83.40	95.36	101.9	85.40	90.81
RN	Mean	87.68	31.56	66.28	131.06	67.30	95.97	55.96	26.55	95.29	
	SD	8.58	6.53	5.90	8.97	5.78	8.80	12.87	3.10	7.56	
	%	-25.50	-36.25	-8.21	-11.81	8.86	-22.93	-47.83	6.51	-20.22	-17.49
TP	Mean	27.87	22.27	28.68	24.91	23.13	27.60	25.20	28.87	27.25	
	SD	0.31	0.38	0.30	0.24	0.35	0.26	0.70	0.35	0.31	
	%	2.95	5.37	1.95	1.50	4.17	2.71	-9.95	1.89	1.71	1.37
AL	Mean	28.15	45.68	39.29	19.71	34.47	63.99	47.57	31.70	76.76	
	SD	4.31	0.12	3.82	0.52	5.51	4.86	0.65	2.44	2.91	
	%	64.47	0.39	26.7	6.56	-28.91	23.43	2.8	28.2	10.75	14.93
AVA	Mean	28.89	3.24	35.41	17.44	49.10	35.75	29.28	37.88	31.43	
	SD	4.18	0.93	2.72	3.29	7.21	7.76	2.79	2.89	7.17	
	%	-27.74	-49.37	8.07	-35.26	-36.05	-53.93	18.34	1.6	-33.2	-23.06

Note: Percent (%) was the change of the variable from the year 1991 to 2015

Forest area = FA, Greenhouse gases = GHG, Population = POP, Rain = RN, Temperature =TP, agricultural land = AL, agricultural value-added = AVA

In table 3, Ethiopia had generally the highest average efficiency scores followed by Mali and the lowest efficiency scores were observed in Botswana as indicated in Table 3. In the 25 years, the efficiency scores in descending order of country were Ethiopia (0.971), Mali (0.816), Benin (0.708), Burkina Faso (0.617), Cameroon (0.598), Kenya (0.420), Ghana (0.378), Nigeria (0.277) and Botswana (0.047). The difference between Ethiopian and Botswana TE was about 92.4%, which is a wide margin for TE of agricultural production of the two countries. TE of Kenya, Ghana, Botswana and Nigeria were below 50% during the segmented period. The major difference was observed between the country with the lowest and highest TE ranging between 4.7% and 97.1%. Between 1991 and 2015, the overall change in TE showed a decline. Highest negative change in TE was observed in Ghana, followed by Benin and

Botswana while the highest positive change was observed in Kenya and Ethiopia.

Generally, the technical efficiency of agricultural production among the selected countries is decreasing trend with an average of 3.6%. The percentage change of efficiency between 1991 and 2015 ranged from -47.97% to 60.47%. Similar sentiments were also noted by Ogundari (2014) where TE in Africa has decreased drastically over time.

Table 3: DEA Technical efficiency scores of Sub-Saharan countries in the last 25 years

Variable	Statistic	BEN	BWA	BFA	CMR	ETH	GHA	KEN	MLI	NGA
1991-2000	Mean	0.801	0.051	0.558	0.599	0.947	0.409	0.376	0.771	0.252
	SD	0.138	0.009	0.057	0.122	0.113	0.042	0.037	0.073	0.030
	Min	0.585	0.043	0.442	0.407	0.694	0.353	0.327	0.674	0.214
	Max	1.000	0.068	0.634	0.844	1.000	0.482	0.443	0.905	0.297
2001-2010	Mean	0.664	0.043	0.671	0.604	1.000	0.402	0.424	0.790	0.333
	SD	0.038	0.006	0.045	0.068	0.000	0.065	0.044	0.037	0.065
	Min	0.587	0.033	0.595	0.509	1.000	0.330	0.363	0.743	0.248
	Max	0.719	0.051	0.731	0.703	1.000	0.490	0.484	0.858	0.459
2011-2015	Mean	0.608	0.045	0.627	0.582	0.961	0.269	0.499	0.961	0.218
	SD	0.035	0.003	0.017	0.033	0.058	0.023	0.035	0.049	0.009
	Min	0.582	0.042	0.603	0.539	0.870	0.245	0.454	0.896	0.211
	Max	0.666	0.049	0.639	0.626	1.000	0.306	0.552	1.000	0.233
1991-2015	Mean	0.708	0.047	0.617	0.598	0.971	0.378	0.420	0.816	0.277
	SD	0.120	0.008	0.069	0.087	0.077	0.074	0.060	0.092	0.065
	Min	0.582	0.033	0.442	0.407	0.694	0.245	0.327	0.674	0.211
	Max	1.000	0.068	0.731	0.844	1.000	0.490	0.552	1.000	0.459
	%	-38.76	-29.70	18.90	-15.31	25.40	-47.97	60.47	10.48	-15.92

Note: SD = Standard deviation, Min = minimum value, max = maximum value; Percent (%) is the change of the variable from the year 1991 to 2015

The results presented in Table 4 highlights only the countries whose results are statistically significant. Model 1 showed that a unit increase in temperature and forest area increased the technical efficiency by 3% and 0.7%, respectively while a unit increase in greenhouse gases decreased technical efficiency by 0.03%. The predictor variables explained 73.94% variations in the efficiency. In model 2, a unit increase in greenhouse gases decreased efficiency by 0.054%, while a unit increase in temperature and forest area increased efficiency by 3.1 and 0.84%, respectively. Controlling for the year significantly increased the magnitude of temperature and forest area and reduced the magnitude of greenhouse gases in influencing efficiency. When the year 1992 is compared to that of 1991, technical efficiency was reduced by 4.5%. The influencing efficiency of temperature change was 3.01% in Model 1 while 3.11% in Model 2. Similarly, the influencing efficiency of forest area change was 0.663 % and 0.835% in Model 1 and 2, respectively, in Table 4. The influencing efficiency of greenhouse gases in model 1 was 0.034 while in model 2 it was 0.054 as indicated in Table 4. The predictive power of the model 1 (73.94%) had been reduced to 66.22% in model 2 after controlling for the year. The changes from year to year reduced the predictive power of the model.

In model 3, the one-way effect of the country, there is an increase in efficiency by 0.882% when forest area increases by one unit. Compared to Benin, technical efficiency of Botswana and Ghana has been reduced by 43.56% and 32.8%, respectively. On the other hand, technical efficiency of Ethiopia and Mali has been increased by 44.28% and 49.96%, respectively with an overall R-squared of 89.68%. In model 4, the two-way effect of country and year showed that a unit increase in forest area significantly increased efficiency by 1.58%. Controlling for the year showed significant changes on the influence of predictor variables on technical efficiency in agricultural production from the year 2002 to 2015.

AGRA (2014) observed that an increase in greenhouse gases in the last 100 years, which has worsened agricultural production in Africa due to erratic weather patterns. The study found an increase in the greenhouse gases and temperature and they reduced and increased TE respectively in the last 25 years. Muller *et al*. (2011) noted that temperature and rainfall changes are the two major determinants of agricultural production. On the other hand, rainfall did not influence the technical efficiency significantly although the rainfall amount declined in the last 25 years. The technical efficiency of agricultural production in selected countries was decreasing in the last 25 years with an average of 3.6%. Population increase far exceeds the growth in agricultural land which will further lead to food insecurity in the short and long term.

Table 4: Panel data analysis results of five selected variables

Variables	Model 1	Model 2	Model 3	Model 4
Greenhouse gases	−0.0003 **	−0.0005 *	−0.0003	−0.0004
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Rain	0.0003	0.0006	0.0003	0.0002
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Temperature	0.0302 ***	0.0311 ***	0.0013	−0.0104
	(0.0068)	(0.0078)	(0.008)	(0.0094)
Forest Area	0.0066 **	0.0084 ***	0.00882 *	0.0158 **
	(0.0020)	(0.0021)	(0.0041)	(0.0057)
Population	−0.0004	0.0010	0.0017	0.0012
	(0.0008)	(0.0010)	(0.0008)	(0.0007)
Factor (Year) 1992		0.0455 *		
		(0.0211)		
Factor (Year) 1993				−0.0596 *
				(0.0247)
Factor (Year) 2002				0.09997 **
				(0.0316)
Factor (Year) 2003				0.0992 **
				(0.0318)
Factor (Year) 2004				0.0897 **
				(0.0331)
Factor (Year) 2005				0.0803 *
				(0.0332)
Factor (Year) 2010				0.0753 *
				(0.0365)
Factor (Year) 2013				0.0768 *
				(0.0380)
Factor (Year) 2014				0.0758 *
				(0.0383)
Factor (Year) 2015				0.0816 *
				(0.0391)
Factor (country) BWA			−0.4356 ***	−0.3548 **
			(0.1191)	(0.1461)
Factor (country) ETH			0.4428 ***	0.6362 **
			(0.1299)	(0.1708)
Factor (country) GHA			−0.3280 ***	−0.3073 *
			(0.0680)	(0.1534)
Factor (country) MLI			0.4996 **	0.8005 **
			(0.1764)	(0.2417)
Constant term	−0.4263 *	−0.5572 *	0.2671	0.2606
	(0.1974)	(0.2211)	(0.3306)	(0.3966)
R-squared	0.7394	0.6622	0.8968	0.9388
Wald statistic	53.39 ***	101.01 ***	3133.41 ***	2603.31 ***
Total Obs.	225	225	225	225

Significance codes: '*' 0.05, '**' 0.01, '***' 0.001

4. Conclusions and Recommendation

A significant decrease in technical efficiency of agricultural production has been observed in selected SSA countries with an average downward trend of 23.06% for the last 25 years. Temperature and forest cover had a significant and positive influence on efficiency and greenhouse gases had a significant and negative influence on efficiency. Rainfall and population changes did not significantly influence technical efficiency. In the last 25 years, technical efficiency declined while greenhouse gases, temperature and agricultural land increased due to population pressure and climate change. The increase in population and agricultural land reduced forest coverage with climatic changes influencing rainfall amount. The agricultural value addition decreased during this period, an indication that farmers are becoming less efficient in adding value to agricultural production even in the face of climatic risks and population increase. The paradox observed was, the increase in population increased greenhouse gases and agricultural land and reduced forest cover that in turn reduced climatic mitigation with an increase in temperature and reduction in rainfall.

Therefore, there is need for concerted efforts to increase agricultural value addition and adopt more efficient agricultural practices. This will reduce deforestation, have sustainable agricultural food production for the increasing population and deal with the adverse effects of climate change in SSA countries.

Conflict of Interest

The author declares no conflict of interest.

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Application of Multivariate Analysis for the Differentiation of Indigenous Goat Populations of South Gondar, Ethiopia

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Abstract: *The study was carried out to describe the indigenous goat population structure in selected districts (Fogera, Farta and Libokemkem) of South Gondar zone by applying multivariate analysis on morphometric variables. Fourteen morphometric traits were taken from 153 male and 357 female goats. The results indicated that the district had a significant effect on all traits of male goats except for body length (BL), height at wither (HW), height at rump (HR), ear length (EL) and scrotal circumference. The district effect in females was also significant for BL, heart girth (HG) and chest depth, paunch girth (PG), HR, and teat length. Age had a highly significant effect on all traits except for EL showing a high heterogeneity among males and females of different flocks. The cluster analysis showed two distinct groups in which Farta goats were included in one cluster while group two included the Fogera and Libokemkem goats under one sub-cluster. The canonical discriminant analysis indicated that Fogera and Libokemkem goats were the closest while the Farta and Fogera goats were the furthest. However, the Mahalanobis distances between the three goat populations were too small indicating the existence of homogeneity among them. The discriminant analysis correctly assigned the respective 58.6%, 62.3% and 63.2% of the Farta, Fogera and Libokemkem goat populations into their source population with an overall 61.4% accuracy rate. In conclusion, multivariate analysis identified BL, HG, HW, PG, HR, canon circumference, rump length, and width as the most imperative traits to effectively differentiate the indigenous goat populations in the studied districts.*

Keywords: Indigenous goats, Morphometric traits, Multivariate analysis, South Gondar

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1. Introduction

Goat production in many developing nations like Ethiopia is one of the major means of improving the livelihoods of poor livestock keepers, reducing poverty, and attaining sustainable agriculture and universal food security. They are the most important livestock species for many smallholder farmers and pastoral communities due to their low maintenance requirements, excellent prolificacy, short generation interval, and potential to adapt a wide range of agro-ecological zones (Peacock, 2005; Okpeku *et al*., 2011). They can easily produce and reproduce on shrubs and trees in adverse harsh environments (including tsetse infected areas) where no other crops can be cultivated. However, more than half of the local breeds in the world are threatened and have not been fully characterized (Arandas *et al*., 2017).

The population of goats in Ethiopia is estimated at 38.96 million (CSA, 2018/19). The size of goat populations in Ethiopia has increased more rapidly (134%) than the sheep (65%) and cattle (38%) indicating their growing importance in the livestock agriculture of the country. They are commonly reared in crop-livestock and agro-pastoral farming systems, and are widely distributed across different agro-ecological zones of Ethiopia (Gizaw *et al*., 2010; Seid, 2017). The majority of them are found in the lowland pastoral and agro-pastoral production systems where pastoralists in the South, East, and West keep them mainly for milk and meat production purposes (Gizaw *et al*., 2010). Goats reared in the mid- and highlands are widely distributed in the crop-livestock production systems with varying flock sizes as a means of cash earnings and meat.

Despite the huge resource perspective, there is limited information on the real genetic potentials of local goat populations that are distributed in various regions of the country. Phenotypic characterization study is the basis for the differentiation of indigenous animal genetic resources and provides useful information in designing appropriate genetic improvement programs for their sustainable utilization and conservation. Such studies mainly depend on the knowledge of the variation of morphological traits, which are important elements in the classification of livestock based on appearance, size and shape (Okpeku *et al*., 2011; Melesse *et al*., 2013). There are different studies carried out by various scholars to characterize the indigenous goat populations of Ethiopia and most of them reported the existence of phenotypic variations between and within the studied goat ecotypes (Alemu, 2004; Hassen *et al*., 2012; Gatew *et al*., 2015; Mekuriaw, 2016). However, there is still limited characterization studies conducted to describe the population structure and genetic potentials of indigenous goat populations found in Amhara Regional State in general and that of South Gondar in particular. For example, Hassen *et al*. (2012) conducted a morphological characterization study on indigenous goats in some zones of the Amhara Region. Although South Gondar zone was considered as one of them, the respective potential districts for goat production were not adequately represented due to limited samples included in that particular study. As a result, the population structure of the indigenous goats in South Gondar zone has not been adequately described. Therefore, this study was conducted to differentiate the indigenous goat populations based on their morphometric traits by applying the multivariate analysis.

2. Materials and Methods

2.1 Site selection and sampling techniques

The study was conducted in three districts of South Gondar zone in the Amhara Regional State, Ethiopia. First, the relevant second-hand information was gathered from the Agriculture and Rural Development office of livestock. Based on the information obtained, multi-stage purposive sampling techniques were applied to select the study districts and kebeles (the smallest administrative unit within the district). In the first stage, three districts namely Farta, Fogera and Libokemkem were selected purposively based on their goat population size and potential. In the second stage, three kebeles from each district were selected purposively based on the distribution of the goat populations. In the third stage, the farmers who own at least five or more matured goats of both sexes were identified within kebeles. Accordingly, 306 goats from Farta and Fogera and the 204 goats from Lobokemkem districts with a total number of 510 were sampled of which 153 and 357 were male and female goats, respectively. The owner's recall method along with dentition classes (pairs of permanent incisors, PPI) was used to estimate the ages of the goats. Accordingly, goats with 1PPI, 2PPI, 3PPI and 4PPI were classified in the age groups of yearling, 2-year-old, 3-year-old and 4-year-old and above, respectively (Ebert and Solaiman, 2010). Each animal was further identified by its sex and sampling site.

2.2 Types of data collected

Data on 14 morphometric traits were collected according to the descriptor list of FAO (2012) for phenotypic characterizations of goats. Accordingly, the following traits were measured: live body weight (LW), body length (BL), height at withers (HW), heart girth (HG), chest depth (CD), chest width (CW), paunch girth (PG), rump height (RH), rump length (RL), rump width (RW), ear length (EL), fore cannon circumference (FCC), teat length (TL) and scrotal circumference (SC). All morphometric traits were taken using plastic tape while body weight using a suspended weighing scale with 50 kg capacity by placing each animal in self-devised holding equipment. All linear body measurements were taken early in the morning before goats leave for browsing.

2.3 Statistical Analysis

Since the sample size was unbalanced among different districts and age groups, data were subjected to GLM procedures by fitting district and age as fixed effects. Since the interaction effect of district by age was insignificant, it was dropped from the analysis. The sex groups (males and females) were analyzed separately due to considerable differences in sample size. When F-test declared significant, means were separated by Least Square Means procedures. Accordingly, least squares means with SE were presented rather than the arithmetic mean. The procedure of the Cluster analysis was performed and a dendrogram graph was constructed based on Euclidean distance to differentiate the goat populations of the three districts using the average linkage method to group the flocks into their morphological similarity. Moreover, the stepwise discriminant analysis was applied using the STEPDISC procedure to determine which the morphometric variables have more discriminating power. The relative importance of the morphometric variables in discriminating the three goat populations was assessed using the level of significance, F-statistic and partial R^2. Collinearity among the variables used in the discriminant model was also evaluated using tolerance statistics. The canonical discriminant analysis was then performed on the identified variables with the most discriminating power using the CANDISC procedure which computed the Mahalanobis distances between class means, uni- and multivariate statistics, and canonical variables with eigenvalues. The TEMPLATE and SGRENDER procedures were also applied to create a plot of the first two canonical variables in a scatter graph for visual interpretation. Finally, discriminant analysis of the DISCRIM procedure was conducted to determine the percentage classification of goats into their source populations using a quadratic discriminant function for the unequal covariance matrices within classes after checking with the Bartlett's homogeneity test. The classification accuracy of the discriminant analysis was further cross-validated by invoking the CROSSVALIDATE option. All multivariate analyses were performed using the Statistical Software of SAS (2012, ver. 9.4).

3 Results

3.1 Morphometric traits

In males, as shown in Table 1, the district showed different influences across traits varying between highly significant (LW, HG, CD, CW, RL, RW and FCC) and non-significant (BL, HW, HR, EL and SC). Fogera male goats had larger HG ($p<0.05$) than those of Farta and Libokemkem while no difference was noted between the latter two. Chest width and CD values were larger ($p<0.05$) for Farta and Fogera male goats than those of Libokemkem. Male goats of Farta had larger ($p<0.05$) RL and RW values than those of Fogera and Libokemkem while those of Fogera had larger RL than those of Libokemkem. A significantly bigger FCC was observed in the male goat populations of Farta and Libokemkem than those of Fogera.

The effect of the district in females was significant for BL, HG, CD, PG, HR, and TL (Table 2). Accordingly, the female goats of Libokemkem had higher BL than those of Farta and Fogera. The latter two did not significantly differ from each other for the same trait. On the other hand, the female goats of Fogera and Farta had larger HG than those of Libokemkem. Likewise, the female goats of Farta had larger CD and PG than those of Fogera and Libokemkem. No significance difference was noted between the latter two. A significantly higher RH was observed in the female goat populations of Fogera than those of Libokemkem and had larger RL than those of the Farta. No significant difference was found in RH and RL values between Farta and Libokemkem female goat populations. The female goats of Farta had higher EL and TL than those of Libokemkem. Teat length of goats from the Fogera district was larger than that of Libokemkem. The effect of age in both sexes was highly significant for all traits except for EL showing a large heterogeneity among males and females of different flocks.

Table 1: Least squares means of live weight (kg) and linear body measurement traits (cm) of indigenous male goat populations as affected by district and age (N= 153)

Morphometric traits	District			Overall mean (±SEM)	Age				Overall mean (±SEM)	Fixed effects	
	Farta	Fogera	Libo-kemkem		1PPI	2PPI	3PPI	4PPI		District	Age
Live weight	31.0^{b}	31.7^{a}	31.0^{b}	31.2±0.16	26.7^{d}	29.2^{c}	33.6^{b}	35.4^{a}	31.2±1.99	0.001	<.0001
Body length	62.4	62.3	62.2	62.3±0.23	58.4^{d}	60.4^{c}	64.5^{b}	66.1^{a}	62.4±1.78	0.576	<.0001
Height at withers	69.7	69.9	69.8	69.8±0.13	66.3^{d}	68.6^{c}	71.4^{b}	72.8^{a}	69.8±1.45	0.434	<.0001
Heart girth	72.9^{b}	73.9^{a}	73.3^{b}	73.4±0.15	70.2^{d}	72.2^{c}	75.0^{b}	76.2^{a}	73.4±1.36	<.0001	<.0001
Chest depth	31.8^{a}	31.7^{a}	31.3^{b}	31.6±0.14	28.5^{d}	30.8^{c}	32.9^{b}	34.2^{a}	31.6±1.25	0.008	<.0001
Chest width	17.1^{a}	16.9^{a}	16.6^{b}	16.9±0.11	14.8^{d}	16.3^{c}	17.7^{b}	18.6^{a}	16.9±0.83	0.002	<.0001
Paunch girth	78.4^{ab}	79.3^{a}	78.1^{b}	78.5±0.34	74.0^{d}	77.2^{c}	80.3^{b}	82.8^{a}	78.6±1.91	0.014	<.0001
Height at rump	72.0	72.1	72.2	72.1±0.17	68.8^{d}	71.2^{c}	73.5^{b}	74.9^{a}	72.1±1.34	0.821	<.0001
Rump length	16.7^{a}	15.9^{b}	15.4^{c}	16.0±0.13	14.9^{d}	15.6^{c}	16.3^{b}	17.4^{a}	16.1±0.53	<.0001	<.0001
Rump width	14.5^{a}	12.9^{b}	13.2^{a}	13.5±0.16	11.5^{d}	13.5^{c}	14.1^{b}	15.1^{a}	13.6±0.76	<.0001	<.0001
Fore canon circumference	8.19^{a}	7.71^{b}	8.35^{a}	8.08±0.14	7.38^{b}	7.70^{b}	8.52^{a}	8.74^{a}	8.09±0.32	0.004	<.0001
Ear length	14.8	14.6	14.9	14.7±0.15	14.7	14.7	14.7	15.0	14.8±0.08	0.237	0.581
Scrotal circumference	23.1	23.3	23.0	23.1±0.15	21.9^{b}	23.1^{ab}	23.7^{a}	23.9^{a}	23.2±0.45	0.332	<.0001

^{a,b,c,d} Means within district and age groups with different superscript letters are significant at $p<0.05$; SEM = standard error of the mean

Table 2: Least squares means of live weight (kg) and linear body measurement traits (cm) of indigenous female goat populations as affected by district and age (N = 357)

Morpho-metric traits	District			Overall mean (±SEM)	Age				Overall mean (±SEM)	Fixed effects	
	Farta	Fogera	Libo-kemkem		1PPI	2PPI	3PPI	4PPI		District	Age
Live weight	27.7^{b}	28.1^{a}	28.0^{a}	27.9±0.10	24.1^{d}	26.5^{c}	29.3^{b}	31.9^{a}	28.0±1.69	0.145	<.0001
Body length	60.2^{a}	60.1^{a}	59.5^{b}	59.9±0.11	56.6^{d}	58.7^{c}	60.8^{b}	63.7^{a}	60.0±1.52	<.0001	<.0001
Height at withers	67.4^{a}	67.6^{a}	67.6^{a}	67.5±0.81	64.4^{d}	66.4^{c}	68.6^{b}	70.7^{a}	67.5±1.36	0.639	<.0001
Heart girth	70.7^{b}	71.2^{a}	71.3^{a}	71.0±0.10	68.0^{d}	70.1^{c}	72.2^{b}	73.8^{a}	71.0±1.26	0.015	<.0001
Chest depth	30.0^{a}	29.7^{b}	29.6^{b}	29.8±0.08	26.8^{d}	28.5^{c}	31.0^{b}	32.8^{a}	29.8±1.33	<.0001	<.0001
Chest width	15.4	15.4	15.4	15.4±0.07	13.7^{d}	15.1^{c}	16.0^{b}	16.8^{a}	15.4±0.66	0.283	<.0001
Paunch girth	75.6^{a}	74.7^{b}	74.4^{b}	74.9±0.16	70.6^{d}	72.7^{c}	77.3^{b}	79.0^{a}	74.9±1.96	<.0001	<.0001
Height at rump	70.3^{b}	70.6^{a}	70.3^{b}	70.4±0.09	67.5^{d}	69.4^{c}	71.7^{b}	73.1^{a}	70.4±1.24	0.008	<.0001
Rump length	15.9^{b}	16.2^{a}	16.1^{ab}	16.0±0.06	15.1^{d}	15.7^{c}	16.4^{b}	17.1^{a}	16.1±0.43	0.051	<.0001
Rump width	13.2^{a}	12.8^{a}	13.1^{a}	13.0±0.12	11.0^{c}	13.2^{b}	13.9^{a}	14.0^{a}	13.0±0.70	0.236	<.0001
Fore canon circumference	7.94^{a}	7.76^{a}	7.89^{a}	7.86±0.08	7.08^{c}	7.69^{b}	7.95^{b}	8.71^{a}	7.86±0.34	0.209	<.0001
Ear length	14.7^{a}	14.6^{a}	14.4^{a}	14.5±0.09	14.4	14.6	14.6	14.6	14.6±0.04	0.095	0.686
Teat length	3.71^{a}	3.72^{a}	3.66^{a}	3.70±0.02	3.04	3.49	4.02	4.24	3.70±0.27	0.007	<.0001

^{a,b,c,d} Means within district and age groups with different superscript letters are significant at $p<0.05$; SEM = standard error of the mean

3.2 Multivariate Analysis

As indicated in Figure 1, the cluster analysis generated a phylogenetic tree that clustered the goat populations of South Gondar into two main groups based on morphometric traits. The first group included goat populations from Farta district while the second group includes those from both Fogera and Libokemkem districts as sub-cluster. Table 3 presents the results of the stepwise discriminant analysis showing Wilk's Lambda, F-values, probability and tolerance statistics. Twelve quantitative traits were subjected to the STEPDISC analysis of which eight were identified as the best discriminating variables. Wilk's lambda test confirmed that all the selected variables had highly significant (p<0.0001) contribution to differentiate the total population into separate groups. The variables with the highest discriminating power were BL, HG, HW, PG, HR, RL, RW and FCC (Table 3). The remaining four variables (LW, CD, CW and EL) had poor discriminating power and were excluded in the subsequent analysis.

All the eight variables were then subjected to canonical discriminant analysis using the CANDISC procedure. The univariate statistics testing the hypothesis that class means are equal which validate that each quantitative variable in sampled populations is a significant (p<0.0001) contributor to the total variation. The multivariate statistics for differences between the districts was also significant (p<0.0001). The hypotheses that assumes the districts' means are equal in the populations was rejected by the Wilk's Lambda (p<0.0001) indicating that differences found between studied districts were statistically different from zero.

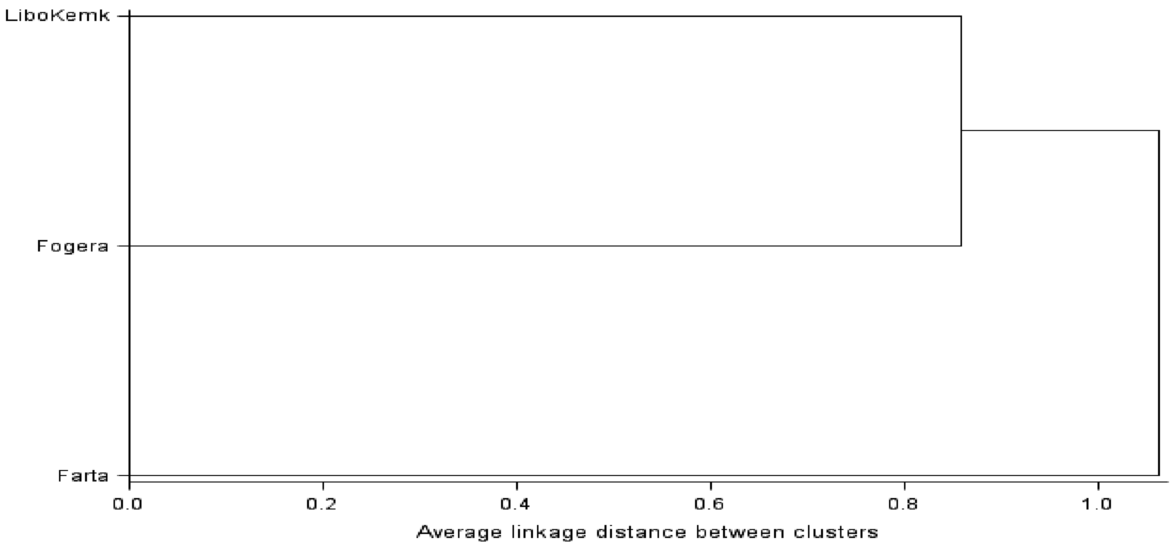

Figure 1: Dendrogram based on average linkage distance between goat populations reared in the three districts of South Gondar using morphometric variables

Table 3: Summary of stepwise discriminant analysis for selection of traits

Step	Variables entered	Pr > F	Wilks' Lambda	Pr<Lambda	ASCC	Pr>ASCC	Tolerance
1	Rump width	0.001	0.9743	0.0013	0.0129	0.0013	0.870
2	Heart girth	<.0001	0.9284	<.0001	0.0358	<.0001	0.687
3	Body length	<.0001	0.8679	<.0001	0.0672	<.0001	0.283
4	Puanch girth	0.003	0.8476	<.0001	0.0779	<.0001	0.239
5	Fore canon circumference	0.004	0.8295	<.0001	0.0882	<.0001	0.233
6	Height at wither	0.113	0.8223	<.0001	0.0923	<.0001	0.129
7	Rump length	0.051	0.8126	<.0001	0.0977	<.0001	0.124
8	Height at rump	0.104	0.8053	<.0001	0.1019	<.0001	0.084

ASCC = average squared canonical correlation

The Mahalanobis distances and probability values for the contrast among the goat populations of the three districts are presented in Table 4. All Mahalanobis distances were significant ($p < 0.0001$). The shortest distance (0.401) was observed between the goat populations of Fogera and Libokemkem districts while the larger between those of Fogera and Farta (0.872). The Mahalanobis distance between Farta and Libokemkem goat populations was 0.858, which is much similar to those of the Farta and Fogera.

Summary of canonical correlations and eigenvalues are presented in Table 5. The multivariate statistics for differences between the districts was significant ($p<0.0001$). Standardized coefficients for the canonical discriminant function, the canonical correlation, the eigenvalues and share of total variance accounted for this study revealed that both canonical variables determined (CAN1 and CAN2) was significant. The CAN1 and CAN2 accounted for 70% and 30% of the total variation, respectively. Table 5 further displayed the likelihood ratio test of the Rao's F approximation, which rejected the hypothesis that assumes the current canonical correlations and all smaller ones are zero.

Figure 2 shows a plot built with the two canonical variables illustrating the relationships between goat populations belonging to different districts. The plot displayed that CAN1 discriminates between the two districts: Farta and Fogera while CAN2 best discriminates between Libokemkem and the other two districts. However, it can be observed in the figure that there is a visible overlapping among the three goat populations indicating the existence of homogeneity.

Table 4: Pairwise Mahalanobis distance values among the three goat populations

Districts	Farta	Fogera	Libokemkem
Farta	0	0.872	0.858
Fogera	0.872	0	0.401
Libokemkem	0.858	0.401	0

All distances are significant at $p<0.001$

Table 5: Summary of canonical correlations, eigenvalues and likelihood ratios

Functions	Canonical correlations	Eigenvalues			Likelihood ratio	Approximate F-value	Pr>F
		Eigen-value	Proportion	Cumulative			
CAN1	0.373	0.161	0.70	0.700	0.805	7.15	<0.0001
CAN2	0.254	0.069	0.30	1.000	0.935	4.96	<0.0001

CAN1 = canonical variable 1; CAN2 = canonical variable 2

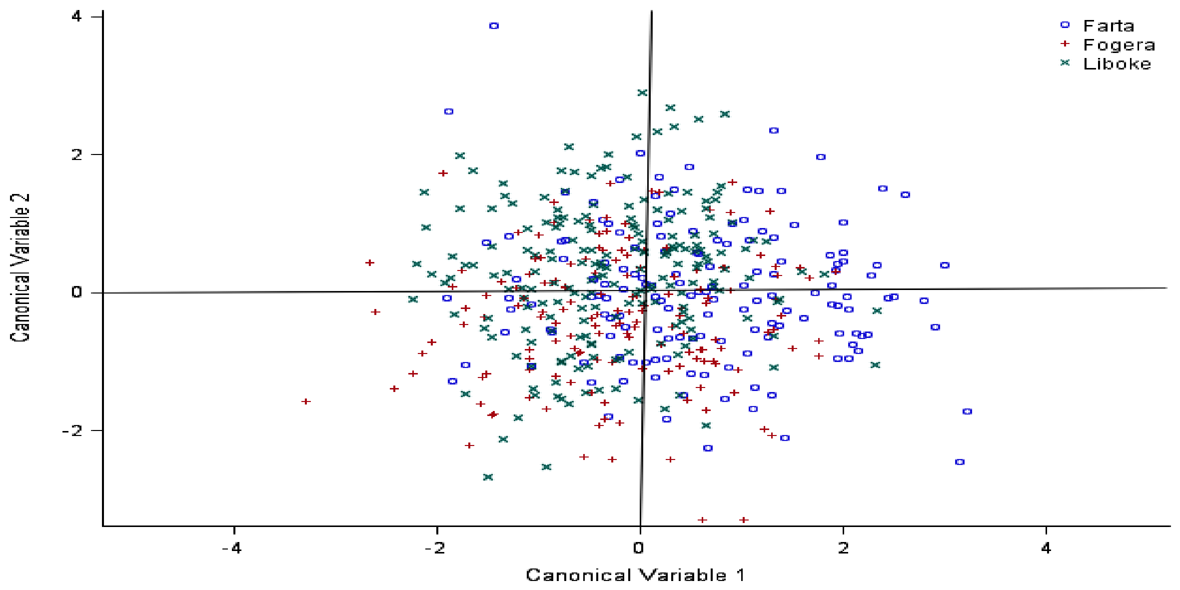

Figure 2: Canonical representation of the goat population in the three districts of South Gondar

Discriminant analysis assumes that the individual group covariance matrices are equal (homogeneity within covariance matrices) and by default, it uses the linear discriminant function for classification.

In the current discriminant analysis, equality of covariance matrices within groups was tested using Bartlett's test of homogeneity for all traits and was significant (χ^2 = 248; p<0.0001) by rejecting the null hypothesis that assumes all covariance matrices within the goat populations are homogenous. Therefore, the within-group covariance matrices were used to derive the quadratic discriminant function criterion for the classification of the three goat populations.

As presented in Table 6, the discriminant analysis correctly classified 58.6% of Farta goats into their respective origin population with 22.4 and 19.1% being misclassified to Fogera and Libokemkem goat populations, respectively. Similarly, 62.3% of Fogera goats were correctly assigned to their source population while the remaining 14.9 and 22.7 being misclassified to Farta and Libokemkem goat populations, respectively. The quadratic discriminant function further differentiated the Libokemkem goat from others with 63.2% correct classification into their original source population with the remaining 13.7 and 23.0% being misclassified to Farta and Fogera goat populations, respectively. The overall error count estimates provide the proportion of misclassified observations in each group being highest in Farta goats (41.4%) and lowest in those of Libokemkem (36.8%).

The classification accuracy of the discriminant analysis was further cross-validated and indicated an overall 53.0% success rate (Table 6). The error count estimate for the cross-validation was 46.7, 50.7, and 43.6% for Farta, Fogera and Libokemkem districts, respectively. The overall error count estimate for classification was 38.6% while it was 47.0% for cross-validation option. It would be worthwhile to note that the cross-validation option achieved a fairly unbiased estimate with a relatively large variance.

Table 6: Percent of individual goats classified into their respective districts and cross-validation of classification based on morphometric variables (values in brackets are number of goats)

Districts	Farta	Fogera	Libokemkem	Total
Re-substitution				
Farta	58.6 (89)	22.4 (34)	19.1 (29)	100 (152)
Fogera	14.9 (23)	62.4 (96)	22.7 (35)	100 (154)
Libokemkem	13.7 (28)	23.0 (47)	63.2 (129)	100 (204)
Error count estimate	0.414	0.377	0.368	0.386
Priors	0.333	0.333	0.333	-
Cross-validation				
Farta	53.3 (81)	25.0 (38)	21.7 (33)	100 (152)
Fogera	18.2 (28)	49.4 (76)	32.5 (50)	100 (154)
Libokemkem	16.2 (33)	27.5 (56)	56.4 (115)	100 (204)
Error count estimate	0.467	0.507	0.436	0.47

4 Discussion

4.1 Quantitative traits

Height at withers and EL were not affected by the district in both sex groups which indicates their similarity in their heights and the size of the ears. In male goats, the district did not affect BL, HR and SC. Similarly, LW, CW, RL and RW in females were not affected by the district. These observations suggest that the genetic improvement of these traits in both sexes of the studied districts might be justifiable. Age of the goats had a significant (P<0.05) effect on all linear body measurement traits except for EL in both sexes. Most of the morphometric traits increased with age, which is in close agreement with the findings of Lorato *et al*. (2015) for Woyto Guji goat type in Loma district. A linear increment of morphometric traits with age indicates a normal body development of goats which suggest the suitability of the production environment for goat rearing. The absence of an increase in the size of ear in both sexes may suggest its limited importance during the physical development of the goats.

In the present study, male goats appeared to be heavier than females. This might be explained by the presence of a high level of the hormone androgen in bucks, which is responsible for muscular growth. This observation was in agreement with that of Seid *et al*. (2016) who reported similar findings in goats reared in the Western highland of Wollega zone, Oromia. On the contrary, Jeda and Asefa (2016) reported that females goats raised in the Bale zone had higher LW than those of bucks. Such inconsistencies might be due to differences in age, breed, management, and accuracy of taking measurements in which the data were collected. Moreover, such differences might be attributed to the result of negative selection practiced by the farmers as fast-growing male kids are sold at an earlier age. Female goats had higher RL than males and FCC and RW values almost the same for both sexes. Rump size is a very important structure for ease deliverance.

The SC is an important trait that is closely associated with the testicular growth and sperm production capacity of domestic animals. Gatew *et al*. (2015) reported relatively higher SC values for bucks in eastern Ethiopia than observed in the current study (27 vs. 23 cm). Since SC size is dependent on the maturity of the animal, the differences could be attributed to the age of bucks when data were collected. This has been supported by the present observation in which SC has been significantly affected by age. Moreover, SC showed a significant positive correlation with the live weight of goats (Tade *et al*., unpublished data), which substantiated the dependency of SC on the body development of the animal. Consistent with the current results, Raji and Ajala (2015) observed a significant effect of body weight on SC for West African Dwarf buck. As SC is an indirect measurement of testicular size, knowing the increased size of testis may be used as an indicator in the onset of active spermatogenesis and, hence, the possibility of using bucks for breeding at an earlier age than normally recommended. Such knowledge might be particularly essential if young bucks may not be kept together with the does for reasons related to control of the occurrence concurrence of inbreeding as well as disease transmission during mating.

The teat length positively affected milk production potentials of does (El-Gendy *et al*., 2014). Merkhan and Alkass (2011) reported 3.6 cm TL for Iraqi Black and Meriz goats, which is comparable with the current findings (3.7 cm). The overall teat length of goats in the present study is comparatively higher than reported by Alemayehu *et al*. (2015) for goats of West Amhara (3.7 vs. 3.40 cm). Teat length is significantly affected by the age of the does, which indicates a linear increase in teat size with the advancing age. In general, the goat populations of Fogera district had the highest BW and HG values as compared to those of Farta and Libo-kemkem districts. However, the goats of the Farta district had the highest CD. The observed variations might associated with differences in the management practices among the communities and the availability of feed and water resources.

4.2 Multivariate Analysis

The Cluster analysis classified the goat populations in two main groups based on their morphometric traits in which the first group included the Farta goat populations while the second group includes the Fogera and Libokemkem goats as sub-cluster. This observation indicates that goats of the Fogera and Libokemkem districts are much closer to each other than those of the Farta and confirmed the results of the cross-classification of population distribution with discriminant analysis.

Except for height at rump, the tolerance values obtained from the present study were greater than 0.1. This is an indication that there was no collinearity problem among the eight most discriminating morphometric variables (Yakubu *et al*., 2010; Selolo *et al*., 2015). Some of the present discriminant variables are similar to those reported by Yakubu *et al*. (2011) for West African Dwarf and Red Sokoto goat breeds.

All Mahalanobis distances were significant which are in line with the findings of Zaitoun *et al*. (2005). The Mahalanobis distance was relatively short for the goat populations of Fogera and Libokemkem districts, indicating that they are homogenous in their morphometric characters probably due to sharing similar genetic identities. This trend has been demonstrated in the dendrogram displayed in Fig. 1. The low Mahalanobis distances between Fogera and Libokemkem goat populations might have resulted from non-selection, continuous inbreeding, and high intermingling rate between these two populations in an open management system of production, which is commonly practiced by many rural communities. Moreover, the two districts (Fogera and Libokemkem) are sharing quite a substantial area of borderline which affirms the homogeneity of the genetic identity of the goats resulting from intermix of genetic materials. On the other hand, the Mahalanobis distance was comparatively larger between goat populations of Farta and Libokemkem as well as between those of Farta and Fogera districts. Comparative large Mahalanobis distances were reported between Damascus and Dhaiwi goat breeds while a moderate distance was observed between Mountain and Dhaiwi (Zaitoun *et al*., 2005). In general, the Mahalanobis distances between the three goat populations were too short indicating the existence of homogeneity among the studied goat populations.

The univariate statistics testing the hypothesis that class means are equal shows that each quantitative variable in sample populations except HG, HW and HR was significant ($p<0.05$) contributor to the total variation. The Wilks' lambda, the ratio of within-group variability to total variability on the discriminator variables, is an inverse measure of the importance of the discriminant functions. The Wilks' lambda test (Table 5) for the population was 0.805, which reflects less part (19.5%) of the variability in the discriminator variables was because of the differences between populations rather than variation within the population.

In the current study, CAN1 and CAN2 accounted for 70% and 30% of the total variation, respectively, indicating a complete representation of individuals of the local goat populations with one scatter plane. The extracted both canonical variables were found to be significantly different, which agrees with the observations of Traoré *et al*. (2008) for goat populations of Burkina Faso. On the contrary, Selolo *et al*. (2015) reported that the CAN1 was significant while CAN2 remained insignificant for local South African goats. There are indeed conflicting reports in the literature on the proportion of total variation explained by both canonical variables (CAN1 and CAN2). For example, Traoré *et al*. (2008) reported a total variation of 94.0% and 5.5% for CAN1 and CAN2, respectively while the corresponding values were 82.4% and 10.7% for Jordan native goat breeds as reported by Zaitoun *et al*. (2005). Selolo *et al*. (2015) reported that 91.9% of the total variation was accounted by CAN1 while only 8.1% by CAN2. The reported differences in the literature might be explained by the sample size, age and breed of goats studied. Rump width, PG, RL and BL dominated CAN1, while FCC showed the largest influence on CAN2. Herrera *et al*. (1996) found that head length and withers height were the most important variables in CAN1, while head width and shin circumference were the most important variables in CAN2 in their discrimination among the five Andalusian goat breeds.

The values computed for CAN1 and CAN2 for each individual were plotted by districts and displayed in Figure 2. Accordingly, the Farta individuals appeared to relatively homogeneous and clustered together on the right hand of the X-axis; the Libokemkem are mainly distributed on the positive values of the Y-axis, and the Fogera individuals showed an intermediate distribution but inclined toward to the Libokemkem goats. In this respect, the discriminant analysis carried out provided complementary information (Table 6) in which most of the goat populations of Libokemkem and Fogera districts were classified into their source population (63.2% and 62.3%, respectively) whilst the rest (13.7 and 14.9) were misclassified as Farta individuals. The discriminant analysis also classified 58.6% Farta individual indigenous goats into their original districts. Similarly, Selolo *et al*. (2015) found that 60.3, 58.1 and 38.5% of the individual goats were classified into their original agro-ecological zones with several individuals being misclassified. Yakubu and Ibrahim (2011) reported that Yankasa (45.9%), Uda (33.5%) and Balami (61.5%) sheep breeds were correctly classified into their source group. Another study conducted by Dossa *et al*. (2007) indicated that more than 70% of individual goats were correctly allocated to their different source groups. Similarly, the respective 79.3% and 82.7% of Sudan and Sudan-Sahel goat populations of Burkina Faso were classified into their source population (Traoré *et al*., 2008). Dekhili *et al*. (2013) reported that 73%, 66.8% and 79.3% of Algeria goats were classified into North, Center and South environments, respectively. Yakubu *et al*. (2010) reported that only 24.4% of rainforest and 22.9% of guinea savanna goats were correctly classified into their source populations. These reports suggest the importance of multivariate discriminant analysis to differentiate indigenous livestock populations that are being reared in various production environments.

Based on the discriminant analysis, the overall average error count estimate was 38.6% for all observations and 61.5% of the overall sampled populations were correctly classified to their origin districts indicating the heterogeneity of goat populations within districts for those variables included in the discriminant analysis. The relatively higher errors of classification for Farta goats may indicate that they might have been extensively mixed with the other local goat populations. The misclassification observed in this study may also suggest that the level of genetic exchange that has taken place overtime between the goats reared in the three districts. In addition, there is a good possibility of admixture among these goats because of the continuous migration of flocks that existed for many generations. Moreover, the assignment errors of local goat breeds might have occurred between goat populations reared in the same production system. Such speculations might be justifiable, as goats reared under the same production system might have been selected naturally and artificially for similar traits (Zaitoun *et al*., 2005).

The low differentiation assessed between Farta and Fogera and between Farta and Libokemkem goats using the Mahalanobis distances and the large classification errors obtained using the discriminant analysis did not give statistical support to separate these goat populations into different distinct ecotypes. Moreover, a significant proportion of cross-classification errors (41.5%) observed in Farta goat populations suggests that they might share a similar genetic basis with the other two goat populations. Such admixtures are possible due to the existence of an active marketing system of goats in the region.

5 Conclusion

Bucks of Fogera district had larger heart girth than those of Farta and Libokemkem while the females of Libokemkem district had higher body length than those of Farta and Fogera. The cluster analysis showed two separate clusters: cluster one included the Farta goat populations as one distinct group while cluster two included the Fogera and Libokemkem goats under one sub-cluster. The canonical discriminant analysis verified similar trend by indicating the Fogera and Libokemkem goats are the closest while the largest Mahalanobis distance was between Farta and Fogera goat populations with all distances being significant. However, the canonical discriminant analysis indicated a visible overlapping among the three goat populations suggesting the existence of homogeneity. The respective 58.6%, 62.3% and 63.2% of the Farta, Fogera and Libokemkem goat populations were correctly classified into their districts with overall error count estimates of 38.6%. The accuracy of the classification was further cross-validated in which the respective 53.3, 49.4 and 56.4 of Farta, Fogera and Libokemkem goats were correctly assigned to their source populations with an overall error count of 47.0%.

Conflict of Interest

The authors declare that there is no conflict of interest.

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Effect of Fertilizer Application and Variety on Yield of Napier Grass (*Pennisetum purpureum*) at Melokoza and Basketo Special Districts, Southern Ethiopia

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Abstract: *In tropical countries, the demand for meat and milk production has been increasing at an alarming rate, which the production, in turn, is requiring sufficient energy and protein feed supply. Four Napier grass varieties (ILRI_16815, ILRI_16902, ILRI_16913, ILRI_15743) and four nitrogen, phosphorus and sulfur (NPS) fertilizer (0, 12.5, 25, 50 kg ha^{-1} N:P:S with a rate of 19% N:37% P_2O_5:7% S) level were laid out in split-plot design at Basketo and Melokoza districts during 2018-2019 cropping seasons to evaluate agronomic and forage biomass yield performance. Data were collected for three consecutive harvestings each year to evaluate yield and agronomic parameters. NPS fertilizer application had no significant variation on growth and yield of Napier grass. In terms of plant height, ILRI_15743 is found to be a shorter variety that had a wider circumference covering the ground, better leaf to stem ratio and a higher number of tillers per plant. The plant height was varied for NPS fertilizer application and the higher plant was at 12.5 kg ha^{-1}(72.2 cm) level. ILRI_16815 demonstrated as the longest 84.6 cm variety among others in the test which encompass higher dry matter yield. Dry matter yields highly correlated ($P<0.001$) with leaf length, leaf number per plant and green forage yield which have less association with circumference, leaf width and leaf to stem ratio. There was better yield recorded at Melokoza than Basketo and applying 12.5 kg ha^{-1} NPS fertilizer is economical in Napier grass production. Therefore, ILRI_16815 could be recommended with 12.5 kg ha^{-1} NPS fertilizer at Melokoza, Basketo and similar agro-ecology to have economical Napier grass yield.*

Keywords: Basketo, Feed, Melokoza, Napier Grass, NPS

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1. Introduction

The demand for meat and milk production in Ethiopia has been increasing (Shapiro *et al*., 2015). Energy and protein source feeds are the two major requirements in dairy production to demand 250 days of milk and calf every year (Mhere *et al*., 2002). The high cost and low availability of good quality animal feed is a critical constraint to increasing productivity of livestock in dairy farms and feedlots, improved family and specialized poultry, and smallholder mixed crop-livestock and extensive livestock production systems (Shapiro *et al*., 2015). To use as a mitigation option of the prevailing livestock production mainly the feed nutritional constraints to livestock productivity, the use of adapted, high yielding, and drought-tolerant improved forages of high quality are recommended (Mengistu *et al*., 2016).

Napier grass (*Pennisetum purpureum* Schumach.) is a fast-growing perennial grass native to Sub-Saharan Africa that is widely grown across the tropical and subtropical regions of the world (Negawo *et al*., 2017). Napier grass, also known as elephant grass, is deep-rooted tropical bunch grass and the most popular perennial forage crop recommended for crop-livestock farming system (Nyambati *et al*., 2010). It is widely used in cut and carries feeding systems (Farrell *et al*., 2002) and is of growing importance in other agricultural systems (Negawo *et al.*, 2017). Napier grass possesses a high yield per unit area; tolerate intermittent drought and high water use efficiency (Kabirizi *et al*., 2015). It has the ability to withstand repeated cutting and will rapidly regenerate, producing palatable leafy shoots (Lowe *et al.*, 2003). The preservation of Napier grass is to ensure continuous feed supply for the animals during a shortage of forages as well as preserving the quality of the grasses (Zailan *et al*., 2018). The yield of Napier grass mainly depends on the type of cultivar used, the environment and management practices employed (Negawo *et al*., 2017).

Production and utilization of improved forages are getting low in the study area due to the limited access of forage seed, shortage of production land and less awareness of the farmers (Community level participatory planning (CLPP) document of AGP-II @ArbaMinch Research Center). Forage production was taken as an option to improve feed requirement of the study area which has been depending on the natural pasture and crop residues. Therefore, this study was designed mainly to investigate the optimum level of NPS fertilizers for Napier grass yield, to identify the response of Napier varieties to NPS fertilizer and to estimate the economic response of Napier grass variety to each unit of fertilizer application at Melokoza and Basketo areas (AGP-II sites).

2. Materials and Methods

2.1 Description of the study area

The study was conducted at ***Zaba*** village (N= 6.16’59’’ E=36.36’55’’) of ***Basketo*** special district and at ***Phircha*** village (N=6.25'12" E=36.37'33')' of ***Melokoza*** district southwestern Ethiopia during 2018-2019 cropping season. The annual rainfalls of ***Zaba*** village and that of ***Phircha village*** were 1060.5 mm and 1820.48 mm, respectively. The altitude of the study areas in the same order were 1910 and 1462 meter above sea level. The maximum average temperature of ***Zaba*** village was 30.79 and that of ***Phircha village was*** 27.22ºC while the minimum average temperatures were 20.03 and 16.84ºC, respectively (Figure 1).

Soil chemical-physical properties of the experimental sites with its description for soil depth of 0-20 cm are presented in Table 1.

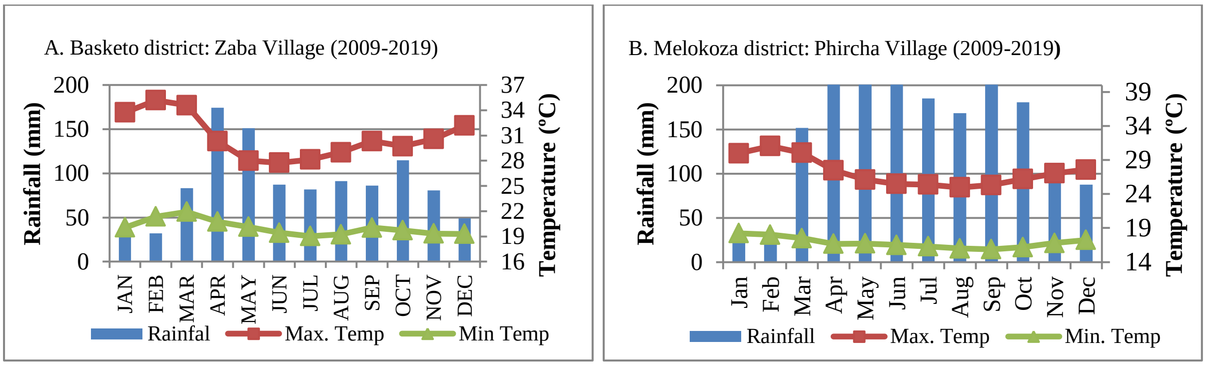

Figure 1: Environmental conditions of the experimental sites

Table 1: Soil laboratory analysis result of experimental soil sampled from the top soil of 0-20 cm depth

Description		Basketo	Melokoza	Status
pH		5.13	5.15	Strongly acidic
Total Nitrogen (TN %)		0.1364	0.14	Low
Organic carbon (OC %)		1.583	1.612	Moderate
Organic matter (OM %)		2.729	2.812	Moderate
Available phosphorus (P ppm)		13.124	13.213	Medium
Exchangeable potassium (K ppm)		153.34	154.32	
Textural class		Clay loam	Clay loam	
	Sand%	40	39	
	Clay%	34	36	
	Silt%	26	25	

2.2 Treatment and experimental design

Four varieties of Napier grass (ILRI_16815, ILRI_16902, ILRI_16913, ILRI_15743) with four levels of NPS fertilizer (0, 12.5, 25, 50 kg ha^{-1}) laid out in split-plot design with three replications in which varieties arranged in main plots and fertilizer rates in subplots. The forage was planted in four rows with 75 cm spacing between rows and 50 cm within rows. All other treatments of the experimental plots including regular weeding, Urea application and others were applied in an equal manner to all plots based on the agronomic recommendation of the International Livestock Research Institute (ILRI) for the grass.

2.3 Data collection

Data was collected from net plot area(4.5 m^2) to compute the circumference of each hole, tiller number per plant, leaf width, leaf length, leaf to stem ratio, leaf number per plant, plant height, green forage yield and dry matter yield. Upon the establishment of the forage, the data for all parameters were collected every 60 days after the first cutting (Zailan *et al*, 2018). Circumference was measured by a tape meter at the base of the plant. Tiller number counted for five randomly selected plants from the plot. Leaf width and length measured for the central leaf at centre of the leaf for selected plants. Leaf to stem ratio was the ratio of leaf dry matter to stem dry matter. Leaf number also counted for randomly selected five plants to identify better leafier plant among the experimental units. Plant height was measured from ground to top of the stem at forage harvesting for randomly selected holes. Green forage yield of a plot was weighed at the field using spring balance and converted to hectare base for fresh yield analysis and dry matter yield was computed by collecting 300-gram fresh sample leaf and stem part of the forage to be dried at 60^0C for 48 hours (Ritz *et al*., 2020) to constant weight and calculate dry matter percent, then dry matter yield was calculated by multiplying fresh matter yield by dry matter percent.

$$\text{DM\%} = \frac{Oven\ dry\ weight}{Fresh\ sample\ weight} x100 \quad [1]$$

Where

DM% is dry matter percent (AOAC, 1990)

$$DMY\left(\frac{t}{ha}\right) = \text{DM\% x Green forage yield } \left(\frac{\text{t}}{\text{ha}}\right) \quad [2]$$

Where

DMY (t/ha) is dry matter yield in ton per hectare (AOAC, 1990).

2.4 Economical and statistical analysis

Partial budget analysis was performed to evaluate the economic advantage of fertilization on Napier grass production (in terms of hay) by using the standard procedure (Upton, 1979). The partial budget analysis involves the calculation of the variable costs and benefits. The benefits are calculated based on the commercial market value of dry matter yield for all expenses recorded at the beginning of the study. Partial budget analysis was undertaken using fertilizer as a variable source of costs, total variable cost (TVC), and dry matter yield of the Napier grass as a source of income. Total revenue (TR) calculated by multiplying the dry matter yield in the current market price of the forage yield. Net revenue (NR) was calculated by deducting total variable cost (TVC) from total revenue (TR) as follows:

$$NR = TR - TVC \quad [3]$$

The marginal rate of return was the result of the change in net revenue divided by change total variable cost and expressed in percentage as indicated below.

$$MMR\% = \frac{\Delta NR}{\Delta TVC} * 100 \quad [4]$$

Where:

MRR (%) = marginal rate of return,

ΔNR = change in net revenue

ΔTVC = change in total variable cost

Analysis of variances for pooled data from Zaba and Phircha kebeles was carried out using SAS statistical computer package version 9.2 (SAS, 2011) and significance of means variation was compared using least significant difference (LSD) at 95% level of confidence.

3 Results and Discussion

The three-round cuts pooled mean values for circumference, tiller number per plant, leaf width and leaf to stem ratio are presented in Table 2. No interaction was observed between variety and fertilizer application for mean values presented in one-way table. NPS blended fertilizer application has no significant effect on variation (p>0.05) of circumference, tiller number per plant, leaf width and leaf to stem ratio. ILRI_15743 was found to be wider in ground covering with higher circumference value whereas ILRI_16815 with lowest circumference. This may indicate the later variety grows vertically up than the former which was covering the ground horizontally. Having a wider ground cover with higher circumference, dwarf variety like ILRI_15743 revealing a higher tiller number per plant than taller plants (Halim *et al.*, 2013). There was wider (P<0.05) leaves recorded for variety ILRI_16902 followed by ILRI_16815 indicating that it could have a broader leaf than the rest. Higher (P<0.05) leaf ratio to stem was recorded for ILRI_16902 followed by ILRI_15743. This might be due to the short internodes of dwarf varieties that might lead the plant to produce more leaves than stem compared to the taller ones. The leaf to stem ratio (LSR) is one of the criteria for evaluating the quality of the pasture grass because the higher proportion of leaves compared to stem indicate a better nutritive value (Zailan *et al.*, 2018). Thus, ILRI_16902 is leafier than the rest in the study.

Table 2: Mean values of selected vegetative growth of Napier grass as influenced by variety and NPS fertilizer at Basketo and Melokoza

NPS rate (kg/ha)	CRF (cm)	TNPP	LW (cm)	LSR
0	144.9	82.5	1.9	1.2
12.5	156.5	84.7	2.1	1.3
25	150.9	92.8	1.9	1.1
50	151.8	95.9	2.1	1
LSD (0.05)	NS	NS	NS	NS
Napier Grass variety				
ILRI-16815	131.5b	91.8	2.1ab	1.1b
ILRI-16902	131.8b	75.7	2.3 a	1.4a
ILRI-16913	150.3ab	89.45	1.9b	0.9b
ILRI_15743	190.6a	98.85	1.7b	1.2ab
LSD (0.05)	22.3	NS	0.2	0.3
CV (%)	9.2	22.7	5.1	18.01

Note: CRF = circumferences, TNPP = Tiller number per plant, LW = leaf width, LSR = leaf to stem ratio. Means in column followed by the same letter/s are not statistical different.

Leaf length, leaf number and stand height presented in Table 3 shows that NPS blended fertilizer application not influenced the leaf length and leaf number while plant height varied. ILRI_16815 possessed higher (P<0.05) leaf length, leaf number per plant and plant height. Increasing the level of NPS blended fertilizer from 0 to 12.5 kg ha^{-1} increased plant height from 60.3 to 72.2 cm, the increment of fertilizer level beyond 12.5 to 50 kg ha^{-1} decreased the height. Nitrogen fertilizer application improves plant height of Napier grass (Zewudu *et al.*, 2003) and the longer leaf observed at Melokoza while a higher number of leaves at Basketo. Plant height is an important parameter contributing to yield in forage crops (Zewudu *et al.*, 2003) that taller variety gives higher cumulative dry matter yield (Halim *et al.*, 2013).

Table 3: Mean values of selected growth parameters of Napier grass as influenced by NPS fertilizer, variety and site

NPS rate (kg/ha)	LL (cm)	LNPP	PH (cm)
0	70.1	9.9	60.3b
12.5	74	10.6	72.2a
25	74.6	10.5	67.4ab
50	72.1	10.7	69.5a
LSD (0.05)	NS	NS	8.5
Napier Grass variety			
ILRI_16815	91.9a	11.8a	84.6a
ILRI_16902	61.5c	10.9ab	71.5b
ILRI_16913	55.4d	8.8c	64.4b
ILRI_15743	82.0b	10.1b	48.9c
LSD (0.05)	4.9	1.1	8.5
Study site			
Basketo	69.0b	10.86a	65.9
Melokoza	76.4a	9.99b	68.8
LSD (0.05)	3.48	0.74	NS
CV (%)	5.9	9.8	12.2

Note: LL = leaf length, LNPP = leaf number per plant, PH = plant height. Means in column followed by the same letter/s are not statistical different.

Dry matter yield of Napier grass varied among varieties in the experiment and location while not for NPS blended fertilizer application. The interaction effect was not significant for either three or two ways (variety x fertilizer x locations). As presented in Table 4, ILRI_16815 had a higher (P<0.05) dry matter yield followed by ILRI_15743. Phosphorus contribution to dry matter yield was not significant for maize forage production (Hani, *et al.*, 2006) report is in line with the present study for NPS fertilization of Napier grass. Dry matter yield variation due to varietal differences reported before and the higher dry matter yield reported 5.8 t ha^{-1}cut^{-1} for four cultivars (Zailan *et al.*, 2018); 13.5 t ha^{-1} cut^{-1} for twelve cultivars (Nyambati *et al.*, 2010); 16.5 t ha^{-1} year^{-1} for four varieties (Maleko *et al.*, 2019). Three cuttings per year mean value dry matter yield in the present study, 12.7 t ha^{-1} cut^{-1}, was in line with 4.6-20.5 t ha^{-1} year^{-1} reported before in Ethiopia (Zewdu, 2005). An increase in dry matter yield could be due to higher plant height in the present study is concurring with the previous result (Atumo, 2018).

Table 4: Dry matter and green forage yields of Napier grass as influenced by NPS fertilizer, variety and site

NPS fertilizer (kg/ha)	GFY (t/ha)	DMY (t/ha)
0	26.51	5.8
12.5	38.41	8.7
25	30.06	8.3
50	34.86	7.6
LSD (0.05)	NS	NS
Napier grass variety		
ILRI-16815	56.02a	12.7a
ILRI-16902	18.81c	4.8c
ILRI-16913	16.83c	3.9c
ILRI_15743	40.42b	9.1b
LSD (0.05)	9.43	2.28
Site		
Basketo	26.58b	6.16b
Melokoza	39.45a	9.04a
LSD (0.05)	6.67	1.61
CV%	11.5	20.9

Note: GFY = green forage yield, DMY = dry matter yield, Means in column followed by the same letter/s are not statistical different.

Pearson correlations of parameters presented in Table 5 showed that dry matter yield positively (P<0.05) correlated with leaf length and green forage yield. Leaf width and plant height negatively (P<0.05) correlated with circumference. A positive correlation (P<0.05) of plant height with leaf width and leaf number per plant with leaf length was observed in this study. Dry matter yield possessed a high positive correlation with leaf length (P<0.001), leaf number per plant (P<0.05) and green forage yield (p<0.001) in the present study. Thus, dry matter accumulation in the crop could be a contribution to the growth and development of agronomic parameters which in turn could be the result of leaf growth and development of Napier grass. In the present study, the varieties with longer plant height were having higher dry matter yield than shorter ones. This result was reported before for the association of plant height with dry matter yield of a given crop (Halim *et al.*, 2013).

Partial budget analysis (Upton, 1979) presented in Table 6 showed that the higher net revenue recorded at 12.5 kg/ha NPS blended fertilizer level. The marginal rate of return also showed that there was a high rate of return at 12.5 kg/ha for each unit of NPS blended fertilizer application at *Basketo* and *Melokoza*.

Table 5: Pearson Correlation of parameters

	CRF cm	TNPP	LW cm	LSR	LL cm	LNPP	PH cm	GFY t/ha
TNPP	0.622							
LW (cm)	-0.764*	-0.63						
LSR	-0.061	-0.62	0.385					
LL cm	0.167	0.501	-0.161	0.086				
LNPP	-0.387	-0.03	0.561	0.406	0.698*			
PH cm	-0.807*	-0.27	0.764*	0.003	0.231	0.667		
GFY t/ha	0.122	0.502	-0.054	0.005	0.963**	0.693*	0.355	
DMY t/ha	0.092	0.499	-0.052	0.027	0.971***	0.039*	0.385	0.979***

*= P<0.05, **= P<0.01, ***= P<0.001, CRF= circumferences, TNPP= Tiller number per plant, LW= leaf width, LSR= leaf to stem ratio, LL= leaf length, LNPP= leaf number per plant, PH= plant height, GFY= green forage yield

Table 6: Partial budget analysis of fertilizer application to Napier grass

Descriptions	ILRI-15743				ILRI-16815				ILRI-16902				ILRI-16913			
	0	12.5	25	50	0	12.5	25	50	0	12.5	25	50	0	12.5	25	50
Total Fixed costs(TFC)	2590	2590	2590	2590	2590	2590	2590	2590	2590	2590	2590	2590	2590	2590	2590	2590
Variable Costs																
Urea (14 ETB/kg)	0	1400	1400	1400	0	1400	1400	1400	0	1400	1400	1400	0	1400	1400	1400
NPS (14 ETB/kg)	0	175	350	700	0	175	350	700	0	175	350	700	0	175	350	700
Total Variable Costs (TVC)	0	1575	1750	2100	0	1575	1750	2100	0	1575	1750	2100	0	1575	1750	2100
Dry matter yield (t/ha)	7.55	12.65	10.25	7.85	6.9	13.7	8.95	9.15	4.55	4.45	6.3	6.2	5.95	4.15	7.6	5.2
Total Revenue (TR=3588ETB/t=50% WB)	27089	45388.2	36777	28165.8	24757	49155.6	32112.6	32830	16325	15966.6	22604.4	22245.6	21349	14890.2	27269	18657.6
Net Revenue	27089	43813.2	35027	26065.8	24757	47580.6	30362.6	30730	16325	14391.6	20854.4	20145.6	21349	13315.2	25519	16557.6
ΔNR		16723.8	-8786.2	-8961.2		22823.4	-17218	367.6		-1933.8	6462.8	-708.8		-8033.4	12204	-8961.2
ΔTVC		1575	175	350		1575	175	350		1575	175	350		1575	175	350
MRR (%)		10.618	-50.2	-25.60		14.491	-98.39	1.05		-1.228	36.93	-2.025		-5.101	69.7	-25.60

MRR- Marginal Rate of Return, WB-Wheat bran

4 Conclusion

Napier grass is more productive at Melokoza lowlands than Basketo midlands. Though dry matter yield variation for fertilizer application was not significant, the higher economical yield was at 12.5 kg/ha NPS application. ILRI-16815 recorded significantly higher dry matter yield among others in the test. Leaf to stem ratio was higher for ILRI-16815. Dry matter yields highly correlated (P<0.001) with leaf length, leaf number per plant and green forage yield which have less association with circumference, leaf width and leaf to stem ratio. There was better yield recorded at Melokoza than Basketo and economically feasible return in applying 12.5 kg ha^{-1} NPS blended fertilizer in Napier grass production. Thus, ILRI-16815 could be recommended for better dry matter yield at Melokoza, Basketo and similar agro-ecology and it is economical to use 12.5 kg/ha NPS in Napier production.

Conflict of Interest

There is no conflict of interest claimed by the authors.

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Heritability, Genetic Advance and Gene Action Determination for Seed Yield and Yield Components Using Generations of Finger Millet [*Eleusine coracana* (L.) Gaertn]

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Abstract: *Finger millet (Eleusine coracana (L.)Gaertn.) is a small seed crop grown in low rainfall areas and its diverse cultural conditions make it an important food security crop; however, its productivity is low in Ethiopia. This research was done to estimate heritability and gene numbers for yield and yield components in parental, filial and backcross generations derived from a cross of two-finger millet cultivars at Koga and Adet Agricultural Research Centers, Northwestern Ethiopia in 2014/15. The experiment comprised six basic generations and four reciprocals of finger millet evaluated in randomized complete block design with two replications. Data on yield and yield component traits were recorded. The result showed the number of genes estimated in both locations ranged from -0.23 to 88.78, indicating that the presence of many genes with small cumulative effect and epistasis gene effect will bias an estimate of the number of genes. Medium to high narrow-sense heritability value coupled with high genetic advance showed the influence of additive variance and ease of improvement for biomass yield and number of ears in this population. While low, medium and high narrow-sense heritability observed together with the low genetic gain in most traits; which showed the presence of small additive variance in most traits with the influence of epistasis; hence intensive selection is required to exploit the characters. In most traits, the number of genes estimated to be negative and/or very small indicates that epistasis was significant and the existence of environmental effect in both locations. The results indicate the presence of genetic variability for developing improved varieties through crossing and selection.*

Keywords: Additive variance, Epistasis, Genetic variability, Polygene

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1. Introduction

Finger millet [*Eleusine coracana* (L.) Gaertn] is an important staple crop grown under rain-fed conditions in Northwestern Ethiopia which has 96.9% area coverage from the Amhara region (CSA, 2020). The total area coverage of finger millet in Ethiopia is 455,580.47 ha with a total production of 112595.79 tons whereas in Amhara Region it covers 236,124.66 ha of land with the production of 59140.23 tons, which has a proportion of 51.83% and 52.5% to the national area coverage and production, respectively (CSA, 2020). However, it is the most neglected cereal crop grown on marginal lands under poor management condition and resulted in very low yield (Salasya *et al*., 2009). Degu *et al*. (2009) also reported that lack of improved varieties is one of the major constraints in finger millet production. This low productivity of the crop emanates due to lack of genetic improvement that hinders overall progress of the crop in developing countries; even though environmental factors also contribute to large losses in yield (Zerihun, 2009).

The knowledge of genetic system present in a given crop species of the character under improvement is of paramount importance for the success of any plant-breeding program (Azizi *et al*., 2006). Hence, estimation of genetic parameters helps researchers understanding genetic variances, heritability, and the number of genes and to facilitate the selection of a desirable breeding method.

The basic and key to bringing about genetic improvement in any crop is the availability of genetic variability. Variability is the occurrence of differences among individuals due to differences in their genetic composition and/or the environment in which they are raised (Allard, 1960; Falconer *et al*., 1996).

Heritability of crops provides information used for breeders in designing appropriate breeding strategies. The magnitude of such estimates also suggests the extent to which improvement is possible through selection. However, Johnson *et al.* (1955) stated that heritability estimates together with genetic advance are more important than heritability alone to predict the resulting effect of selecting the best individuals. Likewise, Bisne *et al*. (2009) also reported that heritability estimates along with genetic advance are normally more helpful in predicting the gain under selection than heritability estimates alone. Genetic advance is also of considerable importance because it indicates the magnitude of the expected genetic gain from one cycle of selection (Hamdi *et al.*, 2003). Genetic advance as percent of the mean (GAM) is a more reliable index for understanding the effectiveness of selection in improving the traits because the estimates are derived by the involvement of heritability, phenotypic standard deviation and intensity of selection. Thus, genetic advance (GA) along with heritability provides a clear picture regarding the effectiveness of selection for improving the plant characters.

In order to develop a high yielding variety, it is very important to know about the genetic structure of each trait including, variability, gene mode of action, heritability and number of controller genes. This information enables breeders to develop improved varieties. Hence, the present investigation is carried out to gather information on heritability and the number of genes governing the expression of yield and yield component traits of finger millet to design appropriate breeding strategies

2. Materials and Methods

2.1 Description of the study area

The study was undertaken in the Northwestern Ethiopia at the research field of Mecha and Adet Agricultural Research Center.

Table 1: Geographical description of the experimental sites

Location	Elevation (masl)	Latitude	Longitude	Temperature (°C)		Annual rainfall (mm)
				Maximum	Minimum	
Mecha	1960	11°25’20” N	37°10’20” E	27.9	9.4	1557.9
Adet	2240	11°16’19’’N	37°28’38’’E	26.4	10.9	1215.2

Source: WAMSC, 2014

Table 2: Soil physical and chemical properties of the experimental area

Location	Soil pH	Textural class	Soil type	O.M (%)	Total N (%)	Available P (ppm)
Mecha*	5.09-5.3	Clay	Nitosol	2.34-4.44	0.18-0.24	3.54-8.7
Adet**	5.38-5.48	Clay	Luvisol	2.67-2.86	0.17-0.47	2.64-2.76

Source: Berhanu *et al*., 2014*; NSRC, 2006**; O.M = Organic matter; ppm = parts per million

2.2 Experimental materials

The experimental materials produced using generation mean analysis, with model parameters of (m), (a) and (d) that consisted of basic generations (P1, P2, F1, F2, BC1, and BC2) and their reciprocals (RF1, RF2, RBC1 and RBC2) derived from a cross of improved variety Necho (P1) and local Tikur dagusa/Abate tikur (P2). The parent varieties were chosen primarily based on their difference in seed yield, yield components and other traits.

2.3 Experimental design

The six basic generations and their four reciprocals were evaluated in a Randomized Complete Block Design with 2 replications at the research field of Mecha and Adet Agricultural Research Center. Each plot for various generations was sown in one, two, and three rows with five-meter lengths for parental, F1 and RF1 generations; for backcross and reciprocal backcross and for F2 and RF2 generations, in the same order (Akhtar and Chowdhary, 2006; Yadav and Singh, 2011). Each generation was planted in a plot of 5 m length with row to row spacing of 40 cm and a within row spacing of 15 cm.

2.4 Management of experimental plants

The seed rate of 15 kg/ha and fertilizer rate of 100/50 kg/ha for DAP and UREA were applied in rows, respectively (Molla, 2012). The total required amount of phosphorous applied at basal but from the total nitrogen applied half was used at planting and the remaining was top-dressed at tillering stage. Hand hoeing and weeding were made one and two times, respectively over the growing season to put the experimental plots free of weeds. Other agronomic management practices were done as required.

2.5 Data collection

The number of plants sampled for traits in each experimental unit (plot) varied among generations depending on the expected level of heterogeneity in the generation. Accordingly, sampled numbers were 10 plants for non-segregating generations such as P1, P2, F1 and RF1 due to its homogeneity; correspondingly for segregating generations, 20 from each backcross and its reciprocals and 30 plants from each F2 and RF2 generations due to its heterogeneity (Akhtar and Chowdhary, 2006; Yadav and Singh, 2011).

The measured traits on a plant basis included plant height, number of effective tillers, number of ears, number of fingers/ear and finger length data were recorded. Other parameters such as days to flowering, days to maturity, grain yield, biomass yield, harvest index and thousand seed weight were recorded on a plot basis. The measurement was done according to the International Board for Plant Genetic Resources (IBPGR, 1985) descriptor.

2.6 Data analysis

Analysis of variance and mean comparison using Duncan's Multiple Range Test at 5% probability level was done with SAS statistical software model with computer application (SAS, 2002).

2.6.1 Generation variance component analysis

Variance components under generation mean analysis (additive, dominance and environment) were estimated as per Kearsey and Pooni (1996) and Mather and Jinks (1971) using the following equations.

$$V(E) = \frac{1}{4}(VP1 + VP2 + 2VF1 \qquad [1]$$

Where:
V(E) = Environment variance; VP1 = Variance parent one; VP2 = Variance parent two and VF1 = Variance first filial generation

$$V(A) = 2VF2 - VBC1 - VBC2 \qquad [2]$$

Where:
V(A) = Additive variance; VF2 = variance second filial generation; VBC1 = Variance backcross one and VBC2 = Variance backcross two

$$V(D) = 4(VF2 - \frac{1}{2V[d]} - V[E]) \qquad [3]$$

Where:
V(D) = Dominance variance; VF2 = Variance second filial generation; V[d] = Variance dominance and V[E] = Environmental variance

$$\left(\frac{D}{A}\right) 1/2 = \left(\frac{V[D]}{V[A]}\right) 1/2 \qquad [4]$$

Where
$\left(\frac{D}{A}\right) 1/2$ = Average degree of dominance variance; V[D] = Dominance variance; V[A] = Additive variance

$$F = VBC1 - VBC2 \qquad [5]$$

Where
F = Association between D and A in all loci; VBC1= variance backcross one; VBC2 = variance backcross two

2.6.2 Heritability analysis

Narrow sense heritability (h^2n) was estimated following the methods described by Warner (1952).

$$h2n = [2VF2 - (VBC1 + VBC2)]/VF2 \qquad [6]$$

Where:

h^2n = narrow sense heritability; VBC1 variance backcross one; variance backcross two; variance second filial generation

According to Robinson *et al*. (1949) heritability (H^2) with the values of H^2<0.2 is classified as low while, values between 0.2 and 0.4 and greater than 0.4 are considered as moderate and high, respectively.

2.6.3 Genetic advance analysis

Genetic advance i.e. the expected genetic gains from selection were calculated using the formula described by Johnson *et al*. (1955) indicated under formula 7 while the predicted genetic advance where the expected genetic gain upon selection was expressed as a percentage of F2 mean using the formula under 8.

$$\Delta G = K * h2n * \sigma F2 \quad [7]$$

Where:
ΔG = Genetic advance; h^2n = narrow sense heritability; σF2 = standard deviation second filial generation

$$\Delta G(\%) = \left(\Delta G * \sqrt{F2}\right) * 100 \quad [8]$$

Where:
ΔG (%) = Genetic advance as percentage of second filial generation; F2 = second filial generation

2.6.4 Minimum number of gene analysis

In order to evaluate the effect of those genes which are involved in yield and yield component traits minimum number of gene was computed using the formula described by Lande (1981).

$$MNG = \frac{(\overline{P1} - \overline{P2})^2}{8[2\sigma^2 F2 - (\sigma^2 BC1 + \sigma^2 BC2)]} \quad [9]$$

Where:
MNG = Minimum number of gene; P1 =parent one cultivar; P2 = Parent two cultivar; σ^2 = variance; F2 = second filial generation; BC1 = Backcross one; BC2 = Backcross two

3 Results and Discussion

3.1 Analysis of variance

Analysis of variance indicated the presence of significant differences (P≤0.01) among generation for all traits at Adet (Table 3) and for all traits except plant height (P≤0.05) at Mecha (Table 4). A significant difference between treatments indicated the existence of genetic variability in genetic materials for the traits studied. These results were in agreement with the findings of Foroozanfar and Zeynali (2013) in bread wheat. The foregoing statement ensures the presence of high genetic potential among these generations so that these results are similar as generation effects found significantly different as suggested by Dvojković *et al.* (2010).

Table 3: Analysis of variance of yield and yield component traits of all generations in finger millet cross at Adet

Source of variation	DF	PH (cm)	FL (cm)	NT	NF	NE	DTF	DTM	SY (kg)	BMY (kg)	HI	TSW (g)
Replication	1	0.55	0.41	0.98	0.2	138.28	31.25	2.45	185978.75	2830528.8	36.96	0.07
Generation	9	24.24**	7.09**	3.32**	4.71**	13.99**	7.25**	56.72**	584122.50**	241071.13**	112.80**	0.07**
Error	9	2.74	0.14	0.32	0.18	0.44	0.58	0.45	2373.57	13455.13	4.2	0.01
CV (%)		2.3	3.62	5.39	4.68	4.89	0.88	0.49	2.14	2.48	4.24	2.36

*, ** = 0.05 and 0.01, respectively; DF = Degree of Freedom, PH = Plant Height, FL = Finger Length, NT = Number of Tiller, NF = Number of Finger, NE = Number of Ears, DTF = Days to Flowering, DTM = Days to Maturity, SY = Seed Yield, BMY = Bio Mass Yield, HI = Harvest Index, TSW = Thousand Seed Weight

Table 4: Analysis of variance of yield and yield component traits of all generations in finger millet cross at Mecha

Source of variation	DF	PH (cm)	FL cm)	NT	NF	NE	DTF	DTM	SY (kg)	BMY (kg)	HI	TSW (g)
Replication	1	25.88	0.5	0.17	0.06	1.38	5	0.8	75651.15	581746.05	6.48	0.01
Generation	9	20.48*	4.96**	5.75**	5.46**	4.79**	8.98**	38.31**	254498.40**	383926.90**	27.34**	0.08**
Error	9	4.62	0.07	0.19	0.21	0.27	0.44	0.69	5451.06	23189.83	2.11	0.01
CV%		3.32	2.59	6.68	5.77	5.11	0.72	0.63	3.69	3.8	2.92	3.31

*, ** = 0.05 and 0.01, respectively; DF = Degree of Freedom, PH = Plant Height, FL = Finger Length, NT = Number of Tiller, NF = Number of Finger, NE = Number of Ears, DTF = Days to Flowering, DTM = Days to Maturity, SY = Seed Yield, BMY = Bio Mass Yield, HI = Harvest Index, TSW = Thousand Seed Weight

3.2 Mean performance of the generations

The mean performance of the generations for yield and its components are presented in Table 5and Table 6. The results revealed the presence of genetic variability for these characters in the studied materials. The F1's mean value for all traits except plant height, days to flowering, days to maturity and thousand seed weight were greater than the mid parental value of finger length, number of tillers, number of fingers, number of ears, seed yield, biomass yield and harvest index.

The F2's mean value was significantly below that of the F1's, except for traits days to flowering, days to maturity and thousand seed weight; whereas, its mean value was better than the mid-value of parental lines for the traits finger length, the number of fingers, days to maturity, seed yield, harvest index and thousand seed weight. The backcross to P1 was significantly different from backcross to P2 excluding thousand seed weight character at Adet (Table 5). Similarly, at Mecha the F1's mean value was greater than to the mid parent and mean of F2's value of all traits except to days to flowering, days to maturity and thousand seed weight. Backcross to P1 was significantly different from backcross to P2 except for seed yield, harvest index and thousand seed weight (Table 6).

Table 5.The mean, standard error and DMRT of main and reciprocal effect generations of finger millet at Adet

Generation	PH	FL	NT	NF	NE	DTF	DTM	SY	BMY	HI	TSW
P1	67.30±0.70^{e}	11.45±0.35^{b}	9.40±0.30^{c}	8.90±0.40^{b}	14.70±3.60^{b}	83.00±1.0^{d}	130.50±0.5^{e}	2387.35±57.10^{b}	4966.00±484.0^{a}	48.43±3.58^{b}	3.05±0.05^{b}
P2	77.75±1.05^{a}	8.70±0.40^{d}	10.98±0.03^{b}	6.45±0.55^{d}	10.20±2.20^{d}	90.50±0.5^{a}	149.00±1.0^{a}	1550.68±76.68^{e}	4305.00±395.0^{c}	38.29±0.60^{d}	3.25±0.05^{a}
F1	72.10±0.60^{bcd}	13.75±0.25^{a}	12.50±0.10^{a}	11.50±0.30^{a}	18.00±2.10^{a}	86.50±1.5^{bc}	135.00±0.0^{c}	3203.85±109.55^{a}	5188.50±418.5^{a}	61.75±3.12^{a}	3.05±0.05^{b}
F2	70.20±1.00^{cde}	10.25±0.22^{c}	9.33±0.13^{c}	9.05±0.05^{b}	12.02±2.89^{c}	86.50±1.5^{bc}	140.50±0.5^{b}	2139.30±57.00^{c}	4592.50±307.5^{b}	46.70±1.90^{bc}	3.40±0.10^{a}
BC1	68.61±1.39^{de}	9.40±0.15^{cd}	9.50±0.30^{c}	9.00±0.20^{b}	14.00±2.60^{b}	86.00±2.0^{c}	133.00±0.0^{d}	2233.83±50.63^{c}	4622.50±519.5^{b}	46.97±2.02^{bc}	2.90±0.10^{b}
BC2	75.15±0.85^{ab}	8.73±0.48^{d}	11.25±0.75^{ab}	7.84±0.16^{c}	11.25±2.25^{cd}	88.00±1.0^{b}	139.50±0.5^{b}	1844.35±131.75^{d}	4301.50±299.5^{c}	42.87±0.08^{cd}	3.00±0.00^{b}
RF1	72.75±0.75^{bc}	13.40±0.10^{a}	12.40±0.30^{a}	11.4±0.40^{a}	17.65±2.65^{a}	86.50±0.5^{bc}	135.50±0.5^{c}	3178.30±124.30^{a}	5220.00±294.0^{a}	60.95±1.05^{a}	3.05±0.15^{b}
RF2	70.18±1.28^{cde}	10.25±0.12^{c}	9.30±0.34^{c}	9.00±0.00^{b}	12.00±2.50^{c}	86.50±1.5^{bc}	140.00±1.0^{b}	2127.40±107.10^{c}	4632.50±354.5^{b}	46.02±1.22^{bc}	3.40±0.00^{a}
RBC1	68.60±1.80^{de}	9.43±0.38^{cd}	9.50±0.80^{c}	8.90±0.30^{b}	13.85±3.15^{b}	86.00±2.0^{c}	133.00±0.0^{d}	2210.25±101.25^{c}	4631.50±401.5^{b}	47.88±1.98^{bc}	2.90±0.10^{b}
RBC2	75.75±1.25^{ab}	8.70±0.20^{d}	11.23±0.58^{ab}	7.85±0.15^{c}	11.69±2.36^{cd}	88.00±1.0^{b}	139.50±0.5^{b}	1849.45±148.95^{d}	4288.00±288.0^{c}	43.09±0.59^{cd}	3.00±0.00^{b}

PH- Plant Height, FL- Finger Length, NT- Number of Tiller, NF- Number of Finger, NE- Number of Ears, DTF- Days To Flowering, DTM- Days To Maturity, SY- Seed Yield, BMY- Bio Mass Yield, HI- Harvest Index, TSW- Thousand Seed Weight, P1-Parent one, P2-Parent two, F1-First filial, F2- Second filial, BC1- Backcross one, BC2- Backcross two, RF1- Reciprocal First filial, RF2-Reciprocal Second filial, RBC1- Reciprocal Backcross one, RBC2- Reciprocal Back cross two

Table 6.The Mean, Standard error and DMRT of main and reciprocal effect generations of finger millet at Mecha

Generation	PH	FL	NT	NF	NE	DTF	DTM	SY	BMY	HI	TSW
P1	59.45±1.15^{d}	10.75±0.45^{b}	6.70±0.40^{c}	8.80±0.80^{b}	10.70±0.10^{b}	89.50±0.5^{d}	121.50±0.5^{d}	2169.60±29.40^{b}	4296.00±104.00^{ab}	50.52±0.54^{b}	3.20±0.20^{bc}
P2	69.55±3.45^{a}	8.35±0.15^{e}	4.70±0.10^{d}	5.50±0.20^{e}	7.35±0.35^{d}	97.00±0.0^{a}	137.50±0.5^{a}	1506.15±17.85^{d}	3194.50±78.50^{d}	47.16±0.60^{bc}	3.50±0.10^{a}
F1	67.50±3.50^{ab}	13.10±0.10^{a}	9.00±0.20^{a}	10.40±0.20^{a}	12.30±1.00^{a}	92.00±0.0^{c}	129.00±1.0^{c}	2603.25±32.00^{a}	4634.00±246.00^{a}	56.30±2.30^{a}	2.93±0.03^{d}
F2	63.83±0.93^{bcd}	10.15±0.15^{bc}	5.30±0.30^{d}	8.30±0.10^{bc}	9.30±0.10^{c}	93.00±1.0^{c}	134.00±1.0^{b}	1881.50±11.50^{c}	4028.00±12.00b^{c}	46.68±0.12^{c}	3.38±0.03^{ab}
BC1	61.18±0.48^{cd}	9.9±0.30^{c}	7.65±0.35^{bc}	7.25±0.15^{cd}	10.48±0.18^{bc}	91.50±0.5^{c}	129.50±0.5^{c}	1921.63±130.63^{c}	3975.50±247.50^{bc}	48.32±0.28^{bc}	3.10±0.00^{cd}
BC2	66.10±0.90^{abc}	9.05±0.25^{d}	4.90±0.10^{d}	6.30±0.30^{de}	9.25±0.25^{c}	95.00±0.0^{b}	133.00±0.0^{b}	1751.00±84.30^{c}	3662.00±229.00^{c}	47.84±0.67^{bc}	3.08±0.03^{cd}
RF1	67.53±2.23^{ab}	12.95±0.35^{a}	8.90±0.40^{a}	10.25±0.25^{a}	12.50±0.50^{a}	93.00±0.0^{c}	129.50±0.5^{c}	2590.00±40.00^{a}	4605.00±261.0^{a}	56.38±2.33^{a}	2.90±0.00^{d}
RF2	63.50±0.50^{bcd}	10.20±0.10^{bc}	5.40±0.20^{d}	8.40±0.10^{b}	9.25±0.25^{c}	93.00±1.0^{c}	134.50±0.5^{b}	1891.65±13.35^{c}	4037.50±6.50^{bc}	46.85±0.25^{c}	3.40±0.00^{ab}
RBC1	62.10±0.90^{cd}	9.85±0.15^{c}	7.75±0.55^{b}	7.30±0.20^{cd}	10.50±0.30^{bc}	92.00±1.0^{c}	129.50±0.5^{c}	1926.50±153.50^{c}	3962.50±262.50^{bc}	48.57±0.67^{bc}	3.10±0.00^{cd}
RBC2	66.10±0.60^{abc}	9.08±0.08^{d}	4.93±0.08^{d}	6.33±0.08^{de}	9.30±0.50^{c}	95.00±1.0^{b}	133.00±0.0^{b}	1752.50±102.50^{c}	3675.50±258.50^{c}	47.73±0.58^{bc}	3.05±0.05^{cd}

PH- Plant Height, FL- Finger Length, NT- Number of Tiller, NF- Number of Finger, NE- Number of Ears, DTF- Days To Flowering, DTM- Days To Maturity, SY- Seed Yield, BMY- Bio Mass Yield, HI- Harvest Index, TSW- Thousand Seed Weight, P1-Parent one, P2-Parent two, F1-First filial, F2- Second filial, BC1- Backcross one, BC2- Backcross two, RF1- Reciprocal First filial, RF2-Reciprocal Second filial, RBC1- Reciprocal Backcross one, RBC2- Reciprocal Back cross two

3.3 Component of genetic variation

Mather (1943, 1973) stated that genetic variability obtained because of crossing, segregation and recombination of parental lines redistributed among the various states, in which it can exist. The existence of genetic variation in the cross shows how much of the variation is heritable and what types of gene effects are involved. Estimates of additive, dominance and environmental variances, degree of dominance, the direction of dominance, heritability values, genetic advance and number of genes are presented in Table 7 and Table 8.

Table 7: Variance components estimates of generations for various characters of finger millet 'Necho x Tikurdagusa' cross at Adet

Traits	A	D	E	$(H/D)^{1/2}$	F	MNG
Plant height (cm)	-0.000045	0.000355	0.000031	-2.81	0.000157	-10.63
Finger length (cm)	-0.001142	0.00166	0.000243	-1.21	-0.000884	-1.29
Number of tiller	-0.001749	0.003864	0.000121	-1.49	-0.000093	-0.27
Number of finger	-0.000249	-0.00262	0.000789	3.24	0.000035	-7.76
Number of ear	0.007348	0.002888	0.012312	0.63	0.003896	2.44
Days to flowering	-0.000013	0.000332	0.000041	-5.05	0.000153	-6.9
Days to maturity	0.000033	-0.000022	0.000008	-0.82	-0.000005	12.37
Seed yield	-0.001411	0.003016	0.000593	-1.46	-0.001531	-3.12
Biomass yield	-0.002061	0.001018	0.002512	-0.7	0.001847	-0.23
Harvest index	-0.000503	-0.000624	0.000654	1.11	0.000977	-2.42
1000 seed weight	-0.000151	-0.000068	0.000142	0.67	0.000249	-0.36

A = Additive variance, D = Dominance variance, E = Environmental variance (E), $(D/A)^{1/2}$ = Degree of dominance, the F = Direction of dominance, MNG = The minimum number of gene

Table 8: Variance components estimates of generations for various characters of finger millet 'Necho x Tikurdagusa' cross at Mecha

Traits	**A**	**D**	**E**	**$(H/D)^{1/2}$**	**F**	**MNG**
Plant height (cm)	0.000093	-0.002254	0.000587	-4.92	-0.000033	5.96
Finger length (cm)	-0.000112	-0.000164	0.000165	1.21	0.000004	-10.94
Number of tiller	0.000393	0.000564	0.000516	1.20	0.001207	5.38
Number of finger	-0.000484	-0.002399	0.000853	2.23	-0.00006	-8.1
Number of ear	-0.000306	-0.001312	0.000624	2.07	-0.00029	-8.82
Days to flowering	0.00003	0.000072	0.000009	1.55	0.000034	4.99
Days to maturity	0.000004	-0.000008	0.000005	-1.41	0.000006	88.78
Seed yield	-0.003037	0.005776	0.000081	-1.38	0.000933	-1.03
Biomass yield	-0.003221	0.00346	0.000746	-1.04	0.000051	-0.64
Harvest index	-0.000064	-0.001232	0.000342	4.39	-0.00003	-1.68
1000 seed weight	0.000007	-0.00107	0.000272	-12.36	-0.000009	16.45

A = Additive variance, D = Dominance variance, E = Environmental variance (E), $(D/A)^{1/2}$ = Degree of dominance, the F = Direction of dominance, MNG = The minimum number of gene

3.3.1 Additive variance

The predominance of additive gene action depicted that it is fixable in nature and selection will be very effective, but the existence of low and negative additive variance in most traits in this cross-required intensive selection to exploit the traits due to the presence of epistasis gene effect. The negative value of dominance and additive variances for the characters indicates that the negative sign may arise due to genotype by environment interaction (Robinson *et al.,* 1955; Haque *et al*., 2013). The environmental variance was higher than the additive variance for the number of fingers, number of ears, and harvest index at both locations and days to flowering and biomass yield at Adet. Whereas, plant height, finger length, number of tillers, days to maturity and thousand seed weight at Mecha, which indicated that, this character lacks value for selection in this cross. At the same time, estimates of low narrow-sense heritability for these traits were also other indicators for a low value of additive variances. This suggests that the environment and non-additive gene effect had influenced the expression of the yield and yield component traits. Therefore, breeding methodologies that can reduce these variations may help improve the rate of gain from the traits; and suggesting that additive variance was playing a major role in the improvement of these traits.

3.3.2 Average degree of dominance

The average degree of dominance revealed high variation in both sites. It ranged from 0.63 (number of ears) to -5.05 (days to flowering) at Adet and -1.04 (biomass yield) to -12.36 (thousand seed weight) at Mecha site (Table 7and Table 8). According to Kearsey and Pooni (1996) and Farshadfar (1998) average degree of dominance is used to determine the importance of dominance effects in relation to the additive deviations of genes and is estimated as partial when the value was less than unity while dominance was greater than unity for traits influenced by over-dominance effects. Hence, in this study partial dominance, dominance and over dominance gene effects present in the inheritance of traits with the range of 0.63 to -12.36.

The results indicated that except the number of ears/plant, days to maturity, biomass yield and thousand seed weight at Adet and biomass yield at Mecha; the other traits in both locations determined by over dominance gene effects. Kutlu and Olgun (2015) reported similar findings where over dominance gene effect was observed for harvest index and grain yield per plant in the mean of average degree of dominance value. This foregoing statement showed a low, narrow-sense heritability because of a strong environmental effect on the expression of this trait.

3.3.3 Direction of dominance

The direction of dominance (F) estimated for the studied traits (Table 7and Table 8)showed positive value for most of the traits except for finger length, number of tillers/plant, days to maturity and seed yield at Adet, and plant height, number of fingers, number of ears, harvest index and thousand seed weight at Mecha. These results indicated that the traits controlled by dominant gene action so that dominant alleles were found more than recessive alleles in the parents. Likewise, Shahrokhi *et al*. (2013) observed the importance of dominant gene action in the inheritance of the above traits. The negative values of F mean, the additive genetic variation controlled the inheritance of the traits. Selection methods are effective to improve these traits in this cross.

3.3.4 Minimum number of genes

Determination of the number and effects of this polygene desired for obtaining optimal genotypes in breeding practice. Hence, estimates of the minimum number of genes controlling yield and yield-related traits are shown in Table 7and Table 8. The estimates of both locations ranged from -0.23 to 88.78 number of genes.

According to individual location estimated number of genes ranged from -0.23 (biomass yield) to 12.37 (days to maturity) at Adet whereas from -0.64 (biomass yield) to 88.78 (days to maturity) at Mecha were controlled by many genes and this happened because of divergence of the two parents, so these cultivars can be used for future breeding programs as genetic materials. The negative sign and small values of the number of genes may indicate the presence of epistasis and environmental effect (Coates and White, 1998). Similarly, Yield and its component traits controlled by polygene, whose expression greatly affected by environments (Ahmed and Khaliq, 2007). Therefore, the estimates of the minimum number of genes of the cross are likely to be inaccurate with the effect of environment and epistasis. Despite a situation, most of the estimates indicate that the yield and its components are quantitatively inherited traits that are amenable to selection.

3.4 Heritability

Heritability estimates for studied characters between Adet and Mecha varied considerably and presented in Table 9, respectively. Narrow-sense heritability estimated in the range of 3.4 (days to flowering) to52.4 (days to maturity) at Adet and 0.52 (thousand seed weight) to 43.37 (biomass yield) at Mecha, respectively. The high heritability of days to maturity and thousand seed weight at Adet and biomass yield at Mecha estimate indicates the selection procedures are simpler and lead to fast genetic improvement of the traits (Khan et *al*., 2008) since these traits are highly heritable from parents to progenies. In addition to that, for traits that expressed high to medium heritability, simple selection would be an effective method (Feyissa and Zinaw, 2014). While, low heritability values were indicating selections might be difficult or virtually impractical and revealed only slow progress for the characters due to some variances constituting the environment variance or the masking effect of environment on genotypic effects (Eid, 2009). The estimated values of narrow-sense heritability (h^2n) were higher in some of the traits in both studied areas due to additive variance being higher. These indicated that additive gene action engaged in the expression of these traits and then selection becomes effective from segregate generations to obtain high performing cultivar (Kutlu and Olgun, 2015).In contrary to the above finding, the additive variance was lower than the environmental variance for traits found in Adet (days to flowering and biomass yield), Mecha (plant height, finger length, number of tillers, days to maturity and thousand seed weight) and in both locations (number of fingers/plant, number of ears/plant and harvest index). This may be suggesting the influence of environmental factors in the inheritance of these characters.

The traits such as plant height, number of finger and days to flowering at Adet and plant height, number of fingers, number of ears and harvest index at Mecha detected low narrow-sense heritability; this condition may happen when dominance and epistasis gene effects are increased (Warner, 1952). This is because of narrow-sense heritability depending on additive variance only.

Therefore, traits with low to high narrow-sense heritability indicated the occurrence of complex inheritance for the traits studied. Hence, the recurrent selection method required for the improvement of traits since it allows recombination and breaking up of undesirable linkage (Ganesh and Sakila, 1999). This cyclic method should continue until a high level of gene fixation attained with early and intensifies selection of later generations (Arora *et al*., 2010).

3.5 Genetic advance

The estimated values of genetic advance and genetic advance as percent of F2 mean for different characters are presented in Table 9. Selection efficiency depends on both heritability and genetic advance as indicated by Johnson *et al*. (1955) and Ubi *et al*. (2001) because the genetic advance is a useful indicator when selection applies to the relevant population to predict the progress that can be expected. In the present study, high heritability coupled with high genetic advance noticed for biomass yield at Mecha while medium heritability along with high genetic advance was recorded for the number of ears and biomass yield at Adet. This indicated the additive nature of genetic variation transmitted from the parents to the progeny. In addition, this trait can easily fix in the genotypes by selection in early generations. These results were in harmony with the finding of the previous researcher (Yadav *et al*., 2011) for biological yield. The information on heritability and genetic advance ascribed the additive gene effects are may be more essential for the above traits than non-additive effects and can be improved through simple or progeny selection methods (Johnson *et al*., 1955; Panse, 1957).

Medium to high heritability accompanied by low genetic advance for finger length, number of tillers, seed yield, harvest index, days to maturity and thousand seed weight at Adet; similarly, finger length, number of tillers, days to flowering, and days to maturity, seed yield and thousand seed weight at Mecha. The result showed that the traits could be improved by inter-mating superior genotypes of segregating population developed from a combination of genotypes with recurrent selection method since non-additive gene actions' was predominance than other gene action. In agreement with this study, consistent estimates reported in previous studies of Yadav *et al*. (2011).

Low heritability with low genetic advance values found for plant height and number of finger and days to flowering at Adet while plant height, number of finger, number of ear and harvest index at Mecha, indicating slow progress through selection for these traits. The reason for the low heritability for these characters was a result of some variances constituting the environment variance. These results find support from the earlier study reported (Eid, 2009) for plant height and number of grain.

Table 9: Estimates of heritability, genetic advance, and genetic advance at a percentage of mean at Adet and Mecha

Traits	Adet			Mecha		
	h^2n	ΔG	ΔG (%)	h^2n	ΔG	ΔG (%)
Plant height	10.4	0.0021	0.29	3.17	0.0005	0.07
Finger length	37.5	0.0067	0.69	25.4	0.003558	0.37
Number of tiller	30.5	0.01332	1.34	26.7	0.046917	4.19
Number of finger	6.8	0.00013	0.01	13	0.000295	0.03
Number of ear	32.6	1.12204	117.95	13.6	0.004006	0.4
Days to flowering	3.4	0.0008	0.11	27.03	0.002339	0.33
Days to maturity	52.4	0.0021	0.31	23.53	0.000242	0.04
Seed yield	28.1	0.037	6.75	34.15	0.000422	0.08
Biomass yield	36.9	0.132	25.26	43.37	89.34	16963.31
Harvest index	28.2	0.0143	1.85	3.91	0.000016	0.002
1000 seed weight	41.8	0.00423	0.34	0.52	0.000009	0.0007

4 Conclusion and Recommendations

According to generation variance analysis additive, genetic variance and dominance genetic variance influenced the expression of finger millet traits. This indicated that both additive and non-additive gene action involved in the control of traits. The average degree of dominance values indicated that number of ears, biomass yield and thousand seed weight at Adet showed partial dominance, while the other traits implied over dominance gene actions. Medium to high narrow-sense heritability value coupled with high genetic advance showed the influence of additive variance and ease of improvement of these important traits in this population. While low narrow-sense heritability along with low genetic advance indicated the occurrence of complex inheritance for the traits studied. Hence, the recurrent selection method required for the improvement of traits since it allows recombination and breaking up of undesirable linkage. The number of genes governing the inheritance of the characters in both locations ranged low to high indicating the inheritance of the traits depends on polygenic action. In connection to this, the result showed the presence of dominance and epistasis, which bias an estimate of a minimum number of genes. Besides, the small and negative value of the number of genes on the study traits indicated the probable presence of epistasis and environmental effects. The results of this study concluded the existence of sufficient genetic variability as well as additive and non-additive type of gene effects in the inheritance of the traits. Therefore, the possibility of developing lines and hybrids were showed clearly in this study; so that, improvement of high heritability coupled with high genetic advance noticed for biomass yield at Mecha while medium heritability along with high genetic advance was recorded for the number of ear and biomass yield at Adet. Medium to high heritability accompanied by low genetic advance for finger length, number of tillers, seed yield, harvest index, days to maturity and thousand seed weight at Adet; similarly, finger length, number of tillers, days to flowering, and days to maturity, seed yield and thousand seed weight at Mecha. These indicated the presence of additive, dominance and epistasis gene action and its improvement could be achieved through recurrent selection at early and later generations.

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