SOMALI REGION PASTORAL AND AGRO-PASTORAL RESEARCH INSTITUTE (SoRPARI)

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Jigjiga Ethiopia

Somali Region Pastoral and Agro-Pastoral Research Institute (SoRPARI)

Proceedings of 2021/22, SoRPARI research report

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Proceedings of 2020/21, SoRPARI research report, Jigjiga Ethiopia

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Preface

Realizing the key role that it plays in the national economy; the Ethiopian government has given due emphasis to the agricultural sector development. The Agricultural and Rural Development Policy and Strategy of the country which was designed nearly a decade and half ago, has highly emphasized the important role of agriculture as a means of ensuring rapid economic growth, enhancing benefits to the people, eliminating food aid dependency, and promoting the development of a market-oriented economy. Guided by this national policy and strategy, different consecutive national plans, programs and projects focusing on the development of the agriculture sector has been implemented and is being implemented throughout the country. In addition to this, our country is designed 10 years strategic plan of which agriculture sector is once recognized as backbone for the national economy. It is believed that, in achieving and implementing these and other national plan, the role of research is expected than ever as it did in the previous plans and research component is added in these national plans.

The aim of the research component is to adapt or generate agricultural technologies, undertake pre-extension demonstration of proven technologies, produce source technologies that would serve as a base for large scale technology multiplication and enhance capacity of the research systems to improve technology supply. Being one of the implementing institutions, the Somali Region Pastoral and Agro-Pastoral Research Institute (SoRPARI) is conducting various technology adaptation and generation, research report proceedings, source technology multiplication and capacity building activities.

SoRPARI is therefore working on generating/adapting technologies suited to the agro-ecologies of the region and demonstrating them in close collaboration with farmer research and extension groups. SoRPARI also supplies source technologies by multiplying them in the mandate areas on farmers field, to address problems related to seed shortage and the like. As part of the agricultural growth program, SoRPARI had a total of 21 activities in 2020/21 including to profile the nutritional value, antinutritional value, mineral contents, functional and physical properties of two food crops. Demonstration of generated or introduced technologies and their multiplication needs serious attention from the stakeholders working in the agricultural system.

The Technical Advisory Committee (TAC)

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Message from Director General

Mr. Mohammed Sharif

Director general of SoRPARI

Research is an advanced stage of study undertaken to discover or establish facts or principles. In agriculture, it involves finding solutions to farmer's problems through systematic experimental procedures. The contemporary agricultural sector faces many new challenges, from new crop and animal diseases to the impacts of climate change. Yet these challenges can often be combatted with new and improved technologies developed through scientific research. In addition to addressing large-scale trends, the research can often solve problems encountered by small-scale agricultural producers – with tangible benefits. For instance, low production of crops, livestock and fish can be overcome by turning to newly developed varieties and breeds. Or better nutrition and food sufficiency can be attained by diversifying diets. Yet in many developing countries, the connection between this research and agricultural development is weak. There is little investment in agriculture-focused research as the immediate impacts are easy to overlook. Therefore, it is important to establish an institute which engaged in research activities and link stakeholders and end user to the different agricultural technologies.

Somali Region Pastoral and Agro-pastoral Research Institute (SoRPARI) was established in 2002 G.C, and effective since 2011 G.C, with objectives of changing the livelihood of pastoralists and agro-pastoralists by introducing, adapting, generating, popularizing and disseminating livestock, forage, crop, natural resource and related technologies. The institute commitment and efforts towards equipping the regional agricultural sector with improved agricultural technologies, and information knowledge are the basic corner stone of its mandate to the region. The institute, through well-orchestrated efforts, had delivered a number of technologies, information and knowledge to pastoral and agro-pastoral communities of the region. By mid-years of its working experience, the institute had faced a lot of challenges which reached up to risking the existence of the institute. Since the reform that happened by 2018 G.C. in our country particularly our region, the institute have been getting the usual support from government and different partners which help its restorage.

Tremendous and tangible changes have been achieved starting from the reform especially since 2021G.C. Some of the major achievement done by the institute are, successful implementation of the so called "Job Evaluation and Grading JEG", completing agro-ecological characterization of the region, opening of two new research directorates (Food science and Nutrition Research Directorate, Technology multiplication and Seed Research directorate), Re-establishment of "Technical Advisory Committee TAC", preparation of different guidelines (Research legislation and Seed management guideline), revising the ten years strategic plan. It is also the year where we have conducted board meeting for the first time in which 2014 E.C. annual report & 2015 E.C. plan and the above-mentioned documents were got approval. The institute become successful when it comes restoring its partnership with different government and non-government stakeholders to reach its end users. We have been working with Mercy corps, LLRP, GIZ, EAIR, ATI and other partners on different mega and mini research projects. To mention some of the projects we work with partners, "Farm system characterization" with EAIR, "PAPREG and other Project" with LLRP, "Nutrition and crop related research" with Mercy corps. Therefore, we believe that, all activities done by the institute and in collaboration with different partners should reach different stakeholders and end users.

As part of its mandate and disseminating finalized research works to stakeholders and end users, the institute has been collected different manuscript from the different research directorates to prepare proceeding where research works of 2011 to 2013 E.C. have been included. In this particular proceeding, 20 manuscripts which were done in the area of crop. livestock, socio-economic, soil & water, agricultural mechanization and food science & nutrition are included. The data obtained in those research works will help government and NGOs partners, stakeholder, researchers as baseline to further include in their different future activities.

Lastly, SoRPARI is always grateful to regional top leaders, both federal and regional agricultural sector bureaus, different NGOs/partners for their support and believing our institute as their potential partners. I as director general and in the name of the institute, we keep promise to enhance our partnerships and actively engaged in all kind projects and activities that change the livelihood pastoral and agro-pastoral community. To all stakeholders, researchers and other interest group, I wish you to enjoy reading of the proceeding and using as baseline for your future developmental projects and research works.

By the end, my especial thanks go to Technical Advisory Committee (TAC) for their compilation and production of this proceeding and their help in all technical aspects of the institute. I would also like to acknowledge researchers, directorates for their commitment and contribution to the reality of this proceeding.

I thank you.

Mohammed Sharif Ali

SoRPARI Director General

Message from Deputy Director General

Mr. Jimaale Ahmed Yusuf

Deputy Director general of SoRPARI

Somali Regional State is endowed with huge natural resources like rivers, vast rangelands, suitable land for crop and forage production, diversified forests and wild live. Most of the population depends on livestock production, crop farming and small-scale trade. Camel, cattle, sheep and goats are the major domestic animals that provide food and income to this pastoral and agro pastoral communities of the region. For the effective utilization these and other natural resources, the research institute plays great role to improve the livelihoods of pastoral and agro-pastoral communities.

The Somali Region Pastoral and Agropastoral Research Institute (SoRPARI) was established in 2002 by Proclamation No. 31/2002, as the first regionally coordinated agricultural research system in the region. SoRPARI was established with a mission to deliver and popularize agricultural technologies, knowledge and information in a participatory and integrated way for all the pastoral and agro-pastoral communities in the Somali Regional State and similar communities in other regions of Ethiopia in general.

In the past four and half years (since mid of 2018 G.C.) SoRPARI has made much efforts to deliver improved technologies through adapting, generating and improving the existing ones, in line with this, the research institute accomplished different research projects, generated different technologies, knowledge and/ or information in the areas of livestock, crops, soil & water conservation, range lands & Agro-forestry, agricultural mechanizations, food science &

Nutrition and Socio-economic that are crucial in improving the livelihood of the Pastoral and Agro-Pastoral communities and strengthen the production and productivity of the agricultural sector in the Region.

Some of the major achievements including researches by the institute include; Developed 10-year strategic plan of SoRPARI that is aligned the 10-year strategic plan of Ethiopian Institute of Agriculture Research (EIAR) and finally endorsed by Board of Directors, 9 improved forage species constituting of grasses, legumes and fodder trees have been tested, selected, diffused for rain fed and irrigated areas and released to reach both pastoral and Argo-pastoral communities of the region, large scale low land irrigated national wheat production pilot and demonstration was planted in Gode, Adadle and Beeraano woredas with the support of federal stockholders (FDRE Ministry of Agriculture, EIAR and Agricultural Transformation Institute), a number of Cereals; Rice-Nerica1, Nerica2, Nerica4, Nerica6, Nerica14, wheat (Fentale 2, Kings Bird, amibara etc) varieties were improved and already reached the pastoral and agro-pastoral communities, Range land recovery and conservation has been treated with holistic range land approach on an area covered by invasive species mostly Prosopis juliflora, Community-based area enclosure for threatened species Yeheb, Cordeauxia edulis plant rehabilitation in its habitat has been done, Agro-ecological characterization & land capability evaluation and farm characterization research were implemented and many others.

SoRPARI would like to take this opportunity to publish 20 manuscripts compiled and implemented in the year 2021/22. The manuscripts include the researches conducted in the area Crop, livestock, agricultural mechanization, Soil & water researches and Socio-economic researches.

Finally, Agriculture sector is the Somali region’s main economic contributor. While the sector has shown improvements recently, there is still huge potential in the region to generate value through a focused agricultural program. Somali Pastoral and Agro pastoral Research Institute would like to see our key stakeholders and other researchers to use this proceeding as baseline, technology transfer, policy input and for further dissemination to the end users through extension system.

By the end, I would like to acknowledge researchers, directorates for their commitment and contribution to the reality of this proceeding. My especial gratitude goes to Technical Advisory

Committee (TAC) for their compilation and production of this proceeding and their help in all technical aspects of the institute.

I thank you,

Jimaale Yusuf

Deputy Director General

Message from Technical Advisory Committee (TAC) chairperson

Mr. Abdulkarim Mohammed Ali

TAC Chairperson

Somali Region Pastoral and Agro-pastoral Research Institute (SoRPARI) was established in 2002 G.C, and effective since 2011 G.C, with objectives of changing the livelihood of pastoralists and agro-pastoralists by introducing, adapting, generating, popularizing and disseminating livestock, forage, crop, natural resource and related technologies. The institute commitment and efforts towards equipping the regional agricultural sector with improved agricultural technologies, and information knowledge were the basic corner stone of its mandate to the region.

SoRPARI conducted a wide range of researches both introduced and tested of intensive crops and forages rangelands over many years and released various suitable technologies, others introduced and adapted, (for both riverine and rain fed farming systems). The institute, through well-orchestrated efforts, had tried to deliver a number of technologies, information and knowledge to pastoral and agro-pastoral communities of the region. Although different events such as conference, workshops, field days and some others were prepared, having well organized scientific report and some other pintables material options are not yet in place. On the other hand, a lot of new technologies has been adapted, developed, re-engineered by the institute which need to be reach to the concerned stakeholders and end users through different mechanism which well-organized system. In similar fashion, modification and improvement has been made on some of the previously released technologies which still need systematic means to reach the end users. For this reason, the institute has organized “Technical Advisory committee” to run all its activities systematically and to have productive scientific report.

The technical advisory committee (TAC) was established in June 15/2022 (Sane 8/2014 E.C.) with initiation from director general of the institute Mr. Mohammed Sharif Ali to actively engaged in and lead the technical activities of the institute. The committee is established to provide service such as Proposal & Research (ongoing and completed) review, Organizing different events at regional, national and international level in collaboration with concerned directorates and stakeholders, Preparation of different printable/compile report, Research related capacity building, Monitoring & Evaluation on the technical part of project and research, Journal development and Other special technical advice and task based on the request from top management.

As part of disseminating finalized research works to stakeholders and end users, the TAC has been collected different manuscripts from the different research directorates to prepare the 1st proceeding where research works of 2014 E.C. have been collected. In this particular proceeding, six research directorates submitted their research works namely crop (8 manuscripts), Livestock (3 manuscripts), Agricultural mechanization (2 manuscripts), Food Science (2 manuscripts), Socio-economic (3 manuscripts) and soil & water (2 manuscripts). Totally, 20 manuscripts have been included under this proceeding.

Last but not list, TAC is always grateful to top management, directorates, center managers, researchers for their help and insightful contribution to the preparation of 1st proceeding. By this TAC will keep its promise in preparing other proceedings and serving SoRPARI community in all aspects of technical assistance. By the end, I wish you to enjoy reading of the proceeding and using as baseline data for your future research work and keeping your cooperation as usual.

I thank you

Abdulkarim Mohammed Ali

TAC Chair Person

1. **Livestock and Forage Research Directorate**



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1.1. Prevalence, Characterization and Determination of Antibiotic Sensitivity on Camel Mastitis Causing Agents in And Around Jigjiga City, Fafen Zone, Somali Region, Ethiopia

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Abstract

A questionnaire-based survey and a cross-sectional study was conducted on purposefully selected 60 individual lactating she-camel owners and 244 lactating she-camels from 3 privately owned camel dairy farms respectively. With the aim of investigating camel mastitis prevalence and characterization and determination of antibiotic sensitivity on camel mastitis causing agents in and around Jigjiga city of Fafen zone, Somali region, Ethiopia. Furthermore, direct interview with dairy camel farm owners were conducted. About 66.7% and 33.3% of dairy camel owners apply herd grazing method and separate grazing method. In this study, 98.3% of the respondents told that there is a feed shortage problem. Moreover, 65%, 25% and 10% of the respondents treat clinically sick camels with modern vet drugs, traditional medicines and combination of the two, respectively. The overall prevalence of she-camel sub- clinical mastitis in the study area was 10.6%. The prevalence of subclinical mastitis at she-camel level was 12.5%, 11.1% and 9.9% in Suleka, Dhaygel and Barkomal dairy camel farms, respectively. Nevertheless, statistically there was no significant difference in the prevalence of sub-clinical mastitis among the studied dairy camel farms (P > 0.05). Age and the hygiene of udder and legs for the examined she camels were the risk factors that statistically influenced the result of CMT (P < 0.05). A total of 510 bacteria consisting three types with four species of bacteria were isolated. Among these the most predominant bacterium was S. aureus with prevalence of 34.5% followed by Sr. agalactiae, Sr. dysgalactiae and Pasteurella multocida with prevalence of 29.8% 19.4% and 16.2%, respectively. Kirby-Bauer disk diffusion method was employed to determine the drug sensitivity of all bacterial isolates for selected antibiotics. Thus, 100%, 89.4%, 61.6% and 69.8% of the S. aureus, Str. agalactiae, Str. dysgalactiae and P. multocida, respectively were found to be highly susceptible to erythromycin. Hence, erythromycin was best drug of choice. From the 510 isolated bacteria 84.5%, 60%, 44.7% and 36.7% were sensitive to Erythromycin, Streptomycin, Oxytetracycline and Tetracycline, respectively. Furthermore, results of the camel dairy farm owners' interview revealed that neither the farmers emphasized the need to milk healthy cows first and the diseased cows later to prevent transmission of mastitis nor the milkers used disinfectant and even water to clean teats before and after milking.

Key words: *Antibiotic Sensitivity, Camel Mastitis, Characterization, Ethiopia, Fafen Zone, Prevalence, Somali region*

Introduction

In Ethiopia, dairy production is generally hampered by different disease of intensification among which udder health problem (mastitis) is the leading one. Mastitis poses its great effects on the dairy industry including; temporary or permanent loss in the female animal ability to produce milk, the milk quality is reduced with less favorable characteristics, reduction in milk price due to high Somatic Cell Count (SCC) presence, milk loss because of antibiotics drug residue, veterinary care and labor costs, reduced productive life of the animal, less meat value of the animal after slaughter and annual losses due to reduced overall production of dairy product (Viguier *et al*., 2009). Milk is a very nutritional food that is rich in carbohydrate, proteins, fats, vitamins and minerals. However, milk and milk products of dairy cows and camel can harbor a variety of microorganisms and can be important sources of food borne pathogens to humans. (Oliver *et al.,* 2005). Very recent studies done in two pastoral districts in southern Ethiopia, reported a cow-level prevalence of mastitis in dairy cows, camels, and goats as 33.3%, 26.3%, and 25.0%, respectively; and quarter-level prevalence of mastitis in cows, camels and goats as 17.6%, 14.5%, and 20%, respectively (Balemi *et al.,* 2021). In Ethiopia, the disease is insufficiently investigated and has less attention. Information relating to mastitis magnitude, distribution, negative effect on milk quality and risk factors associated to consumers is very much limited. So, it is believed that the identification and characterization of risk factors of mastitis, its negative effect on milk and milk products will help to optimize prevention and control options of the disease. On the other hand, mastitis, as a disease, has received little attention; especially the sub clinical form of mastitis (Mekonnen *et al*., 2005; Hundera *et al*., 2005). Very little is known about mastitis concerning their etiology and occurrence in *Camelidae* (Abdel Gadir *et al*., 2006; Kalla *et al*., 2008). However, cases of mastitis in camel have recently been reported in Ethiopia (Geresu *et al*., 2021). Therefore, the present study was aimed to estimate the prevalence and also assess the associated risk factors of camel mastitis occurrences with great emphasis in the isolation, characterization and determination of antibiotic sensitivity on camel mastitis causing agents in and around Jigjiga city, Fafen zone, Somali region, Ethiopia.

Materials and Methods

Description of the Study Area

The study was conducted in and around Jigjiga city, Fafen zone, Somali regional state. Fafen administrative zone, is located in the northern part of the Ethiopian Somali Region, at 9°20' North latitude; 45°56'° East longitude, about 630 km East of Addis Ababa. It covers a total land area of 40.86 km^2 with altitude ranging from 500 to 1,650 meter above sea level (m.a.s.l) (Degefu *et al.,* 2011). The area receives a precipitation ranging from 300 to 600 mm per annum and an average daily temperature of 16°C to 20°C (Keskes *et al.,* 2013). Agro-pastoralist is a dominant production system in Fafen zone. The estimated livestock population of the zone includes 248,435 cattle, 666,130 sheep, 503,881 goats' 72,390 camels and 10,548 poultry (CSA, 2011/2012). According to the report of Birhan (2013), cattle, sheep, goats and 23 camels are the main productive livestock reared in the area, and camel population was estimated to be 85,000. Specifically, Jigjiga city is located 9° 35‟ N latitude and 42° 8‟ E longitude and has an elevation of 1,609 m.a.s.l (htpp//populationmongabay.com/).

Study Population, Study design and Sampling techniques

A cross-sectional study supported by questionnaire survey was conducted from October 2021 to June 2022, on lactating camels, lactating she camel owners and three camel dairy farm owners/managers/attendants of in and around Jigjiga town. With regards to sampling procedure, a total of 60 purposively selected lactating she camel owners and 3 camel dairy farm owners/managers/attendants were interviewed. Experiences of camel owners either under extensive and or intensive farming systems in animal health care and veterinary drug utilization for treatment of mastitis was also exploited. On the other hand, for this study, a total of 244 lactating local indigenous breed dairy she camels of three privately owned camel dairy farms as *Dhaygel* (n=81), *Barkomal* (n=131) and *Suleka* (n=32) dairy camel farms that were kept under semi-intensive farming systems were screened for the presence of sub-clinical mastitis.

Physical Clinical Examination, Milk Collection and California Mastitis Testing (CMT)

Furthermore, camels were examined clinically for any abnormalities at udder, quarters and secretion level according to Quinn *et al.,* (1994). To check on clinical form of mastitis, milk from each quarter was examined using a strip cup and any change in color, odor and consistency was recorded. Then, California mastitis test (CMT) was conducted to diagnose the presence of subclinical mastitis, according to procedures given by Quinn *et al*., (1994).

Bacteriological laboratory examination and Antimicrobial Susceptibility Testing

Bacteriological examination was done according to the NMC (1990), Quinn *et al*., (1994) and National Committee for Clinical Laboratory Standards (NCCLS) (1997). To do so, a loopful of milk sample was streaked on tryptose blood agar base enriched with 5% blood agar (Oxoid, UK) and Mac Conkey Agar using the quadrant streaking method for each quarter. Besides, conventional methods were performed to identify and characterize the pathogens after purifying the bacteria using the standard microbiological techniques. Moreover, sensitivity test was done on diagnostic sensitivity test media using Mueller- Hinton agar media using impregnated disk Antibiogram of commonly used antibiotics (Erythromycin, Streptomycin, Tetracycline, Oxytetracycline,) (Baker *et. al*., 1980).

Data Analysis

Data generated from questionnaire survey and laboratory investigations were recorded and coded using Microsoft Excel spreadsheet (Microsoft Corporation) and analyzed using STATA ver. 16 for windows. An overall prevalence of mastitis was calculated as the number of subclinical mastitis cases divided by the total number of samples tested. The associations of subclinical mastitis with location/farm, age, lactation stage, parity, production system, sources of water and udder and leg hygiene were compared using chi-square test (χ^2). Furthermore, multivariate logistic regression analysis was performed to quantify odds ratio, so as to detect the strength of association for the exposing risk factors towards the prevalence of lactating she camel mastitis where $P < 0.05$ was deemed to be statistically significant.

Results

House Hold Questionnaires and Dairy Camel Farm Owners Interview Survey

Major feed sources for dairy camels in the study area, around 58.3% of the respondents said that feed source is from natural pasture and crop residue whereas the remaining 41.7% of the respondents told that major feed sources for dairy camels lonely comes from natural pastures. On the other hand, 98.3% of the questioned dairy camel owners had feed shortage problems. Of the 60 respondents owning camels that were interviewed, 85% (51/60) of them responded that they were aware about any deformity and abnormalities with the mammary gland and udder of the lactating she camels as clinical mastitis while all of them were not aware of any in apparently sick she camels as subclinical mastitis. Apart from this, 65.0% of the respondents told that they treat dairy camel mastitis with modern vet drugs while 25.0% of camel owners responded that they use traditional medicines particularly, experienced (elder) camel owners indicated that they know traditional ways of treating camel mastitis using traditional folk remedies. According to the accessibility of veterinary services, 93.3% were said that they have veterinary services to their animals while 6.7% said that they have no any veterinary services. Overall results of the questionnaire survey have been summarized in the following tables (Table.1 & 2) and cylindrical column chart (Fig.2).

Table 1: Summary Results of Questionnaire Survey on Dairy Camel Owners in Socio-economic Profile and Camel herds Management.

Categories	**Proportions (%)**
Educational level	
Illiterate	45.0
Primary School	21.8
Religious knowledge	28.3
Secondary school	5.0
Livestock production system	
Pastoral	15.0
Agro – pastoral	85.0
Purpose of keeping camels	
Milk	60.0
Social and cultural values	10.0
Income generation	18.3
All the above purposes	11.6
Stage of Lactation	
Early	30.0
Mid	45.0
Late	25.0
Camel Herd grazing methods	
Mixed with other animals	66.7
Grazing Camels alone	33.3
Major feed sources for dairy camels	
Natural pasture	41.7

Natural pasture and crop residue	58.3
Feed shortage problems	
Yes	98.3
No	1.7
Source of water for camels	
Well	21.6
Dam/pond	51.6
River	18.3
Spring	8.3
Distance to watering point	
At home	5.0
<1 kilometer	13.3
> kilometer	81.6
Frequency of watering	
Freely available	11.6
One day interval	3.3
Two days interval	33.3
Three days interval	38.3
Once in a week	13.3
Housing system	
Together with other spps	66.7
Separately alone	33.3
Do you clean house	
Yes	81.7
No	18.3

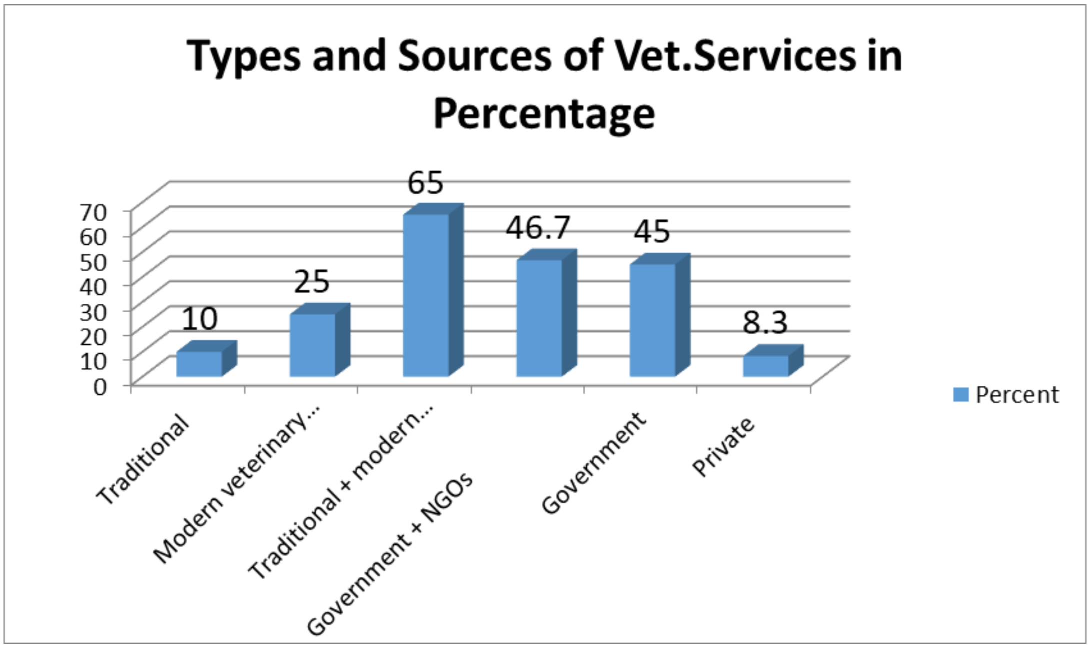

Fig.2. Category and Sources of Animal Health Service Delivery System in the Study Area

Table 2: Camel Milk Production and Handling Practices in the study area

Categories	Proportion (%)
Major constraints to she camel milk production	
Lack of Vet. Services	13.33
Fodder and Vet. Service	18.33
Shortage rangeland and vet. Services	65.00
Marketing, shortage of rangeland and vet. Service	3.33
Type of milking practices	
Few sucks before milking	81.7
Milk without suck	18.3
Where do you milk the camel	
Outside the barn	78.3
Inside the barn	21.7
Washing hands before and after milking	
Yes	75.0
No	25.0
Types of materials used for milking	
Wood	68.3
Plastic	15.0

Both	16.7
purpose of camel milk production	
Selling	41.7
Home consumptions	3.3
Both of the above	55.0
Do you clean the milking equipment regularly	
Yes	96.7
No	3.3
How to consume camel milk	
Raw	96.7
Fermented state	3.3

In addition to, the semi-structured questionnaire survey, direct interview with dairy camel farm owners were conducted for identification and prioritization of causes of mastitis. One questionnaire check list per farm owner/attendant was performed. The entire farms included in the study followed manual milking (hand milking) system and most of the milkers were males. No specific sequence was followed during milking in almost all of the visited farms; rather, it was depending on the placement of the animal in the shed. Majority of the farm owners were educated up to university level. Even though, educated people had better know how about the zoonotic implications of consuming raw milk, predisposing factors for mastitis and drug residue effect on public health following treatment of mastitis animals. None of the farmers emphasized the need to milk healthy cows first and the diseased cows later to prevent transmission of mastitis. Moreover, none of the milkers used disinfectant and even water to clean teats before and after milking. Despite these, the camel milk produced from the studied farms was marketing in raw form to milk vender shops found in Jigjiga town as permanent customers of the farms accordingly.

Prevalence of Subclinical Mastitis at Animal (camel) Level by CMT

The overall she-camel level prevalence of subclinical mastitis in the study area was 10.6% (95% CI: 0.067-0.146). Among the studied three camel dairy farms, subclinical mastitis at she-camel level was highest in *Suleka* dairy camel farm with prevalence of 12.5% (95% CI: 0.003-0.246);

followed by *Dhaygel* and *Barkomal* dairy camel farms with prevalence of 11.1% (95% CI: 0.041-0.181) and 9.9% (95% CI: 0.047-0.151) as 2nd and 3rd for presence of sub-clinical mastitis, respectively. Yet, statistically there was no significant difference in the prevalence of camel mastitis among the different dairy camel farms (P > 0.05) (Table.3).

Table 3: Prevalence of Sub-Clinical Mastitis in the She-Camels from the Three Dairy Camel Farms in the Study Area.

Names of Dairy Camel Farms	Number of examined	Number of positives	Prevalence (%)	χ^2	P value
Dhaygeel	81	9	11.1		
Barkomal	131	13	9.9		
Suleka	32	4	12.5	0.20	0.90
Total	244	26	10.6		

Age categories, hygiene of udder and legs of the studied she camels were the risk factors that statistically influenced the result of CMT (P< 0.05). With regard to these the prevalence of sub-clinical mastitis was relatively higher (36.1% with OR of 10.1) in lactating camels with middle age groups (5-7 years old). Similarly, the prevalence of sub-clinical mastitis was relatively increased (from 0.5-78.2%) as udder and legs hygiene of lactating she camels decreased (changed from good to poor hygiene). However, the current result showed that location/farm, lactation stage, parity production system and sources of water for the farms were not statistically associated with the occurrence of sub-clinical mastitis in the study areas (P > 0.05) (Table 4).

Table 4: Effects of Different Associated Risk Factors with the Prevalence of She-Camel Mastitis to CMT

Risk factors	Number of she-camels examined	Number of Positive, n (%)	OR [95%CI]	χ^2	P value
Location/Farm					
Barkomal	131	13 (9.9)			
Dhaygel	81	9 (11.1)	1.1		
Suleka	32	4 (12.5)	1.3	0.20	0.904
Age					

2-4 years	132	7 (5.3)			
5-7 years	36	13 (36.1)	10.1		
> 7years	76	6 (7.8)	1.5	21.8	0.0000***
Lactation stage					
Early	144	17 (11.8)			
Late	100	9 (9)	0.73	0.50	0.48
Parity					
Few (<3)	162	14 (8.6)			
Many (>3)	82	12 (14.6)	1.8	1.97	0.160
Production system					
Extensive	113	13 (11.5)			
Semi-intensive	131	13 (9.9)	0.84	.16	0.690
Source of water					
Tap water	32	4 (12.5)			
Well	212	22 (10.4)	0.81	0.13	0.722
Udder and Leg hygiene					
Good	170	1 (0.5)			
Medium	51	7 (13.7)	26.8		
Poor	23	18 (78.2)	608.4	88.41	0.0000***

Bacterial Species Isolation Analysis

Among the 26 milk samples which were positive with California mastitis test, 12 samples were yielded bacteria upon culturing on nutrient agar and blood agar aerobically for 24 to 48 hrs. From these a total of 510 bacteria consisting three types with four species of bacteria were isolated with the most predominant bacterium being *Staphylococcus aureus* with prevalence of 34.5% (176/510) followed by *Streptococcus agalactiae, Streptococcus dysgalactiae and Pasteurella multocida* with prevalence of 29.8% (152/510), 19.4% (99/510) and 16.2% (83/510), respectively, (Table 5).

Table 5: Distribution of Isolates and Individual Prevalence of Bacterial Species Isolated from She Camels in the Three Camel Dairy Farms of the Study Area

Name of the farm	***Staphylococcus aureus, n (%)***	***Streptococcus agalactiae, n (%)***	***Streptococcus dysgalactiae, n (%)***	***Pasteurella spps, n (%)***
Barkomal	31 (6.1)	46 (9.0)	27 (5.2)	0 (0)
Dhaygel	80 (15.6)	51 (10.0)	29 (5.6)	40 (7.8)
Suleka	65 (12.7)	55 (10.7)	43 (8.4)	43 (8.4)
Total	176 (34.5)	152 (29.8)	99 (19.4)	83 (16.2)

Biochemical Tests

Using with conventional methods bacterial species were differentiated and identified by carrying out gram staining, aerobic, motility, acid fast, and oxidation fermentation (OF), oxidase and catalase tests to identify the genera of bacterial species Quinn *et al.*, (1994). Moreover, coagulase test was done to identify coagulase-positive staphylococcal species. Furthermore, Indol, Metyl-Red (MR), Voges-Proskauer (VP), citrate utilization, lysine decarboxylase, and urease test were also done for identification of Pasteurella species. The positive controls for each biochemical test were known bacteria which were positive for every test.

Antibiotics Sensitivity Test (Kirby-Bauer disk diffusion method)

The current study revealed the existence of higher levels of susceptibility of *Staphylococcus, Streptococcus and Pasteurella species isolates* to uncommonly used erythromycin antibiotic. Thus, 100%, 89.4%, 61.6% and 69.8% of the *Staphylococcus aureus, Streptococcus agalactiae, Streptococcus dysgalactiae and Pasteurella multocida*, respectively were found to be highly susceptible to erythromycin. Hence, erythromycin was the best acting antibiotic (61.6-100%) indicating that it is the best drug of choice. Furthermore, next to erythromycin, streptomycin was the second-best acting antibiotic (52.8-72.3%) for all identified bacterial species. In contrast, all of the identified bacterial species in this study were shown less sensitive to commonly used oxytetracycline and tetracycline antibiotics. Likewise, all most all of the identified bacterial species were shown the lowest sensitivity of ranging (30.6-43.4%) to tetracycline antibiotic (Table.6). The resistance profile of *Staphylococcus aureus, Streptococcus agalactiae, Streptococcus dysgalactiae and Pasteurella multocida* against tetracycline was shown 30.6%, 43.4%, 34.3 and 38.9%, respectively. From the 510 isolated bacteria 84.5%, 60.0%, 44.7% and

36.7% were sensitive to Erythromycin, Streptomycin, Oxytetracycline and Tetracycline, respectively (Table.7).

Table 6: In Vitro Susceptibility Profile of Bacteria Isolated from Camel Milk Samples with Subclinical Mastitis

Antibiotics	*Staphylococcus aureus*		*Streptococcus agalactiae*		*Streptococcus dysgalactiae*		*Pasteurella multocida*		*Total*	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Erythromycin	176/176	100	136/152	89.4	61/99	61.6	58/83	69.8	431/510	84.5
Streptomycin	93/176	52.8	110/152	72.3	54/99	54.5	49/83	59.0	306/510	60
Oxytetracycline	65/176	36.9	76/152	50.0	45/99	45.5	42/83	50.6	228/510	44.7
Tetracycline	54/176	30.6	66/152	43.4	34/99	34.3	33/83	39.8	187/510	36.7

N = number of sensitive bacteria/evaluated number of bacteria

Discussion

The overall she camel level prevalence for subclinical mastitis of 10.6 %, reported in this study is in agreement with the reports of Mohamud *et al.* (2020) who reported 9.8% of sub-clinical mastitis in dairy she camels in *Benadir* region of Somalia. Also, Juboori *et al.* (2013) reported a prevalence of 11.67% for sub-clinical mastitis in lactating she camels in Abu Dhabi, United Arab Emirates. Similarly, the current findings of camel sub-clinical mastitis prevalence are more or less in lined with the finding of Balemi *et al*. (2021) who reported 14.5% prevalence of camel mastitis in Bule Hora and Dugda Dawa pastoral districts in Southern Ethiopia. However, Geresu *et al.* (2021) reported a slightly higher sub-clinical mastitis of 18.1% in lactating she camels in Gomole district of Borena Zone from Southern Ethiopia.

In contrast, the finding of camel mastitis prevalence in the present study is relatively lower than the reports of Abdi *et al.* (2013), Jemal *et al.* (2017), Mogeh *et al.*, (2019), Alebie *et al.*, (2021) who reported a higher prevalence rate of 25.3%, 24.7%, 25.8% 25.0% and 25.0% for camel subclinical mastitis in Jigjiga Town of Somali region from eastern Ethiopia, Gursum district of Somali region from eastern Ethiopia, in and around Hargeisa of Somaliland from Northern

Somalia and Dubti district of Afar region from North-eastern Ethiopia, respectively. Moreover, Toroitich *et al.*, (2017) reported a higher sub-clinical mastitis of 76.8% in lactating she camels from west pokot county of Kenya which is very extremely higher than the current findings. The higher prevalence of those research studies may be due to the difference in the management system of camels.

On the other hand, Almaw and Molla (2000) reported a lower prevalence of 2.1% for subclinical mastitis prevalence in lactating she camels in north eastern Ethiopia, comparing to the result of the current study. The difference between the present finding of camel mastitis and that of Almaw and Molla (2000) can be due to the difference in the agro ecology of the study areas. The statistical association of risk factors like age of the studied she camels, with prevalence of camel mastitis in the present finding is in lined with the reports of Abdi *et al*. (2013) and Geresu *et al.* (2021) who were found significant difference in camel mastitis among the different age groups, with P< 0.05. Similarly, the current study revealed that udder and leg hygiene measures were also significantly influenced the prevalence of camel sub-clinical mastitis and is agreed with the report of Mahboob *et al*. (2018).
Nevertheless, lactation stage is not significantly associated with the occurrence of camel mastitis in the study areas, with (P>0.05) and this is in agreement with the findings of Mahboob *et al*. (2018) and Mahboob *et al*., (2019). Besides, Alebie *et al.* (2021) reported that both parity and lactation stages were not statistically significant in the association of camel sub clinical mastitis occurrence in lactating she camels from Dubti district, Afar Regional State, North-eastern Ethiopia which is in agreement to the current findings. Yet, Moge *et al.* (2019) was found significant difference in camel sub-mastitis across lactation stage and parity, with (P < 0.05) in lactating dromedary camels in and around Hargeisa, Somaliland. This variation may be related to the type of bacteria studied.

The 34.5% and 29.8% prevalence of *Staphylococcus aureus* and *Streptococcus agalactiae*, respectively in the present study agreed with finding of Wubishet *et al*., (2016) who reported 38.0 % and 27.5% of Staphylococcus aureus and *Streptococcus agalactiae* isolates in lactating she camels with mastitis positive from Borena Zone, Oromia Regional State, Ethiopia. However, in the same work Wubishet *et al*., (2016) reported 1.2% of *Streptococcus dysgalactiae* isolates, which is far lower than the result of the current study which is 19.4%. Nonetheless, Eyassu and

Bekele (2010) found an extremely lower percentage of *Staphylococcus aureus* (4.2%) than the 34.5% in the present study.

Based on the results of antibiotics sensitivity test of the current study, it can be concluded that the preference of antimicrobial drugs for the treatment of mastitis in dairy camels should be first Erythromycin in descending order followed by Streptomycin and Oxytetracycline. This result parallels with the finding of Mody *et al*. (1998). In the current study 84.5% of the isolated bacteria were susceptible to Erythromycin antibiotic. Nevertheless, there was no published work to compare and contrast in this regard.

Conclusion and Recommendations

The current study revealed that camel sub-clinical mastitis was prevalent in the study area and is one of the dairy camel health problems. Age and hygienic measures like udder and leg hygiene were significantly associated with lactating she camel sub-clinical mastitis prevalence among the putative risk factors considered in the present study. Following bacterial species isolation analysis of the current study, *Staphylococcus aureus*, *Streptococcus agalactiae*, *Streptococcus dysgalactiae* and *Pasteurella multocida* had been identified as major bacteria of causing she camel mastitis in the study area. Based on the findings of antibiotics sensitivity test in the present study, it has also been realized that Erythromycin is the drug of choice and Oxytetracycline and tetracycline is the least option for treating mastitis in the study area. Furthermore, the current results of the camel dairy farm owners' interview revealed that neither the farmers emphasized the need to milk healthy cows first and the diseased cows later to prevent transmission of mastitis nor the milkers used disinfectant and even water to clean teats before and after milking.

Based on the above conclusion and the findings of the current study the following recommendations are forwarded:

- Etiological agents other than bacteria need further study
- Exploiting the traditional knowledge of the pastoralists and agro-pastoralists in treating sick animals is helpful for optimization of control options of camel mastitis and other animal diseases in the study areas.
- As mastitis causing bacteria has slightly developed resistance against Oxytetracycline, other drug options need to be available for the studied dairy camel farms

- Advance trainings about herd health and disease management with great emphasis on mastitis in lactating she camels is greatly required to provide dairy camel farm owners/attendants or any other involved entities.
- In order to reduce a relatively high prevalence and further transmission of mastitis among herds, improved dairy camel farm management with great emphasis on milking hygiene, washing of udder/teat with recommendable available antiseptics and disinfectants should be practiced in the study area.

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1.2. Assessment of Agro-Pastoralists' Small Ruminant Breeding Objectives and Production Potential in Fafen Zone for Community-Based Breeding Program

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Abstract

Breeding program described as community-based (CBBP) typically relate to low-input systems with farmers having a common interest to improve and share their genetic resources. A study was conducted in Harishn, Kebri-bayah and Shebelley belong to Fafen Zone, Somali Region with the aim of identifying small ruminant production objectives and potential and major challenges in the study areas. Six kebeles and 20 households from each kebele with a total of 120 households were selected and subject to an interview with semi-structured questionnaires, focus group discussion and field observation. Quantitative data which were collected form the survey such as land holding size, flock composition and flock structures were subjected to Analysis of variance (ANOVA) using the general linear model procedure of Statically Analysis System (SAS 2009) whereas qualitative data such as demographic characteristics and breeding animal selection criteria were analyzed using SPSS (2019). Out of 120 interviewed respondents, from three districts 90% were males with an average of 41 years old. Findings of this study based on educational attainment revealed that more than half of the respondents in the study areas were illiterate, which could have negative impacts on livestock production improvement interventions. Sheep and goats share the highest (33.29 and 28.19) contribution of flock compositions but donkey and chicken share the lowest number (0.37 and 1.81) of the livestock population respectively. Primary reason for keeping sheep and goat in all study areas was income generation with 0.441 index value followed by as sources of food (milk and meat). Other reasons mentioned by small ruminants' owners and their respective indices were), social security (0.059) and social prestige (0.026). Natural pastures (0.313) and grazing and browsing shrubs (0.225) are the dominant feed resources in all study districts where as crop residues supplemented in rear amount. But the availability both in quantity and quality of these feed resources are varied between wet and dry seasons. Body conformation, adaptability, pedigree, growth rate and twining ability were among the selection criteria for selection breeding sheep and goats in all study areas. Ewes and does with short lambing and kidding intervals and good twining rate were more preferred compared to long lambing/kidding intervals and single birth. Most of Agro-pastoralist using breeding calendar for sheep but not for goat because goats have better drought tolerance due to their browsing habitats to different browsing plant species and shrubs. Generally, small ruminants are kept under traditional production system which is constrained by, shortage of feed, diseases, water scarcity, frequent drought, predators, and poor veterinary service. The level of productivity is low and less attention is given to husbandry and breed *improvement. In order to raise productivity, it is important to involve farmers and other stockholders in designing breed improvement interventions, considering the existing breeding practices, management systems and trait preferences of the community. Therefore, to sustainable genetic improvement of small ruminants for improve food security and malnutrition community-based breeding program (with active participation of the society) should be established and implemented properly*.

Key words*: Breeding objectives, major production challenges, production potential small ruminants*

Introduction

Ethiopia holds the largest livestock population in Africa estimated about 65.35 million head of cattle (97.76% local, 0.32% exotic and 1.91% hybrid), 39.89 million of sheep, 50.5 million goats, 7.7 million of camel and 48.96 million of poultry (CSA, 2020). Despite of the huge livestock sources, adaptation and resistance to most endemic diseases and harsh climatic conditions, the current level of indigenous livestock productivity in Ethiopia is one of the lowest in the world due to genetic and non-genetic factors (Zeleke *et al*., 2020). Genetic improvement of livestock is often viewed as a complex process, requiring technical and organizational sophistication. Planning for sustainable livestock genetic development should, from the outset, take account of genetic differences among the species, the breeds and the animals considered for use, along with their adaptive fitness to the production environments in which they will be kept. Sustained livestock genetic improvement activities that meet national needs without jeopardizing community needs can make a vital contribution to food security and rural development. Lessons learned from countries that have initiated and sustained genetic improvement activity during the past half-century provide a solid basis for the effective use of animal genetic diversity. The results are impressive, especially those achieved in developed countries, where the productivity of breeds subjected to genetic improvement has been doubled or tripled.

In developing countries like Ethiopia, centralized breeding schemes were usually run by a governmental organization attempting to undertake all or part of the complex processes and breeding strategy roles (*i.e*., data recording, genetic evaluation, selection, distribution of genetically improved animals and feedback to farmers. The current level of productivity of the indigenous Ethiopian sheep and goat breeds under the smallholder production systems is low (Tibbo, 2006; Getachew *et al*., 2016; Taju, 2018; Eyayu, 2020; Kiflay *et al*., 2019). The demand for sheep and goat products has increased due to a growing human population, urbanization and demand from Gulf States. Therefore, an urgent need to improve productivity in order to raise smallholders' incomes and meet the demands of the growing human population with an integrated approach that considers genetics, nutrition, health, input supply and services, and markets is necessary. Sustainable strategy to improve productivity needs to be tailored to the specific goals of the targeted communities and production systems/environments as no single strategy fits all situations. Understanding owners' trait preferences provides insights into which traits are particularly important in their agro-ecosystem and how these can be incorporated in to the design of sustainable breeding programs.

A new approach gaining global interest is a community-based breeding program (CBBP). Programs that adopt this strategy take into account farmers/pastoralists' needs, views, decisions and active participation, from inception through implementation, and their success is based upon proper consideration of farmers/pastoralists' breeding objectives, infrastructure, participation and ownership (Sölkner *et al*., 1998; Wurzinger *et al*., 2011, Mueller *et al*., 2015; Aynalem *et al*., 2018). Designing a community-based breeding program is much more comprehensive than simply applying genetic theories to achieve increased productivity. Instead, its success combines infrastructure, community development and the opportunity for improved farmers/pastoralist livelihoods by creating integrated processes for productive breeding of adapted animals and the markets for their products. Community-based breeding programs have also been implemented in Mexico and Argentina with goats, in Bolivia with llamas and in Uganda and Malawi with goats. However, the methodological framework for their implementation, genetic gains achieved and the socioeconomic impacts of such programs in Africa have not yet been reported. Some successful sheep CBBPs in Ethiopia were implemented on Bonga, Horro and Menz sheep for both productive and reproductive performances, genetic progress and positive socioeconomic impact of communities were achieved (Ayenalem, *et al*., 2020). The main objectives of the study were to defining Agro-pastoralists' small ruminant breeding objectives and production system, determine, small ruminant production potential, husbandry and breeding practices of small ruminants in the study areas and identify major small ruminant production opportunities and constraints for selected sites.

Materials and Methods

Description of study Areas

The study was conducted in Fafen Zone of Somali Regional State located at 628 km east, of Addis Abeba. Fafen zone is situated in the northern part of Ethiopian Somali regional state with total land coverage of the zone is 40, 861 km^2 of which the rangeland extends over 36, 629 km^2 (IPS, 2002). About 52.6%, 31% and 7% of the landscape of the zone can be categorized as flat to gentle slopes, hills and steep slope, respectively. Harishn, Kebri-Beyah and Shabelley districts were among the eleven districts of Fafen purposively selected for the community-based breeding program project based on the small ruminant potentialities, practicing cultivation of different crops and road accessibility. Study districts have an altitude range from 500 to 1650 m.a.s.l. and lies between approximately 8°44′N to 11°00′N latitude and 40°22′E to 44°00′E longitude (IPS, 2002). The mean minimum and maximum temperature ranges from 16 to 20 °C and 28–38 °C, respectively (NMSA, 2005). The rainfall distribution in the zone is very erratic with a mean annual rainfall of 600 to 700 mm (NMSA, 2005). A study district comprises pastoralism, agro-pastoralism and sedentary production systems among those agro-pastoralism is the dominant production system.

Sampling Technique and Sample Size

Six kebeles and 20 households from each kebele with a total of 120 households were selected and subject to an interview with semi-structured questionnaires. Study sites (rural *Kebeles*) were selected based on sheep and goat potentiality, infrastructure accessibility and security. Both pastoral and agropastoral production system are the main agricultural activities in all study sites. The major crops grown in the study sites are sorghum and Maize. Goats, sheep, camel, cattle and donkey are reared Harshin, Kebri-byah and Shabelly districts. Discussions were made with key informants such as Pastoral and agropastoral’ representatives/elders and livestock experts in the Bureau of agriculture and rural development of the study areas. One focus group discussion (10 participants each group) for each rural kebele were addressed for common agricultural activities, small ruminant production trends, small ruminant production potential, livestock market channels and livestock production constraints in the study sites.

Data sources and Management

Both primary and secondary data were used in the study. Primary data were obtained through field observation, focus group discussion, and interviews while secondary data were collected from literatures, magazines, publications and governmental and non-governmental reports. Survey method was used to generate data on household information, landholding and farm activities, livestock holding and flock composition, Feed sources and feeding practices, identification of small ruminant production potential areas, production constraints and common diseases in the area, small ruminant selection criteria's and breeding practices, productive and reproductive performances, breeding objectives, marketing system and marketing value of some important production traits. Before conducting the formal survey, the questionnaire was pre tested and modified to match with the study area's livestock production system and for its appropriateness.

Data analysis

Both qualitative and quantitative data obtained from survey were subjected to statistical analysis. Qualitative data were analyzed using Statistical package for Social Sciences (SPSS, 2019; Version 26). Descriptive statistics (frequency, percentage histogram and pies) were used to presented variables. Indices were calculated for all ranking data using the formula: Index = Σ [3 for rank 1 + 2 for rank 2 + 1 for rank 3] given for an individual reason divided by Σ [3 for rank 1 + 2 for rank 2 + 1 for rank 3] for all reasons where indices represent weighted averages of all rankings for a particular trait or reason (Kosgey, 2004).

Quantitative data which were collected form the survey such as land holding size, flock composition and structures and demographic information were subjected to Analysis of variance (ANOVA) using the general linear model procedure of Statically Analysis System (SAS 2009; version 9.1). Duncan's multiple range tests was used to examine mean significant differences among districts on flock composition breeding objectives and selection criteria for breeding animals.

Results and Discussion

Demographic and Socio-economic Characteristics of Respondents

Result of the study revealed that a total of 120 smallholder pastoralists and agro-pastoralists interviewed, from three districts 90% were males (Table 1). Age as one of the household characteristics is important to describe households' situation and can provide a clue on experiences households in small ruminant breeding and management practices. Majority of the respondents mean age were found to be 41 years. In all the three districts, the majority of household heads indicated that they are agro-pastoralists, growing some crops (Maize and Sorghum) in addition to keeping animals. Similar findings of age distributions were revealed by Chenyambuga *et al*., (2012) and Nenganjwa (2005).

Findings of this study based on educational attainment revealed that more than half of the respondents in the study areas were illiterate, which could have negative impacts on livestock production improvement interventions. Among the three study districts Kebribayah has better (70%) literacy rate. This may be due to people near the town (old) having high probability to get education. Similar findings were also reported by Chang *et al*. (2010), Omondi and Meindert (2011), Chumpawadee *et al*., (2007), Evans (2013) and Ogola *et al*., (2010). Whereas, this finding is higher than 32.6% illiteracy rate reported in Tigray (Kiflay *et al*., 2019). This variation may be due to different factors such as mode of social livelihood, availability of infrastructure and socio-economic factors etc. The low literacy levels in all study areas also highlight the need for additional efforts by the regional government to avail adult learning interventions in pastoral communities.

Table1. Demographic and Socio-economic Characteristics of the Smallholder Agro-pastoralists

Descriptor variables	**Mean ± SD**			**Overall mean ± SD**
	Harishn (N = 40)	Shebelly (N = 40)	Kebri-bayah (N = 40)	(N = 120)
Age (years)	47.00 ± 6.13	41.30 ± 10.6	41.20 ± 9.72	43.17 ± 9.36
Family size	8.80 ± 3.33	7.10 ± 4.52	6.8 ± 2.67	7.57 ± 3.66
Land ownership (percent)				
Yes	100.00	100.00	100.00	100.00
No	-	-	-	-
Sex (percent)				
Male	90.00	80.00	70.00	80.00
Female	10.00	20.00	30.00	20.00
Educational level (percent)				
Illiterate	70.00	30.00	70.00	56.7
Read & write	30.00	50.00	20.00	33.3
G 1-8	-	20.00	10.00	10.0
G 9-10	-	-	-	-
Religion (Percent)				
Muslim	100.00	100.00	100.00	100.00
Orthodox	-	-	-	-

N = Number of Respondents, SD = Standard Deviation

Land is a critical factor endowment of any production activities and as such in agriculture. All respondents have their own land using for different agricultural activities. The findings show the Land trends was decreasing from time to time this is due to the increasing of human population within a limited land resource.

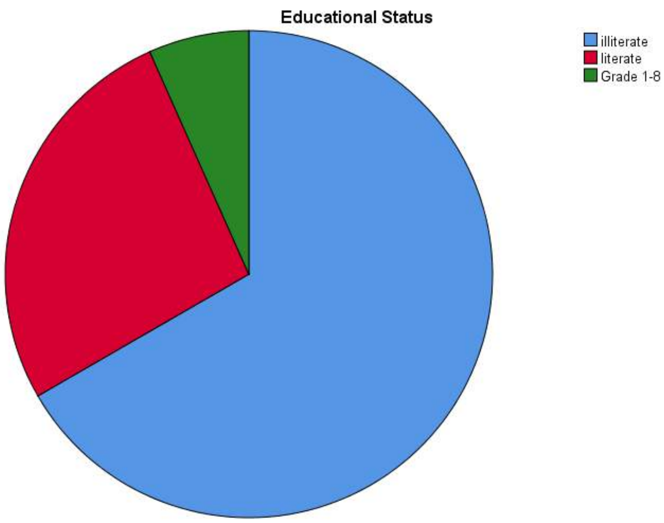


Figure 1. Educational status of the respondents of selected study sites

Herd Structure and Flock Composition of Livestock

Livestock composition per household in all study areas are presented in Figure 2. The overall mean of livestock owners was around 112 animals per households. Sheep, goats, cattle, camel, donkey and chicken are reared by the communities whereas, sheep and goats share the highest contribution of flock compositions but donkey and poultry share the lowest number of the livestock population on all study areas. Low number of poultry in the study areas reviled that there is a minimal intervention done on livestock diversification since animals (sheep, goat camel and cattle) mostly relay on seasonal grazing/browsing on Natural pasture, crop residues and shrubs. Similar findings reported in afar pastoral and agro-pastoral communities with low poultry production customs rather their livelihood is mostly depended on sheep, goat, camel and goats (Anware, 2018), African development group (2010) also reported that around 35 sheep per household, 6.5 camel and 4.6 cattle per households in Somalia. Furthermore, Adugna (2007) reported that 9.5 camel and 1.2 chickens' per-household heads of agro-pastoral communities at Moyale district of Somali region.

Traditionally, livestock production has been an important source of income for the rural poor in all the study areas. It is anticipated that expansion of livestock production will offer one of the best opportunities for improved livelihoods and economic integration between pastoralists and farmers in the region under the improved management systems. Informed planning and decision-making are key for the success of livestock production and health management. The current findings indicate that the flock size in Kebri-bayah was significantly ($p < 0.001$) lower compared to the rest of two study districts. This situation arises from small land holding size, relatively poor animal welfare, lack of feed in both quantity and quality, especially during dry season and low water availability. Furthermore, Harshin district performed better sheep and goat compare to Shebeley and Kebri-bayah districts in Fafen zone of Somali regional state. Therefore, further genetic improvement interventions are vital for those potential areas

Table 2 Small ruminant herd structures and flock compositions in the study areas

Species	Variables	Mean ± SE			P value
		Districts			
		Harshin (N = 40)	Kebri-**bayah** (N = 40)	Shebelley (N = 40)	
Sheep age categories	Male < 6 months	2.8 ± 0.14[a]	1.9 ± 0.16[b]	2.2 ± 0.13[b]	<0.001
	Male 6 months -1-year	2.4 ± 0.13[a]	1.4 ± 0.15[b]	1.8 ± 0.15[b]	<0.001
	Male > 1 year	1.88 ± 0.12[ns]	1.48 ± 0.11[ns]	1.68 ± 0.13[ns]	**<0.223**
	Castrated	1.08 ± 0.09[ns]	1.13 ± 0.10[ns]	0.85 ± 0.06[ns]	**<0.448**
	Female < 6 months	4.05 ± 0.18[a]	2.95 ± 0.14[b]	4.03 ± 0.19[a]	<0.001
	Female 6 months - 1-year	6.93 ± 0.25[a]	6.93 ± 0.22[a]	6.98 ± 0.24[a]	<0.092
	Female > 1 year	18.5 ± 0.36[a]	14.58 ± 0.29[b]	13.55 ± 0.26[b]	<0.001
	Overall Sheep population	37.63 ± 0.53[a]	30.40 ± 0.47[b]	31.83 ± 0.50[b]	<0.001
Goat age categories	Male < 6 months	2.7 ± 0.12[a]	1.35 ± 0.06[b]	1.63 ± 0.09[b]	<0.001
	Male 6months -1-year	3.03 ± 0.13[a]	1.23 ± 0.07[b]	1.75 ± 0.09 [b]	<0.001
	Male > 1 year	2.38 ± 0.13[a]	1.58 ± 0.13[b]	2.13 ± 0.10 [a]	<0.001
	Female < 6 months	4.55 ± 0.18[a]	2.80 ± 0.13[b]	4.10 ± 0.15 [a]	<0.001
	Female 6 months - 1-year	4.73 ± 0.19[a]	3.90 ±0.12[b]	4.43 ± 0.18[ab]	<0.001
	Female > 1 year	17.95 ± 0.34[a]	14.43 ± 0.27[b]	9.93 ± 0.21[c]	<0.001
	Overall Goat population	35.33 ± 0.48[a]	20.78 ± 0.53[c]	28.45 ± 0.57[b]	<0.001
Cattle	Cattle population	6.33 ± 0.22[a]	6.63 ± 0.23[ab]	4.90 ± 0.18[b]	<0.001
Camel	Camel population	9.0 ± 0.20[a]	3.9 ± 0.29[b]	0.90 ± 0.47[c]	<0.001
Donkey	Donkey population	0.5 ± 0.06[a]	0.4. ± 0.02[ab]	0.2 ± 0.01[b]	<0.001
Chicken	Chicken population	1.76 ± 0.12[ns]	2.00 ± 0.12[ns]	1.68 ± 0.12[ns]	**<0.861**
Overall	Total Livestock number	111.13 ± 0.87[a]	79.15± 0.78[b]	84.95 ± 0.83[b]	<0.001
LHS (Ha)	Land holding size/household	20.6 ± 0.38[a]	15.05 ± 0.28[b]	17.10 ± 0.31[ab]	<0.001

[a-c]Means with in a column with different superscripts differ (P < 0.05); LHS (Ha) = Land Holding Size in Hectare, LSM = Least Mean Square, SE = Stander Error

Sheep and Goat Production Objectives

Table 3 shows the purpose of keeping small ruminants and their respective rank in all the study areas. Better understanding of the purposes of keeping small ruminant is a prerequisite for defining breeding goals (Jaitner *et al*., 2001). Primary reason for keeping sheep and goat in all study areas was income generation with 0.441 index value followed by as sources of food (milk and meat). Other reasons mentioned by small ruminants' owners and their respective indices were), social security (0.059) and social prestige (0.026). Similar findings have been reported in the intergovernmental authority on development (IGAD) countries (Djibouti, Eritrea, Ethiopia, Somalia, Uganda and Kenya) where pastoralists keep livestock to provide food (Sanford and Ashley, 2008) and Anne *et al*. (2016). Agro-pastoral communities sell their animal and animal products for the purpose of predominant to pay for school fees education, health care and social securities were notably considered of great importance. In addition to that majority of respondents in Harshin, Kebri-bayah and Shebelley indicated that's slaughtering of sheep and goats for family/home consumption is done mostly during religious festivals and wedding ceremony.

Group discussion revealed that small ruminant's rearing for income generation and household milk and meat consumption were common and contribute to livelihood in the study areas, especially as alternative income sources to the poor. Given the breadth of purposes that farmers have for keeping sheep, much care is required in the choice of breeding objectives and breeding strategies as the function of the animals is closely linked to the traits desired by the producers (Jimmy *et al.,* 2010). Knowledge of reasons for keeping animals is a prerequisite for deriving operational breeding goals (Jaitner *et al.,* 2001).

Table 3. Sheep and goat production objectives in the study areas

Districts	**Sheep Production objectives**	**Ranks**			**Index**
		1st	2nd	3rd	
Harshin	Income	29	7	8	0.454
	Meat	5	12	15	0.225
	Milk	2	16	12	0.208
	Social Security	3	3	4	0.079
	Social Prestige	1	2	1	0.033
	Over all	40	40	40	0.999
	Goat Production Objectives				
	Income	15	19	19	0.425
	Milk	20	11	8	0.375
	Meat	3	7	12	0.146

	Social Security	2	2	0	0.042
	Social Prestige	0	1	1	0.013
	Over all	40	40	40	1.001
Shebelley	**Sheep Production objectives**				
	Income	24	17	13	0.496
	Meat	8	10	15	0.246
	Milk	6	8	10	0.183
	Social Security	2	4	2	0.067
	Social Prestige	0	1	0	0.008
	Over all	40	40	40	1.00
	Goat Production Objectives				
	Income	16	24	12	0.45
	Milk	16	7	9	0.296
	Meat	8	4	6	0.158
	Social Security	0	1	11	0.054
	Social Prestige	0	4	2	0.042
	Over all	40	40	40	1.00
Kebri-bayah	**Sheep Production objectives**				
	Income	20	20	12	0.467
	Meat	12	12	12	0.3
	Milk	3	6	5	0.108
	Social Security	4	2	8	0.10
	Social Prestige	1	0	3	0.025
	Over all	40	40	40	1.00
	Goat Production Objectives				
	Income	12	12	20	0.333
	Milk	14	17	11	0.363
	Meat	8	4	8	0.167
	Social Security	4	6	1	0.104
	Social Prestige	2	1	0	0.033
	Over all	40	40	40	1.00

The engagement of livestock management practices presented in (Figure 3) showed that there was distribution in households such as husband, wife and children. Feeding, watering and disease control were performed dominantly by husband while selling of animal products and herding were handled by wife in all the study areas. Similar investigation was reported wife have a great contribution in herding and selling livestock products such as milk, butter and proceeded milk products in Afar and Tigray regions reported by Anware (2018) and Kiflay *et al*., (2019) respectively. In all agro-pastoral production systems, mostly sheep and goats were kept in open kraal and separated from family house which is constructed from wood and branches of acacia.

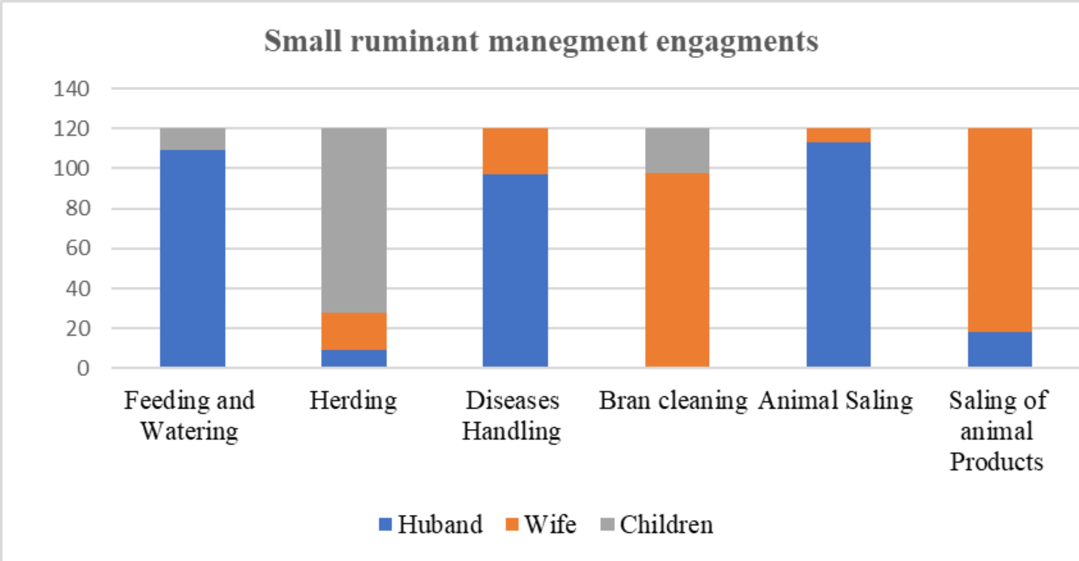


Figure 2. Small ruminant management practices (Survey results, 2021)

Sheep and Goat Feed Resources in the Study Areas

Major small ruminant feed resources across the study areas are presented in Table 4. Natural pastures (0.313) followed by grazing and browsing shrubs (0.225) are the dominant feed resources in all study districts. Natural pastures (herbaceous vegetation composed mainly of grasses and forbs and browses (shrubs, tree leaves and pods) are dominantly utilized by small ruminants in all study districts. Browse plant species form an important component of the livestock diet, particularly in the dry season. Browsing plant species such as *Acacia tortilis* (*qudhac*), *Acacia seyal* (*waadhi*), *Acacia mellifera* (*Bilcil*), *Acacia etbaica* (*Sogsog*), *Acacia nilotica* (*maraa*), *Acacia bussei* (*Galool*) and other browse species such as Balanites aegyptiaca (*Quudka*), Commiphora species and others play a very important role as sources of feed primarily for the browsing species such as goats, camels and sheep in the study areas. These livestock feed sources which are very important during dry season also were reported by Adugna (2007) at Moyal district of Somali region. Availability of feed resources is determined greatly by rainfall. Better access to communal pasturelands as observed in this study is essential for the conservation and management of the local small ruminants'' genetic resources.

Crop residues, particularly maize and sorghum Stover, are also used to limited extents as animal feed after the crop is harvested in the agro pastoral areas. Although there is less feed available in times of drought, grazing is still the main source of livestock feed resources. The multipurpose natures of browses as fuelwood, shade, feed poles, etc. as well as their potential to improve soil fertility and conservation are added advantages.

Table 4. Sheep and goat feed resources in the study areas

Districts	Major Small ruminant Feed Resources	Ranks			Index
		1st	2nd	3rd	
Harshin	Natural pasture	12	15	9	0.3125
	Crop residue	8	10	7	0.2125
	Grazing and Browsing shrubs	9	7	13	0.225
	Bushes	4	3	4	0.09167
	Different Acacia Spices	7	5	7	0.15833
	Overall	40	40	40	1.0
Shebelley	Natural pasture	8	14	9	0.254
	Crop residue	6	10	7	0.188
	Grazing and Browsing shrubs	8	9	11	0.221
	Bushes	8	3	8	0.1583
	Different Acacia Spices	10	4	5	0.1792
	Overall				
Kebri-bayah	Natural pasture	13	11	8	0.288
	Crop residue	12	15	14	0.333
	Grazing and Browsing shrubs	9	8	7	0.208
	Bushes	3	4	6	0.096
	Different Acacia Spices	3	2	5	0.075
	Overall				1.0

Many similar researches across sub-Saharan African countries (Ayantunde *et al*., 2012 and 2014), Tesfaye (2008) and Yayneshet (2010) also reported that natural pasture is the largest contributor of feeds for livestock in developing countries of Africa. There is no fodder cultivation by the respondents either as community or individually as well as non-availability of factory compounded feeds; as a result of these, livestock production performances are greatly limited especially during dry season. The recurrent drought in Somali region causes losing of huge livestock resources every year, especially during 2021 the region was extremely affected by drought as result more than 250, 000 livestock were lost. Therefore, it needs alternative feed development strategies to minimize such type of economic losses.

Small Ruminant Breeding Practices

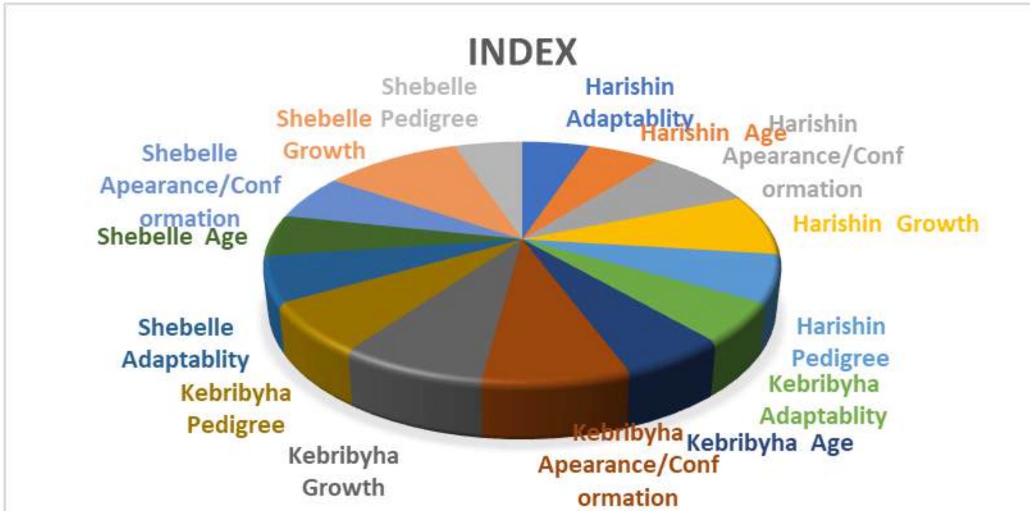
Due to mechanisms for preventing lamb losses during the dry season, almost all small-holder owners used a controlled sheep mating system, while uncontrolled goat mating systems were used in all study districts. Goats, however, have better drought tolerance due to their browsing nature on shrubs and various Acacia trees. The main sources of breeding males for all species were forming their own herd and neighboring during the communal grazing. In all the three districts (Harshin, Shebeley and Kebri-bayah), the pastoralists indicated that they practiced some form of selection for the male animals they preferred for mating in their flocks. Respondents suggesting that availability of breeding males are not a constraint to acquisition of new breeding males. Key practices employed included castration (ram) of nonbreeding males culling of inferior males to prevent them from breeding purposely mating the best males to the best females allowing males to mate only a certain number of females separating male and female animals all study districts. Similar findings were reported by Karen *et al.,* (2019) in Somali land. There are no records and traditions for culling rate and age of small ruminants in the study area.

Agro-pastoralists' small ruminants selection criteria's

Majority of pastoralists practices selection of replacement stock (male and female animals). Body appearance (body size and body structure), growth rate and age of the male animals were given high priority in selecting breeding rams and bucks whereas body size, twining ability and pedigree information were mainly focused in deciding to retain the best breeding ewes and does in all the study areas. More preference for a bigger body size observed in the current study is in agreement with the previous reports (Getachew *et al*., 2010; Mirkena *et al*., 2012, Duguma *et al*., 2011) for Menze, Horro and Afar sheep, adapted to different agro-ecologies of Ethiopia. Farmers' preferences for bigger ewes could be due to their expectation that bigger ewes are often better at rearing larger litters, and/or larger lambs/kids. In addition to, that Pastoralists give great attention to colors for selecting both male and female breeding animal, accordingly black head with white body, white, red and brown colors were preferred for sheep and goats respectively. Pastoralist and agro-pastoralist have perception on white color due to the ability of heat tolerance in the arid and semi-arid areas of Somali region. This perception has a logical sound that white color has less sunlight absorption compare to black and brown colors.

The score given by the household heads for each trait were grouped and a relative rank determined from the index calculated based on the weighted by Kosey (2004). The ranks for traits slightly differed between spices. For example, horn and adaptability were given attention during selection of goats but not for selection breeding sheep. The current findings are line with Getachew *et al*., (2020) finding which, reported that farmers have multiple trait preferences/selection criteria however the sale of live animals for income generation and consumption of milk and meat were identified as the major production objectives of Borana goat not only that Kiflay *et al*. (2019) also reported that body conformation and twining ability were among the prioritized traits during selection of breeding ewes of common Tigray highland sheep breed in selected zones of Tigray regional state. Furthermore, Gizaw *et al*. (2018) reported that lamb pre-weaning survival, body weight at six months of age (market age), growth rate, and lambing interval were found to be the most economically important traits for Menz sheep. Farmers have a preference for ewes/does with big body size and multiple births compared to ewes with small body size and single birth. This is because the profitability of a flock is directly related to the growth performance of the lambs and the litter size per ewe and doe. Moreover, when ewes produce multiple lambs with better growth performance and with short lambing intervals, they are preferred by smallholder farmers, and it is also important to achieve a faster genetic gain in the flock.

Ewes and does with short lambing and kidding intervals and good twining rate were more preferred compared to long lambing/kidding intervals and single birth. This perception of agro-pastoralist might have arisen, in addition to the benefit from increased productivity, to protect the flock from the risk of total loss from a natural and artificial disaster. This perception has logic because large flock size has a low probability of risk of total sheep loss compared to small flock size. Moreover, short lambing intervals have a better contribution to genetic improvements of the stock by reducing the average generation interval. In developing a breeding program for such traits, cooperation with farmers' indigenous knowledge (breeding calendar) is essential to rapidly detect the most appropriate phenotypes with these attributes.



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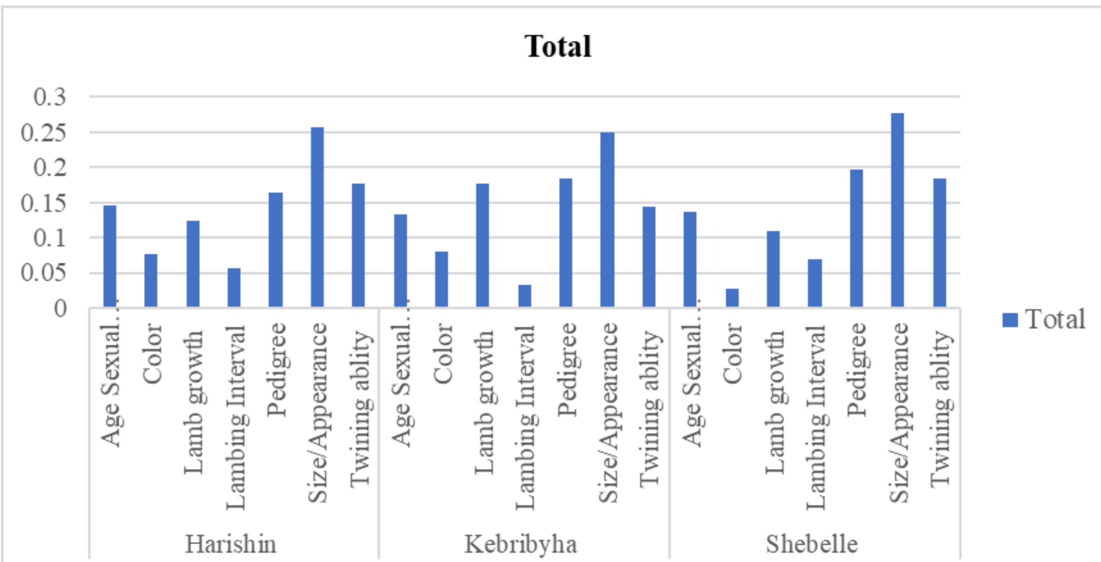

b

Figure 3. Sheep selection criteria in the study areas (**a**) male selection and (**b**) female selection (Survey results of 2021)

Small Ruminant Reproductive Performances

The results on reproductive performance, viz average age of sexual maturity, weaning age and ewe reproductive life span across all districts are presented in Table 5. Good reproductive performance is a prerequisite for any successful livestock production program. Previous study suggested that differences exist in reproductive performance between indigenous sheep breeds and their variation allow for the selection of suitable breeds for a given environment (Shashie and Mengistu, 2019).

Age at first mating (Sexual Maturity)

Puberty in the lamb/kid is the time at which animals ready for mating to replace their offspring. The age at puberty depends primarily on the growth of the lamb/kid, which depends on the supply of sufficient and quality nutrition during the growth period. As indicated in Table 6 there is statistically significant difference ($p < 0.05$) of age at first mating (sexually maturity) for both species and sexes across the study sites. Small ruminant reared under Harshin agro-pastoralists have relatively better age of puberty (8.83 ± 0.17 for goat and 8.43 ± 0.12 Sheep) compared to Kebri-bayah (10.68 ± 0.16 for goat and 11.05 ± 0.19 for sheep) and Shebelly (9.99 ± 0.14 for goat and 10.05 ± 0.18 for sheep) this could be due to the Presence of huge flock size compared and better feed availability in the district. Similar finding was reported by Helen *et al*. (2015) age of sexual maturity for Black head Ogaden sheep range from 7.07 ± 0.19 to 10.22 ± 0.17 months in Pastorals and agro-pastoral production systems. Furthermore, Kiflay *et al.*, (2019) also reported that 8.3 ± 0.09 months for comm Tigray highland sheep under comparative study of different management practices in northern Ethiopia.

Lambing and Kidding interval

Lambing/kidding interval is the period between two consecutive parturitions that determines reproductive efficiency in sheep and goat production. The mean ± SE, lambing interval and kidding interval were 7.36 ± 0.16/8.15 ± 0.7, 9.91 ± 0.17/8.55 ± 0.16 and 8.53 ± 0.15/8.45 ± 0.19 Months for Harshin, Kebriy-bayah and Shabelley districts for goat and sheep respectively which is lower than 13.8 ± 0.27 months lambing interval of Black head Ogaden sheep at Jigjiga agro-pastoralists production system (Helen *et al*., 2015). This variation could be due to covered non potential area and season of the study. Furthermore, areas with better flock size and feed availability have high probability for better reproductive performance including lambing interval, weaning age and lifespan of ewes and do under agro-pastoral communities.

Males are sold at early age during the holy days and festivals. Furthermore, farmers across the study sites sell their animals when they are faced with financial problems. Sheep and goats are primarily sold in the nearby market where local traders are principal actors in the marketing process. Overall, across of the study areas, average market ages of ram and buck were 10.75 and 11.61 months respectively. This finding is similar with report of Kiflay *et al*. (2022) for common Tigray highland sheep in northern Ethiopia.

Table 5. Small ruminant reproductive performances at agro-pastoral communities

Parameters	Districts (Mean ±SE)						P-value
	Harshin		Kebri-bayah		Shabelley		
	Goat	Sheep	Goat	Sheep	Goat	Sheep	
Female average weaning age	3.12 ± 0.06[b]	3.20 ± 0.08[C]	3.52 ± 0.17[a]	4.25 ± 0.16[a]	3.32 ± 0.06[a]	3.88 ± 0.12[b]	P < 0.0133
Male average weaning age	3.04± 0.05[b]	3.05 ± 0.06[c]	3.30± 0.06[a]	3.33 ± 0.02[b]	3.91± 0.07[a]	3.85 ± 0.03[a]	P < 0.0133
Average Kidding/Lambing interval	8.56 ± 0.16[b]	8.55 ± 0.07[a]	10.42 ± 0.09[a]	8.60 ± 0.07[a]	9.74 ± 0.10[a]	9.63 ± 0.39[a]	P < 0.0133
Doe/Ewe Lifespan (Longevity)	7.36 ± 0.16[b]	8.15 ± 0.7[a]	9.91 ± 0.17[a]	8.55 ± 0.16[a]	8.53 ± 0.15[b]	8.45 ± 0.19[a]	P < 0.014
Female average age at sexual maturity	8.83 ± 0.17[c]	8.43 ± 0.17[c]	10.68 ± 0.16[a]	11.05 ± 0.19[a]	9.99 ± 0.14[a]	10.05 ± 0.18[b]	P < 0.001
Male average age at sexual maturity;	8.18 ± 0.18[c]	7.98 ± 0.14[c]	10.06 ± 0.20[a]	9.60 ± 0.15[a]	9.20 ± 0.19[b]	8.7 ± 0.13[b]	P < 0.001
Male market age	12.34 ± 0.21[a]	10.88 ± 0.20[a]	11.40 ± 0.15[ab]	10.73 ± 0.21[a]	11.10 ± 0.18[b]	10.65 ± 0.22[a]	P < 0.041

[a-c] Means with in a row with different superscripts for both species differ significantly ($P < 0.05$); SE = Standard Error

Small Ruminants Production Constraints

The major constraints in sheep and goat production in the study areas are presented in Table (6). The results indicate that feed shortages, health problem (disease), water scarcity, loss of small ruminants by predators and long distance move on foot were the major constraints affecting sheep and goat production with index values of 0.335, 0.322, 0.296, 0.028 and 0.019 respectively. Among those constraints feed shortage, diseases and water scarcity were top three constraints across the entire studied districts. Both internal and external parasites are the major small ruminant production challenges in all the study areas, with very limited treatments provided, even Shebelley district performs better vaccination was given compare to Harshin and

Kebri-bayah districts this may be due to nearest to Jigjiga city where more animal medications are available. Moreover, water scarcity in Kebri-bayah district the first constraint followed by feed shortage especially during drought season. Additional constraints identified in all the three districts include lack of Agro-pastoral knowledge/education, limited access to good breeding stock, lack of animal records, limited access to veterinary services, and lack of an established marketing chain. Similar feed shortage is reported in different area numerous numbers of constraints that limits the productivity of sheep and goat in Ethiopia such as feed shortage, drought, housing and occurrence of disease, which affect their production potentials (Tesfaye, 2008). Feed shortage especially in the long dry season is critical problem in all study sites. This factor extremely affects the growth rate and body energy reserve of animals rendering them to have a low-quality meat (Zelalem *et al*., 2014). Furthermore, IGAD (2011), Legesse *et al*. (2014), and Bryony *et al*. (2021) reported that diseases which are caused highly mortality of both adult and young animals record many economic losses in small ruminant producers in Ethiopia, Tanzania and Uganda.

Table 6. Small ruminant Production constraints in the study areas

Districts	Major Constraints	Ranks			Index
		1st	2nd	3rd	
Harshin	Feed shortage	21	11	5	0.375
	Health Problem	15	15	10	0.354
	Water scarcity	3	10	20	0.204
	Predators	1	3	0	0.038
	Transport	0	1	5	0.029
	Overall	40	40	40	1.00
Shebelly	Feed shortage	15	18	6	0.363
	Health Problem	19	12	8	0.371
	Water scarcity	6	7	22	0.225
	Predators	0	2	1	0.021
	Transport	0	1	3	0.021
	Overall	40	40	40	1.001
Kebri-bayah	Feed shortage	9	16	5	0.267
	Health Problem	6	15	10	0.242
	Water scarcity	24	9	20	0.458
	Predators	1	0	3	0.025
	Transport	0	0	2	0.008
	Overall	40	40	40	1.00

Proper feeding with high-energy diets increases the meat quality through increasing the muscle glycogen reserve, which helps to keep the pH low after rigor mortis, and improve intramuscular fat content (Sibut *et al*., 2008). Furthermore Kiflay *et al*., (2014) reported that supplementation of soybean meal to black head Ogaden sheep shown dramatic improvement (99 g/day) in body weight which implies there is hope for genetic improvement through intervention methods. Therefore, proper feeding of animals for growth milk and meat quality should be practiced carefully for sustainable genetic improvements of small ruminants in agro-pastoral communities.

Conclusions and Recommendations

Sheep and goat in the study area were principally bred as source of income, meat and milk for home consumption, social security and social prestige. Agro-pastoralist practiced selection of small ruminants for replacement of the flocks. Body conformation, adaptability, pedigree, growth rate and twining ability were among the selection criteria for selection breeding sheep and goats in all study areas. Most of Agro-pastoralist using breeding calendar for sheep but not for goat, because goats have better drought tolerance due to their browsing habitats to different browsing plant species and shrubs. Majority of feed sources of small ruminants were depended on the natural pasture, browsing plants, shrubs and in limited amount of crop residues but not supplemented their animals through improved forages and agro-industrial by products because there is no improved forage production in all study locations. Among the three study districts Harshin have better livestock and feed potential which leads better animal performance. In general, small ruminants are kept under traditional production system which is constrained by, shortage of feed, diseases, water scarcity, frequent drought, predators, and poor veterinary service. The level of productivity is low and less attention is given to husbandry and breed improvement. In order to raise productivity, it is important to involve farmers and other stockholders in designing breed improvement interventions, considering the existing breeding practices, management systems and trait preferences of the community and the multipurpose roles of sheep and goats in agro-pastoral community.

Recommendations

- For better and sustainable production improvement regional and national government should give attention and working with communities (such as community-based breeding program) at ground level.

- There is high feed fluctuation during wet and dry season which is directly affect the livestock productivity, therefore, it is better to design a sustainable feed development such as introduction different feed conservation techniques and improved forage development in the area.
- Regional government should give emphases for build awareness on modern livestock production system and better health management.
- Therefore, to sustainable genetic improvement of small ruminants for improve food security and malnutrition community-based breeding program (with active participation of the society) should be established and implemented properly.

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1.3. Ethno-Botanical Study of Medicinal Plants Used to Treat Livestock and Human Diseases in Fafan and Jerar Zones of Somali Region, Ethiopia.

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Abstract

Ethno botanical study of traditional medicinal plant species was conducted from October, 2021 to May, 2022 with the aim of identifying and documenting medicinal plants used for livestock and human diseases treatments and also the associated indigenous knowledge in purposefully selected six districts of Fafen and jerar zones of Somali region, Eastern Ethiopia. The Data was collected through semi-structured and key informative interviews supported by field observations. All of the collected ethno botanical data were analyzed using descriptive statistics; Additionally, Pearson's correlation analysis was employed to determine correlation of medicinal plant knowledge with potentially associated intrinsic factors. A total of 75 indigenous ethno-medicinally important plant species used for different animal and human diseases distributed in the study area were recorded in this study. Of the total medicinal plants collected, the majority (53.3%) were used to treat human diseases followed by animals as 26.7% and both humans and animals as 20.0%. The findings of the present study revealed body and back ache as common diseases in the area followed by headache, stomach ache, muscle ache, placenta retention, wounds and common cold. However, the scientific names of these plants are not yet identified and grouped in accordingly. On the other hand, important livestock diseases reported in the study area were mastitis, pasteurellosis, CCBP, CBPP, Bloat, coughing and pneumonia in young stocks, poor milk yield and stunted growth. The most commonly used plant parts for herbals preparation in the study areas were roots (30.7%) followed by leaves (25.3%), stems (10.7%) and whole parts (9.3%) of the total reported plants. The study also revealed that among the different routes of application utilized, oral application was the most widely used (58.7%) followed by topical (25.3%). Our result mainly showed that all most all of the medicinal plants were obtained from natural forest. This designates essential to give priority to the conservation of the habitats most preferred by the medicinal plants of the study area together with awareness raising activities on the community.

***Key words**: Ethno-botanical, Ethiopia, Human Diseases, Somali Region, Livestock, Medicinal Plants.*

Introduction

In Africa, recent years (Mundy- Mathias and Mccrokle, 1992, Bizimana, 1994) plants medicine interest seems to have coincided with the rising popularity of participatory development approaches which include recognition of local skills practices, and requirement for animal health projects to address the problem of sustainability in veterinary services. Regarding the traditional veterinary knowledge of Somali pastoralists, it is widely recognized that Somalis are skilled herdsmen and women can accurately describe the clinical signs and epidemiology of many livestock diseases. a survey on acaricide usage in four zones (Degahbur, warder, Korahay and Fik) which included 250 elders indicated that people were willing to depend on old livestock practices rather than use acaricides which was often ineffective (Hirad,1994).

Accounts of traditional methods used by Somalis for treating and preventing livestock diseases are included in papers by Mares (1951, 1954a, 1954b) and Catley and Mohamed (1995), however, there is a need to document these skills more thoroughly and the case of plant remedies, to conduct trials after documentation in order to determine the efficacy of the more popular treatments are demanded. During SERP project, there was a survey made by RMEU (Range management unit, 1996) collected 12,683 records plants,2403 plants species identified,1759 medicinal or gums used for medicines while 1418 uses for human medicine and only 361 were usable on veterinary medicine were included.

However, a veterinarian was not involved in the design of the survey and consequently, a specific plant category for veterinary medicines was lacking. Also, the interviewers were not veterinarians or veterinary assistants and therefore discussions on animal health were not fully developed during the interviews with key informants. 21% of records describing veterinary uses of plants were considered to be incomplete and were not included in the data analysis. Therefore, a specific study on veterinary medicinal plants in Somali region of Ethiopia would be important. Ethno- veterinary knowledge is a local knowledge unique to a particular society, ethnic group, clans or even a family which deals with folk beliefs, knowledge, skills, methods and practices pertaining to the health care of animals (Mundy and Corkle 1989, cited by Ayelew 1997).

Indigenous knowledge or traditional medicine is defined as the sum total of all knowledge and practices whether explicable or not, used in diagnosis, prevention and elimination of physical, mental, or social imbalance and relaying exclusively on practical experience and observations to handed down from generation to generation whether verbally or written form (WHO**,** 1976 cited by Abayneh,1997). The indigenous knowledge of livestock owners forms the foundation for and complements the success of all sustainable animal health care programs in developing countries ((Abayneh *et al.*, 1997), probably because of absence, poor and/or inadequate veterinary service in developing countries. Although, there are a lot of things that professionals can learn about traditional medicines, specially use of medicinal plants, from traditional healers, very limited surveys were conducted in Ethiopia (Dawit and Ahadu**,** 1993).

Dawit and Ahadu (1993), cited by Abayneh**,** (1997), working in Northern Ethiopia gathered over 240 medicinal plant species. It is expected that such indigenous knowledge is highest in pastoral and mixed farming systems as livestock owners depend mainly on traditional medicine as a first line of health problem alleviation. The various professional veterinary practices have got a little attention and not documented despite being of vital importance in rural livestock health cares. There are a number of traditional healers in different agro- climatic zones of the country and these medicinal plants are endangered due to introduction and impact of modern and secrecy of herbs and ingredients they use. On the other hand, such traditional healers are becoming fewer and fewer (Masfin and Obsia**,** 1994). Exploitation of this indigenous knowledge which can complement and /or reduce complete reliance on Western style veterinary medicine is paramount importance. Therefore, this survey was initiated with the aim of identifying and documenting valuable medicinal plants used for treatments of livestock and human ailments.

Materials and Methods

Description of Study Area

Fafen administrative zone, is located in the northern part of the Ethiopian Somali Region, at 9°20' North latitude; 45°56'° East longitude, about 630 km East of Addis Ababa. It shares border with Shinile zone to the North, the Hararghe highlands of Oromia Region to the West, Degahbur to the South, and Somalia to the East. It covers a total land area of 40.86 km2 with altitude ranging from 500 to 1,650 meter above sea level (masl) (Degefu *et al.*, 2011). The area receives a precipitation ranging from 300 to 600 mm per annum and an average daily temperature of 16°C to 20°C (Keskes *et al.*, 2013). Agro-pastoralist is a dominant production system in Fafen zone. The estimated livestock population of the zone includes 248,435 Cattle, 666,130 sheep, 503,881 Goats' 72,390 Camels and 10,548 Poultry (CSA, 2011/2012). According to the report of Birhan (2013), cattle, sheep, goats and 23 camels are the main productive livestock reared in the area, and camel population was estimated to be 85,000. Specifically, Jigjiga city is located 9° 35‟ N latitude and 42° 8‟ E longitude and has an elevation of 1,609 m.a.s.l (httpp//populationmongabay.com). On the other hand, Jerar zone is bordered on the south by

Korahay zone, on the southwest by Nogob zone, and on the northwest by Fafan zone and southeast by Dollo and Northeast by Somalia. Degahbur town is the main administrative center of the zone. Dhagahbour town is located at 787.6 km from Addis Ababa. It is located at 8°13’ N latitude and 43°34’ E longitude. Hence, the average annual temperature of the town is 20°C indicating the existence of sub-tropical temperature condition whereas the mean monthly temperature varies from 17.34°C to 21.43°C in December and April, respectively. The hottest month is May while December is the coldest month with an average annual temperature of 20. 02 °C. The mean annual rainfall of Degahbur is just about 588 mm. The mean monthly amount of rainfall varies between 10.2 mm to 102.2 mm in February and April, respectively (Jigjiga Meteorological Station, 2014).

Selection of Targeted Kebeles and Respondents (Non-healers and Traditional healers)

In this study two zones (Jerar and Fafan zones) of Somali region were purposively selected based on the availability of traditional medicine practitioners, traditional medicine use history and presence of all livestock species. From the two zones, three districts namely Jigjiga, Kebribeyah and Awbare from fafan zone and Degahbur, Birkot and Ararso from Jerar zone were again purposively selected due to the major availability of traditional medicine practitioners, traditional medicine use history and also because of their representativeness for pastoral and agro-pastoral society. Then six kebeles (one kebele from each district) of the total kebeles from the selected districts of the two zones were targeted. Considering gender ratio, among the selected 6 kebeles, in average 10 key informants of comprising both human and animal healers from each kebeles were interviewed. Thus, a total of 60 participants were interviewed for this study. Moreover, Key informants were selected based on the information gathered from the local people.

Reconnaissance Survey and Collection of Ethno-botanical Data

An informal survey was conducted from October, 2021 to May, 2022 with the aim of identifying and documenting medicinal plants used for livestock and human diseases treatments in the study area. According to Mekonen, (2013); key informants’ interview was employed for medicinal plants data collection. First key informants were identified in each kebele by the facilitation of kebele administrates. Ethno-botanical data was obtained from general informants and key informants/traditional healers through semi-structured interview, following methods described by Martin (1995) and Alexiades (1996). Informants were interviewed individually in their local language, ‘Somali’. In addition, Semi- structured interviews were used to address issues regarding name, age, gender and level of education, about the local names of the plants, diseases treated in both animals and humans, plant parts used, methods of preparation of remedies, route of application of the remedies, dosage, and factors that threaten medicinal plants and others were compiled as did by Tizazu Gebre (2018) and Lulekal *et al.* (2014).

Data Analysis

All of the collected ethno botanical data on the local use of medicinal plants to treat livestock and human diseases were entered into Microsoft Excel spreadsheets and analyzed by using STATA software application and summarized using appropriate descriptive statistical methods for quantifying plant habit, plant parts used and methods of preparation, dosages and routes of administration. Additionally, Pearson’s correlation analysis was be used to determine correlation of medicinal plant knowledge with potentially associated intrinsic factors of key informative. Finally, the data was summarized and presented in the form of tables and charts.

Results and Discussion

Gender of the informants

In this study, all of the interviewed respondents were males (100%). Likewise, similar studies (Etana Tolasa, 2007; Sintayehu Tamene, 2011) indicated that males played a dominant role in the traditional medical system and were better in revealing pertinent information. This is mainly due to cultural influences prevailing in Somali Region. Firstly, as respondents claimed physiologically Somali women believe that it is a great risk for them to test the medicinal value and efficacy of a particular plant by themselves unlike men. Secondly, is that because of prohibiting women to be outsiders for searching plant medicine and also there is a need for keeping the secret and the privacy of traditional medicine application as an independent profession by men; since women are relatively poor in possession of secrecy and privacy unlike of men.

Age Categories of the Informants

The highest age category was those above and equal to 60 (51.8%) followed by 40–59 (35.0%). But, the age groups 20–29 were represented by the lowest number of respondents (Table 1). Similar age categories pattern was also used by Kefeyalew *et al*. (2017) in the ethno-botanical investigation of Jigjiga Woreda, eastern Ethiopia. The majority of informants interviewed in this study were in the age class of 60 and above.

Educational levels

The educational status of informants showed that 83.3% of the respondents were illiterate while the remaining 6.7%, 8.3% and 1.7% attended alimentary, primary and secondary school, respectively. Although most of the participants were illiterate which coincided mainly with age group above 60, they are generally considered as an important fountain of traditional knowledge including the knowledge and wisdom of utilizing plants for human and veterinary purposes.

Table.1. Background of the Respondents

Variables	Frequency	Percentage (%)
Sex		
Male	60	100.00
Female	0	0.00
Age group		
20 - 39	8	13.33
40 - 59	21	35.00
≥ 60	31	51.67
Educational Level		
Illiterate	50	83.33
Alimentary	4	6.67
Primary	5	8.33
Secondary	1	1.67

Traditional medicinal plants diversity documented in the study area

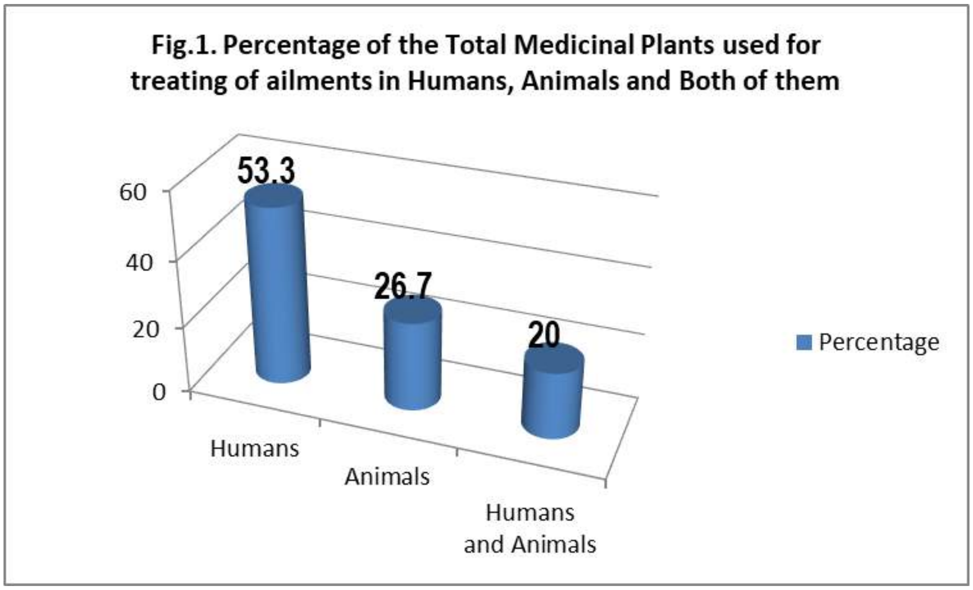
A total of 75 indigenous ethno-medicinally important plant species which were used for different animal and human diseases distributed in the study area were recorded in this study. However, the scientific names of these plants are not yet identified and grouped in accordingly. This may suggest that there is a wide utilization of medicinal plants and of course the consumption of such substantial number of medicinal plants by the people of the study area may indicate that the majority of the local people still employ and possibly may continue to use plant resources for medicinal purpose. Consequently, this indicates that traditional medicine plays a significant role in the health care system of the studied districts.

Proportion of Traditional Medicinal Plants Used for Treatments of Ailments in Humans, Animals and both Human and Animals

The total of 75 medicinal plants collected in the study area, the majority (53.3%) were used to treat human diseases followed by animals as 26.7% and both humans and animals as 20.0% (Fig. 1). This may indicate that there is a wide usage and aged cultural practice of herbal medicinal mainly in solving health problems of humans. The results from this study are in line with a number of studies (Tizazu Gebru, 2018; Ermias Lulekal *et al*., 2008; Mirutse Giday *et al*., 2009; Tesfaye Hailemariam *et al*., 2009; Gidey, 2010c; Reta Regassa, 2013; Engedasew *et al*., 2015; Getu *et al*., 2015). The findings of the present study revealed body and back ache as common diseases in the area followed by headache, stomach ache, muscle ache, placenta retention, wounds and common cold (Table 2). On the other hand, important livestock diseases reported in the study area were mastitis, pasteurellosis, CCBP, CBPP, Bloat, coughing and pneumonia in young stocks, poor milk yield and stunted growth.

Table 2. The Most Common Human and Livestock Diseases in the Study Areas

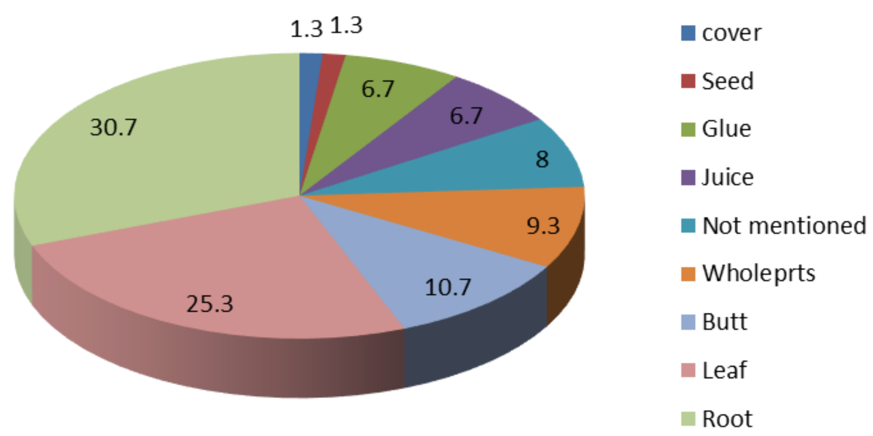
Disease Category	Types of Diseases	Local Names	Frequency	Percentage
Human	Arthritis	Xubno xanuun	4	6.0
	Bach ache	Dhabar xanuun	5	7.4
	Human mange	Cambaarta	6	9.0
	Stomach ache	Calool xanuun	6	9.0
	Diabetic	Macaanka	4	6.0
	Tonsillitis	Qummanka	2	2.9
	Toothache	Ilko xanuun	2	2.9
	Infection	Caabuq	4	6.0
	Placenta retention	Madheer ku dheg	5	7.4
	Dysuria	Kaadi kudhegga	6	9.0
	Diarrhea	Shubanka	4	6.0
	Pneumoia	Oof	3	4.4
	Open wound	Nabar furan	8	11.9
	Conjunctivitis	Indho xanuun	2	2.9
	Kidney problems	Kalyo xanuun	4	6.0
	Malaria	Duumo	2	2.9
		Total	**67**	
Animals	Mastitis	Candho xanuun	3	13.6
	Anthrax	kudka	2	9.1
	Listeriosis	Shimbirta Madaxa	5	22.7
	Dysuria	Kaadi ku dhega	4	18.1
	Toxic bite	Qaniinyada sunta ah	5	22.7
	Pneumonia	Oof	3	13.6
		Total	**22**	



Proportion of Traditional Medicinal Plants Parts Used for Treatments of Humans and Domestic Animals Diseases in the Study areas

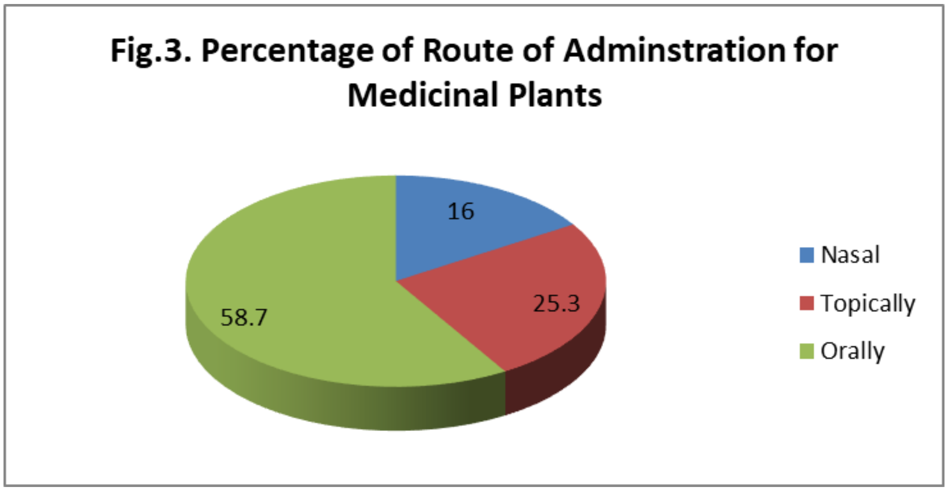
The most commonly used plant parts for herbals preparation in the study areas were roots (30.7%) followed by leaves (25.3%), stems (10.7%) and whole parts (9.3%) of the total reported plants. This finding is in agreement with several ethno-botanical studies (Debela Hunde *et al*., 2004; Kebu Balemie and Fassil Kebebew, 2006; Ermias Lulekal *et al*., 2008; Fisseha Mesfin *et al*., 2009) found that roots were the most widely used plant part in the preparation of traditional curatives. Such wide harvesting of roots, which are important for survival of plants has a negative influence on the survival and continuity of useful medicinal plants and hence affects sustainable utilization of the plants. Large proportion of herbal prescription from root sources was also reported by Yineger *et al.*, (2007) and Addis *et al.*, (2001) in their ethno-botanical investigations. However, other studies including (Etana Tolasa, 2007; Haile Yineger and Delenasaw Yewhalaw, 2007; Gidey Yirga, 2010c; Sintayehu Tamene, 2011; Gidey Yirga *et al*., 2012; Yalew Addisie *et al*., 2012; Mengistu Gebrehiwot, 2010; Reta Regassa, 2013; Engedasew Andarge *et al*., 2015; Getu Alemayehu *et al*., 2015) carried out in different parts of Ethiopia and elsewhere across the globe (Grace *et al*., 2004; Musa *et al*., 2011) reported that leaves were the most widely used plant parts in the preparation of traditional herbal curatives. These researchers were explained that the most probable reason for the widespread usage of leaves in the preparation of traditional remedies may be the comparative ease of harvesting (Mirutse Giday *et* *al*., 2009) and simplicity of remedial preparations (Sintayehu Tamene, 2011). Collecting leaves do not pose a greater danger to the existence of an individual plant as compared with the collection of roots, barks, stems or whole plants and hence do not affect sustainable utilization of the plants (Engedasew Andarge *et al*., 2015).

Fig.2. Percentage of Plant Parts used for treatments of Huamans and Animals Ailments



Proportion of Route of administration for Plants Parts Used in Treating of Humans and Domestic Animals Diseases

The study also revealed that among the different routes of application utilized, oral application was the most widely used (58.7%) followed by topical (25.3%) (Fig.3). These findings agree with those reports by recent work of Tizazu Gebru (2018) who reported 70.5% and 20.5 in oral and topical routes of administration respectively. Likewise, the present findings agree with the study of Getu *et al.* (2015) who reported 54.0% and 29.0% in oral and topical application, respectively. Both the dominant routes of administration (oral and topical/dermal) routes permit rapid physiological reaction of the prepared medicines with the pathogens and increase the curative power. Additionally, informants who participated in the current study told that oral application of remedies is painless and an easy way of taking the medicines. Moreover, for this study nasal route accounted the least percentage as 16.0%. Correspondingly, Lulekal *et al.*, (2008) reported that nasal application of traditional remedies was the least (9.0%) engaged administration route.



Intimidations to Medicinal Plants in the Study Area

The current study exposed that the studied districts were rich in medicinal plant diversity and associated indigenous knowledge. However, people in the study area stated that medicinal plants were highly endangered by recurrent drought, firewood collection and charcoal production and thus have effects in threatening the medicinal plants and associated indigenous knowledge in the study area. The other reason for the loss of the ethno-botanical knowledge on medicinal plant is modernization and refusal to practice or inherit the knowledge by new generation. Likewise, the present study revealed that the progressive dominance of modern health institutions in both medical and veterinary service extensions and also the existence of environmental and cultural modifications were among the reasons for the loss of the indigenous knowledge on ethno-botanical medicinal plants. Additionally, threats that erode indigenous knowledge emanate from secrecy, oral based knowledge transfer, and reluctance of young generation to gain the knowledge. Despite of the above-mentioned threats, very poor conservation efforts threaten medicinal plant survival in the study area. Thus, conserving all the living medicinal plant species, especially endangered species in their natural habitats and environment is highly recommended.

Conclusion and Recommendations

The study revealed that the communities in the study area were used traditional medicine to treat both human and livestock diseases, with a total of 75 unclassified medicinal plants. Among these, majority (53.3%) were used to treat human diseases followed by ailments in animals as 26.7% where as 20.0% of the observed medicinal plants were used in the treatments of diseases in both humans and animals. The most common diseases affecting humans in the study areas were body and back aches while mastitis, pasteurellosis, CCBP, CBPP, Bloat, coughing and pneumonia in young stocks were important livestock diseases reported in the study area. The most commonly used plant parts for herbals preparation in the study areas were roots and leaves (56.0%). Similarly, freshly harvested plant materials are mostly used in the preparation of remedies which strongly indicated the availability of plant materials in the vicinity. The current study also revealed that among the different routes of application utilized, oral application was the most widely used (58.7%) followed by topical (25.3%). However, most of these plants were under threats, which may potentially contribute the decline of the associated indigenous knowledge. The important threats for medicinal plants in the study area arise from re-current drought, firewood and charcoal production. While threats that waning indigenous knowledge of medicinal plants originate from modernization and refusal to practice or inherit the knowledge by new generation. Hence, based on the above conclusion the following recommendations are forwarded: -

- Awareness rising should be made among the healers to avoid attrition of the indigenous knowledge and to ensure its sustainable use.
- Advance biological studies should also be conducted on the reported medicinal plant species of the study area so as to utilize them in drug development for treatments of ailments in humans and animals.
- Training and awareness about conservation methods should be given to both traditional healers and non-healers.
- Also, traditional healers should be encouraged to transfer their indigenous knowledge to their family and relatives so as to preserve for the next generation.

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2. Crop Research Directorate

2.1. Adaptation Study of Released Haricot Bean (*Phaseolus vulgaris L.*) Varieties in Irrigated and Rainfed Areas of Somali Regional State, Ethiopia.

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Abstract

Haricot bean is an important source of protein, calories and cash for small holder farmers of Ethiopia. Studies on the evaluation of variety performance provide opportunities to increase productivity of haricot bean. therefore, the current study evaluates the performance of varieties on growth, yield and yield components of Haricot bean at two locations of Fafen and Dollo-ado station. The treatment consisted of six nationally released varieties. The experiments were conducted during 2021 and 2022 main cropping seasons at Fafen and Dollo-ado station, respectively. It was laid out in a randomized complete block design with three replications. Data on growth, yield and yield related parameters were collected and analyzed using GenStat software. The results showed that at Fafen station varieties had a significant effect on days to maturity, number of pods per plant, total biomass, 100 seed weight, and grain yield while at Dollo-ado station a significant variation on plant height, number of pods per plant, number of seed per pod and grain yield. The highest grain yield was recorded from Seri 119 (1484 kg/ha) and Seri 125 (2142 kg/ha) while the lowest grain yield was recorded from Awash-2 (680.6 kg/ha) and Awash-mitin (716 kg/ha) at Fafen and Dollo-ado station respectively. Accordingly, these two varieties are recommended for the study area and similar agro ecologies. If need arises for additional confirmation; further adaptation trials across more locations and years are of paramount importance.

Keywords: *Haricot bean, phaseolus vulgaris L. adaptations, varieties.*

Introduction

Haricot bean (*Phaseolus Vulagris L*), locally known as 'Digir' also known as dry bean, common bean, kidney bean and field bean are a very important legume crop grown worldwide. Haricot bean positively contributed to improve the nutritional composition of balanced health diets due to its high protein content and micro-nutrient concentration (Worku, 2015). It is an annual crop which belongs to the family Fabaceae. It grows best in warm climate at temperature of 18 to 24^{o} (Teshale *et al*., 2005). Haricot beans are among the most important grain legumes produced by small-scale farmers for both subsistence and cash mainly in the lowlands and in the rift valley areas of Ethiopia (Lemu, 2016).

In Ethiopia, Haricot bean is grown predominantly under smallholder producers as an important food crop and source of cash. It is one of the fast-expanding legume crops that provide an essential part of the daily diet and foreign earnings for most Ethiopians (Girma, 2009). The crop grows well between 1400 and 2000 m.a.s.l (Fikru, 2007). Early maturity and moderate degree of drought tolerance led the crop's vital role in farmers' strategies for risk aversion in drought prone lowland areas of the country (Fikru, 2007).

Low production and productivity are the main problem for Ethiopia due to low level of adoption of improved haricot bean technologies, poor agronomic and marketing systems (Amanuel and Girma, 2018). Haricot bean is considered as the main cash crop and protein source of farmers in many low lands and mid altitude zones of Ethiopia (Beyene *et al*., 2020). However, little research is done so far in this regard, despite its importance the crop has been introduced inadequately to this part of the country.

Like many other pulse crops, haricot beans are short cycled crops. This characteristic of the crop makes it an important technology for areas like Somali regional state. Although the area has got potential for production of common bean, the crop has not been widely grown. Therefore, to improve the production of haricot bean in this area, it is imperative to select the most adaptable haricot bean varieties to the local agro-ecological conditions. Therefore, there is a need to test the adaptability of the improved haricot bean varieties to the target areas and improve productivity and production in SRS. Therefore, this activity was initiated with the objective to select and recommend the best adapted haricot bean varieties in the study area.

Materials and Methods

The experiments were conducted in Dolo-ado and Fafen research stations in 2021 and 2022 respectively. Six recently released varieties were tested (Table 1). The experiment was conducted using Randomized Complete Block Design (RCBD) with three replications. The gross plot size was 6.4 m^2 having 4 rows while the 2 middle rows was used for data collection. The spacing used was 40 cm between rows and 10 cm plants respectively. Fertilizer and other agronomic practices were applied as per the recommendations to the specific locations.

Table 1. List of haricot bean varieties used for the experiment.

No	Variety name	Year	Source
1	Awash-2	2017	Melkassa ARC
2	Awash mitin	2017	Melkassa ARC
3	Tefach	2015	Melkassa ARC
4	SER119	2014	Melkassa ARC
5	SER 125	2014	Melkassa ARC
6	Ada (KAT B1)	2013	Melkassa ARC

Data collection and analysis

Data were collected on days to 50% emergence, days to 50% flowering, days to 50% maturity, plant height, number of pods per plant, number of seeds per pod, grain yield per plant, grain yield per plot, 1000 seed weight, disease resistance. The collected data was subjected to ANOVA model using GenStat 15. Least Significant Difference (LSD) test at 5% probability level was used for mean comparison when the ANOVA showed significant difference.

Results and discussion

Days to emergency: Days to emergence wasn't significantly influenced by varieties at both locations (Table 2). the highest number of days to emergence was recorded from Awash-mitin (6.000 days) and Ada (7.00 days) while the lowest was observed both from Seri125 (5.333 and 6.333 days) at Fafen and Dollo-ado station respectively (Table 2).

Days to flowering: The mean number of days to flowering in haricot bean wasn't significantly different among the varieties (Table 2). the highest number of days to flowering was recorded from Awash-2 (56.67 and 41.00 days) while the lowest was observed from Tefach (55.33 and 39.67 days) at Fafen and Dollo-ado station respectively (Table 2).

Days to maturity: Mean number of days to maturity was highly significantly influenced by varieties tested in both locations (Table 2). the longest days to mature was recorded from Seri119 (84.33 days) and Ada (70.00 days) while the lowest days to maturity was recorded in Awash-2 (75.00 days) and Seri119 (69.00 days) at Fafen and Dollo-ado station respectively (Table 2). The variation of days to flowering and maturity is due to variation of their inherent genetics and study areas. The difference in days to flowering and maturity among varieties might be attributed to genotypic variation as reported by Kwabena *et al*. (2016); Temesgen and Zewdu. (2021) and Rezene *et al*. (2013).

Plant Height (cm): The current study revealed plant height was highly significantly ($p < 0.01$) affected by varieties at Dollo-ado station and non-significant at Fafen station (Table 2). The highest plant height was in SERI199 (51.60 cm) and Awash-mitin (74.93 cm) while the lowest plant height was recorded from Awash-mitin (41.73 cm) and Tefach (49.73 cm) at Fafen and Dollo-ado station (Table 2). The difference in plant height among varieties is attributed to inherent genotypic variability and growing environment. This finding was in conformity with previous results reported by Welde, (2022), Mekonen *et al*. (2012); Wondwosen *et al*. (2018), who also reported significant differences in plant heights among haricot bean varieties.

Table 2: Mean values of growth and yield components of Haricot bean varieties tested at Fafen and Dollo-ado Agricultural Research Center on station in 2021 and 2022

		Fafen				**Dollo-ado**				
Varieties	DE	DsF	DM	PH	NPPP	DE	DsF	DM	PH	NPPP
Ada	6.333[a]	56[a]	80.33[a]	45.60[a]	22.67[a]	7.000[a]	40.33[a]	70.00[a]	50.53[c]	12.53[de]
AWASH-	6.000[a]	57.33[a]	75.33[a]	41.73[a]	18.33[b]	6.667[a]	41.00[a]	69.33[a]	74.93[a]	22.40[ab]
SER119	6.000[a]	57.67[a]	84.33[a]	51.60[a]	18.40[b]	6.667[a]	40.33[a]	69.00[a]	73.33[ab]	19.13[bc]
AWASH-2	5.667[a]	56.67[a]	75.00[a]	44.33[a]	18.60[b]	7.000[a]	41.00[a]	69.33[a]	69.80[ab]	15.33[cd]
Tefach	5.667[a]	55.33[a]	79.33[a]	49.70[a]	13.33[c]	6.667[a]	39.67[a]	69.67[a]	49.73[c]	10.13[e]
SER125	5.333[a]	56.33[a]	79.67[a]	45.40[a]	12.47[c]	6.333[a]	39.67[a]	69.33[a]	56.13[bc]	25.27[a]
Mean	5.83	56.56	79.0	46.4	17.30	6.72	40.33	69.44	62.4	17.47
CV%	11.7	2.7	5.5	14.0	6.4	7.0	2.0	1.0	15.4	13.9
LSD	1.243	2.772	7.94	11.82	2.028	0.858	1.485	1.228	17.54	4.428
Variable	**Mean square value**									
Replication	0.0000	0.056	118.50	3.14	0.320	0.2222	2.0000	2.0556	2.31	43.287
Varieties	0.3667ns	2.222ns	36.13ns	39.37ns	43.119**	0.1889ns	1.0667ns	0.3556ns	452.52**	102.373**
Error	0.1074	2.322	19.03	42.18	1.243	0.2222	0.6667	0.4556	68.29	5.924

Keys: *, **: significant at 5% and 1% respectively, CV=coefficient of variation, LSD= Least Significant Difference. Means followed by different letters within columns are significantly different by Duncan's new multiple range test (P = 0.05), DF=days to flowering, DM=days to maturity, PH (cm)=plant height, NPPP=number of pods per plant

Number of pods per plant: Mean number of pods per plant was highly significantly ($p < 0.01$) influenced by varieties tested at both locations (Table 2). The lowest number of pods per plant were recorded for variety Seri 125 (12.47) and Tefach (10.13), while the highest was recorded for variety Ada (22.67) and Awash-mitin (74.93) at Fafen and Dollo-ado station (Table 2). the variation in number of pods per plant among the varieties might be due to the difference in varieties. In line with these findings by Welde, (2022); Habtamu and Wakjira (2018) and Fahad *et al*. (2014) reported that significant variability was observed for number of pods per plant.

Number of seed per pod: Mean number of pods per plant was highly significantly ($p < 0.01$) influenced by varieties at Dollo-ado location and non-significant at Fafen (Table 3). The lowest number of pods per plant were recorded from Tafach (5.267 and 3.867), while the highest was recorded in Seri 118 (5.833) and Seri 125 (6.333) at Fafen and Dollo-ado location (Table 3). The difference in the number of seeds per pod mainly attributed difference in seed size among varieties and environment. In line with these findings by Degefa *et al*. (2021); Alemu and Getachew (2018); Habtamu and Wakjira (2018) and Fahad *et al*. (2014), reported that significant variability was observed for number of seed per pod.

Thousand seed weight (g)

Mean number of thousand seed weight was significantly ($P \leq 0.05$) influenced by varieties at Fafen and non-significant at Dollo-ado (Table 3). The highest thousand seed weights were recorded in Tafach (48.33 and 25.33g), while the lowest thousand seed weight was recorded from Awash-mitin (25.00 g) and Seri 125 (18.67 g) at Fafen and Dollo-ado station respectively (Table 3). The variation in hundred seed weight among the varieties might be due to the differences in seed size that exist among the varieties which was actually influenced by growth environment. A recent report by Welde (2022): Degefa *et al*. (2021); Alemu and Getachew (2018); Daniel *et al*. (2014) also revealed a very highly significant variation among haricot bean varieties for thousand seed weight.

Table 3. Yield and yield components of haricot bean as affected by varieties at Dollo-ado and Fafen agricultural research center on stations (2021-2022).

	Fafen				Dollo-ado			
Varieties	**NSPP**	**TSW**	**BY**	**GY**	**NSPP**	**TSW**	**BM**	**GY**
Ada	5.600[a]	43.00[ab]	5038[a]	1162[b]	4.533[b]	22.00[a]	32917[a]	972[d]
AWASH-MITIN	6.000[a]	25.00[c]	3438[b]	771[c]	3.933[b]	22.00[a]	38611[a]	716[e]
SER119	5.833[a]	36.00b[c]	3757[b]	1484[a]	5.000[b]	22.00[a]	34306[a]	1865[b]
AWASH-2	5.400[a]	28.33[c]	2347[c]	681[c]	4.533[b]	21.00[a]	33056[a]	1382[c]
Tefach	5.267[a]	48.33[a]	2417[c]	1071[a]	3.867[b]	25.33[a]	33194[a]	874[d]
SER125	5.667[a]	33.00[bc]	3847[b]	1153[b]	6.333[a]	18.67[a]	38194[a]	2142[a]
Mean	5.63	35.6	3474	1054	4.70	21.83	35046.3	1325.1
CV%	11.0	17.0	8.5	11.1	12.6	18.9	18.7	6.5
LSD	1.130	11.01	538.8	213.1	1.077	7.508	11921.92	156.95
Variable	**Mean square value**							
Replication	0.0406	14.00	274143	528	0.0350	6.50	325617	417
Variety	0.2192ns	681.33**	3032982**	141749**	2.4573**	13.83ns	3617284**	996724**
Error	0.3859	26.93	87713	11689	0.3503	17.03	330247	7442

Keys: *, **: significant at 5% and 1% respectively, CV=coefficient of variation, , LSD= Least Significant Difference. Means followed by different letters within columns are significantly different by Duncan's new multiple range test (P = 0.05)., NSPP=number of seed per pod, TSW=thousand seed weight, BM (kg/ha) =biomass, GY (kg/ha) = grain yield

Biomass yield (kg/ha): a significant (P≤0.05) variation was observed among varieties with respect to biomass yield of the haricot bean plants at Fafen and non-significant variation at Dollo-ado station (Table 3). The highest value was recorded from Ada (5038 kg/ha) and Awash-mitin (38611 kg/ha), while the lowest value was from Awash-2 (2347 kg/ha) and Ada (32917 kg/ha) at Fafen and Dollo-ado respectively (Table 3). Hence, this variation could be attributed to the heritable characteristics of the varieties when responding and adapting to growth conditions at Fafen and Dollo-ado, as well as other ecological conditions. This finding conforms to previous reports by A recent report by Welde, (2022): Wondimu and Tana (2017) who found significant differences among haricot bean varieties with respect to biological yield at harvest.

Grain Yield (kg/ha): The current study revealed grain yield was highly significantly (p< 0.01) affected by varieties at both locations (Table 3). The highest grain yield was recorded from Seri 119 (1484 kg/ha) and Seri 125 (2142 kg/ha) while the lowest grain yield was recorded from Awash-2 (680.6 kg/ha) and Awash-mitin (716 kg/ha) at Fafen and dollo-ado station respectively

(Table 3). The greatest yield of the varieties SERI125 and SERI119 could be due to their inherent genetic potential and growing environment. Differences in growth habit and morphology among the genotypes may have attributed to the report differences in yield performance. This finding was in agreement with the previous reports of Degefa *et al*. (2021); Welde (2022); Daniel *et al*. (2014); Alemu and Getachew (2018); Habtamu and Wakjira (2018) and Fahad *et al*. (2014).

Conclusion and recommendations

Production of haricot bean trough adaptation and selecting high yielding, improved varieties could provide an important contribution to change the livelihood of farmers in in areas like SRS where there is lack of practice of producing improved varieties of haricot bean. However, Evaluating the adaptability of improved varieties is the major and important activity where there is no technology delivered before. The genetic and environmental factors can cause a different level of variation of the tested characteristics of haricot bean. In order to boost productivity of haricot bean in the study area, it is better to consider the characters of the best variety having high yield advantage by resisting different biotic and abiotic stresses. Thus, this research work was initiated to identify high yielding common bean varieties those are adapted to the area and disseminate for further production. Therefore, performance of six nationally released varieties was evaluated at Fafen and Dollo-ado research centers during the 2021 and 2022 cropping season respectively. The result of this experiment indicated that Seri 125 and Seri 119 varieties were higher yielders at Dollo-ado and Fafen respectively. these varieties have also large number of pods per plant, longest plant height, high total biomass and grain yield as compared to other varieties. Accordingly, these two varieties are recommended for the study area and similar agro ecologies. Therefore, these varieties can be promoted in farmers' field for dissemination and scaling up.

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2.2. Evaluation of Soybean Varieties (Glycine Max L Meril), For Adaptation for Irrigated of Somali Regional State, Ethiopia.

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Abstract

Pulses and legumes in general are important staple crop for smallholders in Ethiopia. Achieving national food security and diversifying export earnings from agricultural products is one of the major challenges currently facing developing countries like Ethiopia. Pulse crops in general and soya bean in particular play great role in improving households' food security, increasing income for smallholder farmers. The process of plant growth and development is important to the successful adaptation of a species to its geographic and climatic environment. Evaluating the adaptability of released soybean varieties in diverse agro ecology is important for efficient use of nationally released varieties in their area of adaptation and thereby increases production and productivity of soybean in the country. The trial was conducted with 5 released soybean varieties in the year 2022 main cropping season at Dollo-ado and Jarati research station, Eastern parts of Ethiopia. The experimental design used was RCBD with three replications. The parameters collected include; days to emergency, days to flowering, days to maturity, plant height, number of pods per plant, number of seed per plant, hundred seed weight, biomass yield and grain yield. Combined analysis of variance (ANOVA) showed significant variability among varieties for some of the parameters studied such as days to flowering, thousand seed weight, biomass yield and grain yield. The varieties Pawe-02 and Pawe-03 were found to be high yielding varieties with mean grain yield levels of 2195 and 1890 kg/ha-1, with combined mean yield of 1972 and 1978 kg/ha respectively at Dollo-ado and Jarati research station. Therefore, these two varieties are recommended for production in the study area and similar environments.

Keywords: Soybeans, Varieties, Ecology, Adaptation and grain yield

Introduction

Soybean (Glycine max L Merr) is one of the world's most important cultivated crops grown for use as food and feed. It was known to be grown on over 120 million hectares around the world in 2017 (FAOSTAT, 2019). The world soybean production increased by 3.79% annually from 2000 to 2020 and reached an average annual production of 361 million tons in 2020. Soybean is a good source of protein for human and animal nutrition and as a biofuel feedstock (Delele, 2021). It consists of more than 36% proteins, 30% carbohydrates, and excellent amounts of dietary fiber, vitamins, and minerals (Chuwang *et al.*, 2018). The soybean grain accounts for 57% of the world's oilseed production, which makes it the most important crop for producing edible oil (USDA, 2001; SOYSTATS, 2011).

Soybean is the most important crop due to its good chemical composition. Soybean seed contains 36% protein, 19% oil, 35% carbohydrate, 5% minerals and several other components including vitamins (Dixit *et al*., 2011). It is an ideal crop for improved nutrition, food security, sustainable crop production and suitable in livestock irrigation systems (Mahasi *et al*., 2010). Increasing soybean production to meet the required quantities can best be achieved through an increase in yield per unit area, which can partly be achieved by the cultivation of high-yielding improved varieties. Consequently, the introduction and careful selection of newly improved soybean genotypes in increasing soybean production. This study aims to assess yield performance and adaptability of 5 newly developed soybean genotypes. However, the performance of the released varieties was not evaluated in the past in SRS, therefore the present study was conducted to test the performance of released soybean varieties at the study areas and recommend adoptable varieties for production.

Materials and Methods

The experiments were conducted in Dollo-ado and Jarati agricultural research stations during 2022 cropping season. Five recently released varieties were tested (Pawe-02, Pawe-02, Pawe-03, Gizo and Gazale). The experiment was conducted using Randomized Complete Block Design (RCBD) with three replications. The gross plot size was 3x1.6m having 4 rows while the 2 middle rows was used for data collection. The spacing used was 40cm between rows and 10cm plants respectively. Fertilizer and other agronomic practices were applied as per the recommendations to the specific locations.

Data collection and analysis

Data was collected on days to 50% emergence, days to 50% flowering, days to 50% maturity, plant height, number of pods per plant, number of seeds per pod, grain yield per plant, grain yield per plot, 1000 seed weight, disease resistance. The collected data was subjected to ANOVA model using GenStat 15.

GGE- biplot: GGE-bi-plot methodology, which is composed of two concepts: the bi-plot concept. (Gabriel, 1971) and the GGE concept (Yan *et al.*, 2000), was used to visually analyze the METs data. This methodology uses a biplot to: show the factors (G and GE) that are important in genotype evaluation and that are also the source of variation in GEI analysis of METs data (Yan ,2001).The GGE-biplot shows the first two principal components derived from subjecting environment centered yield data (yield variation due to GGE) to singular value decomposition (Yan *et al*., 2000).

Results and Discussion

The combined analysis of variance for all varieties at different environmental conditions for grain yield and yield related traits was presented in Table 1. The result revealed that varieties showed the presence of highly significant ($P \leq 0.01$) differences for days to flowering, biomass and seed yield; significant difference ($P \leq 0.05$) for days to thousand seed weight. The presence of significant differences among varieties indicates the presence of genetic variability for each of the characters among the tested varieties. While location had highly significant ($P \leq 0.01$) differences for all studied parameters; significant difference ($P \leq 0.05$) for number of seed per pod. The genotype by environment interaction exhibited highly significant ($P \leq 0.01$) differences for thousand seed weight, biomass and grain yield; significant difference ($P \leq 0.05$) for days to flowering and number of pods per plant.

Agronomic Performance for Soybean Yield Related Parameters

Days to 50% flowering: From the result of analysis of variance, the five tested soybean varieties affected days to flowering at ($P<0.05$) level of significant (Table 1). The maximum days to flowering was recorded for variety Pawe 03 with (57.17 days) and the minimum days to flowering was for Pawe 02 variety (56.00 days) and the grand mean being (56.40 days) (Table 2). This variation is due to the different genetic traits and location among the 5 soybean genotypes studied. In line with Asmamaw *et al*. (2017): Ibié *et al*. (2022); Baig *et al*. (2018) also claimed that significant variation on days to flowering among studied soybean varieties.

Table 1: combined Analysis of variance of major agronomic and yield components of soybean Varieties tested at SRS, Dollo-ado and Jarati research stations in 2021

Source of variation	*Mean square*									
	DF	DE	DsF	DM	PH	NPPP	NSPP	TSW	BM	GY
Rep	2	0.0333	0.4000	0.900	11.86	30.75	0.0280	2.0230	1141146	19032
Variety	4	0.1167^{ns}	1.2167**	4.133^{ns}	119.33^{ns}	62.29^{ns}	0.1033^{ns}	2.8392*	1962312**	698622**
Location	1	80.0333**	1228.8000**	36.300**	293.28**	15169.51**	0.5880*	315.5763**	39045021**	1240333**
V*L	4	0.1167^{ns}	1.212267*	1.800^{ns}	116.70^{ns}	162.68*	0.3047^{ns}	3.1538**	1526766*	129757**
Error	18	0.1074	0.3259	3.381	55.29	66.85	0.1391	0.6556	382072	22678
Total	29									

Keys: *, **: significant at 5% and 1% respectively, E=environment, V * E=variety verses environment, CV=coefficient of variation, DF=degree of freedom DsF=days to flowering, DM=days to maturity, PH=plant height, NPPP=number of pods per plant, NSPP=number of seed per pod, TSW=thousand seed weight, BM=biomass, GY= grain yield

Days to 90% Maturity: From the result of analysis of variance varieties exhibited non-significant difference on days to maturity (Table 1). The highest prolonged duration to reach days to maturity was (99.33 days) from Pawe 02 followed by Pawe 01 (97.83 days) which was significantly at par with 'Gizo' and the minimum duration of days to maturity (95.33 days) was observed in 'Gazale' which was significantly at par with Pawe 01 (Table 2).

Plant Height: The effect of varieties on plant height was non-significant (Table 1). the highest plant height was recorded from 'Gizo' (63.37cm) while the minimum plant height was (54.73cm) from Pawe 01 and the average mean being (59.8cm) (Table 2).

Number of pods per plant: from the result of analysis of variance varieties had no significant influence on number of pods per plant (Table 1). The highest number of pods per plant (62.53) was recorded in 'Gazale' and the minimum number of pods per plant is 54.57 in 'Pawe 02' and the mean being (59.1) (Table 2).

Table 2. Combined mean of agronomic traits of Soyabean varieties tested at SRS, Dollo-ado and Charati research station at (2022).

Variety	DE	DF	DM	PH	NPPP	NSPP	TSW	BM
Gazale	8.333[a]	56.33[b]	95.83[a]	63.33[a]	62.53[a]	2.333[a]	7.617[b]	5135[c]
Gizo	8.500[a]	56.17[b]	97.83a	63.37[a]	56.97[a]	2.633[a]	7.767[b]	6019[ab]
Pawe 01	8.333[a]	56.33[b]	97.17[a]	54.73[a]	60.47[a]	2.433[a]	9.083[a]	5619[bc]
Pawe 02	8.500[a]	56.00[b]	96.83[a]	55.10[a]	54.57[a]	2.467[a]	9.033[a]	5298[bc]
Pawe 03	8.167[a]	57.17[a]	97.83[a]	62.37[a]	60.77[a]	2.633[a]	8.250[ab]	6550[a]
Mean	8.367	56.40	97.10	59.8	59.1	2.500	8.35	5724
CV%	3.9	1.0	1.9	12.4	13.8	14.9	9.7	10.8
LSD	0.3975	0.692	2.231	9.02	9.92	0.4524	0.982	749.8

Keys: CV=Coefficient of Variation, LSD= Least Significant Difference. Means followed by different letters within columns are significantly different by Duncan's new multiple range test (P = 0.05). DF=days to flowering, DM=days to maturity, PH (cm)=plant height, NPPP=number of pods per plant, NSPP=number of seed per pod, TSW(g)=thousand seed weight, BM (kg/ha) =biomass

Number of seeds per pod: from the result of analysis of variance varieties had no significant influence on number of seeds per pods (Table 1). The mean separation indicated that, the maximum number of seed per pod (2.633) was observed in 'Pawe 03'; at par with 'Gizo' while the minimum was from 'Pawe 01' is (2.433) and the mean being (2.500) (Table 2).

Hundred seed weight (g): The analysis of variance revealed that varieties had highly significant ($P<0.001$) influence on thousand seed weight (Table 1). The highest thousand seed weight value recorded was from Pawe 01 (9.083 g); which is at par with Pawe 02 (9.033 g) followed by Pawe 03, while the minimum thousand seed weight was recorded for Pawe 02=10.04g and the average being (12.31g) (Table 2). The variation in hundred seed weight among the varieties might be due to the differences in seed size that exist among the varieties which was actually influenced by growth environment. These variations agreed with Zorome (2017): Yechalew *et al*., (2021); Asmamaw *et al*., (2017). Wedajo, 2015 also stated that, the difference of seed weight among soybean varieties of hundred seeds was because of crop potential of the yield, growth rate, higher nutrients translocation and hereditary superiority.

Biomass yield (kg/ha): The result from analysis of variance varieties showed that, there was highly significant difference (P<0.001) on soybean biomass yield (Table 1). This means, there were difference among the tested varieties across locations (Table 2). The highest biomass value recorded was from Pawe 03 (6550 kg/ha); while the minimum biomass recorded was for Gazale (5135 kg/ha) (Table 2). Hence, this variation could be attributed to the heritable characteristics of the varieties and growing conditions when responding and adapting to Dollo-ado and Jarati. This is in line with Guo-Liang *et al*. (2018).

Yield performance of Soyabean varieties Across Locations

Grain yield (kg/ha): The result from analysis of variance varieties, location and their interaction exhibited highly significant different (P<0.001) on grain yield (Table 1). At Dollo-ado and Jarati research stations, the highest grain yield value, (2195 and 1890 kg/ha), respectively, were recorded for variety Pawe-02 and Pawe-03; while the recorded minimum grain yield (1394 and 1373 kg/ha) were for Pawe-01 and Gizo. However, at Dollo-ado research station the grain yield of Pawe-02 performed similarly with varieties Pawe-03 (Table 03) (Table 3). Regarding the combined mean the highest grain yield was recorded from Pawe 03 (1978 kg/ha) which is significantly at par with Pawe 02 (1972 kg/ha) and the lowest grain yield was from Pawe 01 (1205 kg/ha). The greatest yield of the varieties Pawe 03 and Pawe 02 could be due to their Differences in growth habit and their inherent genetic potential among the varieties which may have resulted to the reported variation in yield performance. This is in line with Ibié *et al*. (2022): Yechalew *et al*. (2021); Asmamaw *et al*. (2017) who reported same variation.

Table 3. Means of grain yield (Kg/ha) of Five Soyabean varieties across location

	Locations		
Varieties	Dollo-ado	Jarati	Combined mean
Gazale	1949[a]	1067[d]	1508[b]
Gizo	1526[b]	1373[c]	1449[b]
Pawe 01	1394[b]	1017[d]	1205[c]
Pawe 02	2195[a]	1750[b]	1972[a]
Pawe 03	2066[a]	1890[a]	1978[a]
Mean	1826	1419	1622
CV	11.1	137.7	9.3
LSD	383.2	5.2	182.7

Keys: CV=Coefficient of Variation, LSD= Least Significant Difference. Means followed by different letters within columns are significantly different by Duncan's new multiple range test (P = 0.05).

Genotype and Genotype by Environment interaction (GGE) bi-plot analysis

In GGE bi-plot (Figure 1), IPCA 1 and IPCA 2 explained 94.25% and 5.73% of variation, respectively, of Soyabean variety by environment interaction and made a total of 99.98%. Environments and genotypes that fall in the central (concentric) circle are considered as ideal environments and stable genotypes, respectively (Yan, 2002). A genotype is more desirable if it is located closer to the ideal genotype. Thus, using the ideal genotype as the center, concentric circles were drawn to help visualize the distance between each genotype and the ideal genotype. Therefore, the ranking based on the genotype-focused scaling assumes that stability and mean yield are equally important (Ashna, 2014). Pawe-03 and Pawe-02, which fell into the center of concentric circles, were ideal varieties in terms of higher yielding ability and stability, compared with the rest of varieties. In addition, Pawe-03 and Pawe-02 located on the next concentric circle, may be regarded as desirable varieties while Pawe-01 and Gizo were far from the ideal genotypes considered as most unstable varieties with poor performance across locations (figure 1).

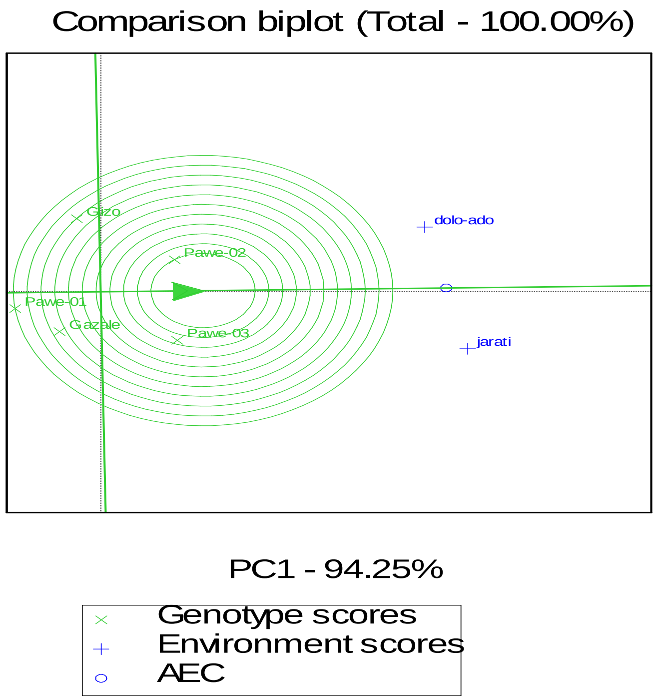

Figure-1. GGE-bi-plot showing the "ideal" genotype

Conclusion and Recommendations

Production of soybean trough adaptation study and selection of high yielding improved varieties could provide an important contribution to change the livelihood of farmers in areas like SRS where there is no practice of soybean production. However, Evaluating the adaptability of improved varieties is the major and important activity where there is no technology delivered before. In order to boost best materials and improving the productivity of soybean in the study area, it is better to consider the characters of the best variety having high yield advantage by resisting different biotic and abiotic stresses. Thus, this research work initiated to identify high yielding soybean varieties those are adapted to the area and disseminate for further production. Therefore, performance of five nationally released varieties was evaluated at Dollo-ado and Jarati research centers during the 2022 cropping season. According to this study, varieties Pawe 03 and Pawe 02 gave higher yield respectively over location. These varieties have performed best agronomic traits and yield performances recorded. According to these varieties are recommended for the study areas and similar agro ecologies. Therefore, these varieties can be promoted in farmers' field evaluation and demonstration.

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2.3. Multi-Locations adaptability study of Soybean (Glycine Max L. Merill) Varieties in Irrigated areas of Somali regional state, Ethiopia

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Abstract

*Soybean (Glycine max) is one of the most valuable crops in the world, due to its multiple uses as a source of livestock and aquaculture feed, protein and oil for the human diet. Field experiments were conducted at Godey and Kelafo research station to evaluate the adaptation of six soybean varieties for the last two years of (2021 and 2022) to this agro-ecological zone. The varieties were Pawe-01, Pawe--02, Pawe-03, Gizo, Gazale and Tefatch. The parameters collected and analyzed include Days to 50% emergency, Days to 50% Flowering, Days to 90% maturity, plant height, number of pods per plant, number of seed per pod, biomass yield (kg/ha) and grain yield (kg/ha). The statistical analysis performed on combined data showed that varieties and location had significant differences ($p < 0.05$ and $P \leq 0.001$) on all the studied parameters. year showed Highly significant for all studied parameters, except Days to 50% emergency and number of pods per plant. Genotype by environment interaction showed a significant difference except plant height and grain yield. Year*location showed a significant variation for all parameters, except Days to 50% Flowering and number of pods per plant. Year * location * genotype was highly significant only on Days to 50% emergency and maturity. significantly higher mean value of grain yield and stability was recorded from Pawe-03 (1539 kg/ha) and Pawe-02 (1372 kg/ha). According to these varieties are recommended for the study areas and similar agro ecologies. Therefore, these varieties can be promoted in farmers' field evaluation and demonstration.*

***Keywords**: Soya bean, varieties, adaptability, grain yield, GGE-biplot*

Introduction

Soybean (Glycine max (L.)) is emerging as important feed, food as well as raw material for producing high-quality protein and oil products in the world and in Africa including Ethiopia (Deresse, 2017). Its production in Ethiopia is very crucial to overcome malnutrition and it is cheap substitute for expensive animal protein (Zinaw *et al*., 2013). Due to the economic importance of the crop, soybean has been the focus of research, especially in the area of genetic improvement, to obtain improved cultivars, carrying genes capable of expressing broad adaptation and tolerance to biotic and abiotic factors, representing significant contributions to the productive sector (Soares *et al.*, 2015).

Even though, Soyabean is very important oil crop in our country, its distribution through the country was limited to a certain area. Also, many improved Soyabean varieties were released from research institutions but not well reached to the farmers. Adaptation study of the released varieties by different institution/ research centers/ is the good approach in selection the best variety/ies which solve the limitation of improved seed distribution. Therefore, the objective of this study was to identify the adaptability of improved soya bean varieties that gives best yield for the study area and similar agro ecologies.

Materials and Methods

Description of the study area: The experiment was conducted at Godey and Kelafo research stations during the cropping seasons 2021 and 2022.

Experimental materials and design: The five released haricot bean varieties were used (Table 1). The Randomized Complete Block Design with three replications was used. Experimental unit comprised four rows of 4 meters length with row-to-row distance of 40 cm and plant-to-plant distance of 10 cm. The gross plot size was 4mx1.6m having 4 rows while the 2 middle rows was used for data collection. Fertilizer and other agronomic practices were applied as per the recommendations to the specific locations.

Table 1. List of soybean varieties used in the experiment.

No	Variety name	Year	Source
1	Pawe-03	2016	Pawe ARC
2	Gazale	2015	Hw ARC
3	Pawe-01	2015	Pawe ARC
4	Pawe-02	2015	Pawe ARC
5	Gizo	2010	Pawe ARC

Data collection and analysis

Data collected on plant basis

Plant height: The length of the central axis of the stem was measured from the soil surface up to the tip of the stem.

Number of pods per plant: Were determined by counting total number of pods per plant.

Number of seeds per pod: The mean number of seeds per pod obtained by counting the number of seeds.

Data collected on plot basis

Days to 50% emergency: was recorded when 50% of the plant emerged in each plot**.**

Days to 50% Flowering: was recorded as the number of days from sowing to when 50% of plants in a net plot produced flower through visual observation.

Days to 90% maturity: This was recorded as the number of days from sowing to the time when about 90% of the plants in a plot had mature pods in their upper parts with pods in the lower parts of the plants turning yellow. The yellowness and drying of leaves were used as indication of physiological maturity.

Biomass yield (kg/ha): the biomass yield from each plot was measured at harvesting time and converted in to kg ha^{-1}.

Grain yield (kg/ha): It was determined by weighing total yield on the plot and converted to hectare.

Data collection and analysis

Data was collected on days to 50% emergence, days to 50% flowering, days to 50% maturity, plant height, number of pods per plant, number of seeds per pod, grain yield per plant, grain yield per plot, 1000 seed weight, disease resistance. The collected data was subjected to ANOVA model using GenStat 15.

GGE- biplot: GGE-bi-plot methodology, which is composed of two concepts: the bi-plot concept. (Gabriel, 1971) and the GGE concept (Yan *et al.*, 2000), was used to visually analyze the METs data. This methodology uses a biplot to: show the factors (G and GE) that are important in genotype evaluation and that are also the source of variation in GEI analysis of METs data (Yan ,2001).The GGE-biplot shows the first two principal components derived from subjecting environment centered yield data (yield variation due to GGE) to singular value decomposition (Yan *et al*., 2000).

Results and Discussion

Mean square of analysis of variance for varieties at different environmental conditions for grain yield and yield related traits are presented in (Table 2). Highly significant differences were detected among varieties ($P \leq 0.01$) for biomass; a significant difference ($P \leq 0.05$) for Days to 50% Flowering, Days to 90% maturity, number of pods per plant, number of seed per pod, thousand seed weight and grain yield Yechalew *et al*., (2020). location effect was highly significant for all parameters, except plant height. year effect was highly significant for all studied parameters, except Days to 50% emergency and number of pods per plant. Genotype by environment interaction was highly significant ($P \leq 0.01$) for Days to 50% Flowering, number of pods per plant, number of seed per pod and biomass; significant difference ($P \leq 0.05$) for Days to 50% emergency and maturity. Year * genotypes effect was highly significant for Days to 50% Flowering and maturity; significant difference ($P \leq 0.05$) for Days to 50% emergency Yechalew *et al*., (2020) (Table 2). The combined analysis of year and location effect was significant for all parameters, except Days to 50% Flowering and number of pods per plant. Year * location * genotype was highly significant only on Days to 50% emergency and maturity.

Table 2**.** Combined analysis of yield and yield component of Soyabean varieties at SRS, Godey and Kalafo research station tested for two years (2021-2022)

Source of variation	**DF**	**Mean square**							
		DE	DF	DM	PH	NPPP	NSPP	BM	GY
Rep	2	0.0667	2.400	3.467	167.05	69.58	1.1167	400446	98594
Variety	4	0.2750*	9.942*	12.150*	65.14^{ns}	217.43*	0.6990*	4520863**	412932*
Environment	1	46.8167**	7774.817**	498.817**	36.19^{ns}	6506.25**	14.9002**	324058560**	28412681**
Season	1	0.1500^{ns}	646.817**	3182.817**	2642.72**	125.57^{ns}	31.2482**	44962727**	13205869**
V*E	4	0.5250*	8.858**	12.900*	82.04^{ns}	355.17**	1.0143**	3181059**	42861^{ns}
V*Y	4	0.6083*	13.692**	56.567**	55.18^{ns}	101.72^{ns}	0.3823^{ns}	334965^{ns}	285261^{ns}
E*Y	1	0.0167^{ns}	558.150**	176.817**	4454.82**	127.90^{ns}	29.5402**	6710070**	17697728**
V*E*Y	4	0.2250^{ns}	7.942**	47.317**	64.27^{ns}	93.41^{ns}	0.3577^{ns}	904249^{ns}	107863^{ns}
Error	38	0.1193	1.856**	4.133	64.88	58.65	0.2423	533065	149804
Total	59								

Keys: *, **: significant at 5% and 1% respectively, S.V=source of variation, E=environment, L= year V * E=variety verses environment, V*L= variety verses year, E*Y= environment verses year, V*E*Y= variety verses environment and year, CV=coefficient of variation, DF=degree of freedom DsF=Days to 50% Flowering, DM=Days to 90% maturity, PH=plant height, NPPP=number of pods per plant, NSPP=number of seed per pod, TSW=thousand seed weight, BM=biomass, GY= yield

Table 3. Combined mean of agronomic traits of Soyabean varieties tested at Godey and Kalafo research station for two years (2021-2022)

Varieties	**DE**	**DF**	**DM**	**PH**	**NPPP**	**NSPP**	**BM**
Gazale	5.417^{a}	59.25^{ab}	90.83^{abc}	61.85^{a}	53.65^{abc}	3.158^{a}	8661^{ab}
Gizo	5.417^{a}	57.92^{c}	91.67^{a}	66.35^{a}	54.88^{ab}	3.158^{a}	8256^{bc}
Pawe-01	5.083^{b}	58.25^{bc}	89.33^{c}	67.30^{a}	58.67^{a}	3.108^{a}	7544^{d}
Pawe-02	5.167^{ab}	57.33^{c}	89.83^{bc}	67.63^{a}	47.37^{c}	2.608^{b}	7825^{cd}
Pawe-03	5.333^{ab}	59.50^{a}	91.42^{ab}	65.28^{a}	50.83^{bc}	3.158^{a}	9062^{a}
Mean	5.283	58.45	90.62	65.7	53.08	3.038	8270
CV%	6.5	2.3	2.2	12.3	14.4	16.2	8.8
LSD	0.2855	1.126	1.680	6.66	6.329	0.4068	603.4

Keys: CV=Coefficient of Variation, LSD= Least Significant Difference. Means followed by different letters within columns are significantly different by Duncan's new multiple range test (P = 0.05). DE= Days to5 0% emergency, DF=Days to 50% Flowering, DM=Days to 90% maturity, PH (cm)=plant height, NPPP=number of pods per plant, NSPP=number of seed per pod, TSW (g)=thousand seed weight, BM (kg/ha) =biomass

Mean performance of the varieties for the characters

Combined mean of agronomic traits is presented in Table 2. The result from analysis of variance revealed that varieties had a significant difference ($P \leq 0.05$) on Days to 50% emergency, Days to 50% Flowering, Days to 90% maturity, number of pods per plant, number of seed per pod; highly significant difference ($P \leq 0.01$) for biomass yield and non-significant difference on plant height (Table 2). Highest mean of Days to 50% emergency was recorded from Gizo (5.417 days); which was at par with Gazale (5.417 days) variety, while the lowest was observed from Pawe-01 (5.083 days). maximum number of Days to 50% Flowering was observed in Pawe-03 (59.50 days) and the lowest was from Gizo (57.92 days): which was at par with Pawe-02 (57.33 days). Gizo variety was late to mature (91.67 days) while Pawe-01 was early (89.33 days) to mature Habte (2018) and Obidiebube *et al*. (2013) and Ibié *et al*., (2022). the highest number of pods per plant was obtained from Pawe-01 (58.67) while the lowest was obtained from Pawe-02 (47.37) Habte (2018); Obidiebube *et al*. (2013) and Guo-Liang *et al*. (2018). Similarly, differences in Days to 90% maturity in different genotypes were reported Yechalew *et al*. (2021); (Adiyata *et al*. 2011) and Yechalew *et al*. (2020). Similarly, Yechalew *et al*. (2020) reported significant number of pods per plant was observed on the varieties ranging from 70.0 to 35. Pawe-01 was recorded the highest number of seed per pod (3.158); which was at par with Pawe-03, Gizo and Gazale variety, while the lowest number of seed per pod was recorded from Pawe-02 (2.608) Wakil *et al*. (2018); Obidiebube *et al*. (2013). It was also reported a variation of number of seed per pod ranging from 129.1 to 72.6 by Yechalew *et al*. (2020). The highest mean value of biomass yield was recorded from Pawe-02 (9062 kg/ha) and the lowest was recorded from Pawe-01 (7544 kg/ha) Guo-Liang *et al*. (2018).

Combined mean grain yield across location and year

Table 4. Means of grain yield (Kg/ha) of 5 Soyabean varieties across location and years

	Godey		Qalafo		
Varieties	2021	2022	2021	2022	Combined mean
Gazale	750^{c}	895.8^{ab}	830^{c}	1071^{d}	887^{d}
Gizo	792^{c}	885.4^{ab}	1275^{b}	833^{e}	946^{d}
Pawe-01	1031^{b}	958.3^{ab}	1408^{ab}	1354^{c}	1188^{c}
Pawe-02	1167^{b}	1010.4^{a}	1472^{ab}	1838^{b}	1372^{b}
Pawe-03	1562^{a}	812.5^{b}	1767^{a}	2012^{a}	1539^{a}
Mean	1060	912	1350	1422	1186
CV	8.6	8.9	17.2	5.9	13.5
LSD	172.5	152.1	438.5	158.3	132.7

Keys: CV=Coefficient of Variation, LSD= Least Significant Difference. Means followed by different letters within columns are significantly different by Duncan's new multiple range test (P = 0.05).

Combined mean grain yield is presented in Table 4. The result from analysis of variance revealed that varieties had a significant difference ($P \leq 0.05$) on grain yield. significantly higher mean value of grain yield (GY) at Godey station was recorded from Pawe-03 (1562 kg/ha) and Pawe-02 (1010.4 kg/ha) in 2021 and 2022 respectively (Table 4). While at Kelafo station highest grain yield was observed in Pawe-03 (1767and 2012 kg/ha) in 2021 and 2022 respectively. On the contrary, Gazale and Gizo had significantly lower (1 mean value of grain yield across location and year as presented (Table 3). The variations in varieties and climatic factors in both locations have been partly responsible for the difference in yield of soybeans. Habte (2018); Obidiebube *et al*. (2013) and Guo-Liang *et al*. (2018) also reported the same results.

Evaluation of genotypes relative to an ideal genotype

An ideal genotype is defined as genotype with the greatest PC1 score (mean performance) and with zero GEI, as represented by an arrow pointing to it (Figure 1). An ideal genotype, which is located at the center of the concentric circles in Figure 3, is the one that has both high mean yield and high stability. An ideal genotype should have the highest mean performance and be absolutely stable (Yan and Kang, 2003). Thus, using the ideal genotype as the center, concentric circles were drawn to help visualize the distance between each genotype and the ideal genotype. Therefore, the ranking based on the genotype-focused scaling assumes that stability and mean yield are equally important. In this study, G5 which fell closest to the ideal genotype was identified as the most desirable genotype as compared to the rest of the tested common bean genotypes (Figure 1).

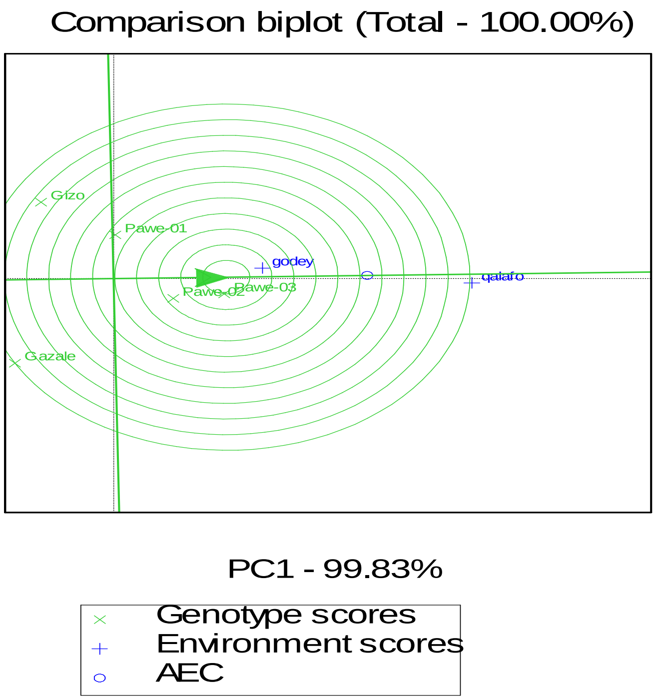

Figure 1. GGE biplot based on genotype -focused scaling for comparison the genotype with the ideal genotype.

Conclusion and Recommendations

Production of soybean trough adaptation study and selection of high yielding improved varieties could provide an important contribution to change the livelihood of farmers in areas like SRS where there is no practice of soybean production. However, Evaluating the adaptability of improved varieties is the major and important activity where there is no technology delivered before. In order to boost best materials and improving the productivity of soybean in the study area, it is better to consider the characters of the best variety having high yield advantage by resisting different biotic and abiotic stresses. Thus, this research work initiated to identify high yielding soybean varieties those are adapted to the area and disseminate for further production.

Therefore, performance of five nationally released varieties was evaluated at Godey and Qalafo research centers during the 2021-2022 cropping season. According to this study, varieties Pawe-03 and Pawe-02 gave higher yield respectively over location. These varieties have performed best agronomic traits and yield performances recorded. The difference in genetic and environmental factors resulted a different level of variation of the tested characteristics of soybean. According to these varieties are recommended for the study areas and similar agro ecologies. Therefore, these varieties can be promoted in farmers' field evaluation and demonstration.

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2.4. Haricot Bean (Phaseolus vulgaris L) Adaptability and Performance Evaluation at Shabelle zone of Somali regional state, Eastern Ethiopia

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Abstract

*Haricot bean (Phaseolus vulgaris L.) is one of the most important food legumes of Ethiopia and it is considered as the main cash crop and the least expensive source of protein for the farmers in many lowlands and mid altitude of the country. Low production and productivity, which is mainly associated with lack of access to improved varieties, was one of the major problems in haricot bean production. A field experiment was conducted at Godey and Kalafo research stations in Shabelle zone of Somali Regional State during 2021 and 2022 cropping season with the objective of to select and recommend the best adapted haricot bean varieties in the study areas. Six haricot beans (Phaseolus vulgaris L.) varieties were evaluated. The trial was laid out in the randomized complete block design with three replications. Combined analysis of variance (ANOVA) showed significant variability among varieties, locations and year for all the parameters studied. The genotype*environment interaction showed significant differences among treatments like number of pods per plant, number of seed pods per plant, biomass yield and grain yield. Variety*year showed the presence of significant differences for all the studied traits. Location*year*varieties showed highly significant differences only on Number of pods per plant and grain yield. The varieties Seri119 and Seri125 were found to be high yielding varieties with mean grain yield levels of 1960 and 1821 kg/ha-1, respectively. Therefore, these two varieties are recommended for production in the study area and similar environments.*

***Keywords**: Haricot bean, grain yield, Variety, Evaluation*

Introduction

Haricot bean (Phaseolus vulgaris L.) is one of the most important pulse crops grown in Ethiopia in terms of both area and quantity produced. It is one of the major grain legumes widely cultivated and grown as source of protein and cash by smallholder farmers by the smallholder farmers in the Southern Ethiopia (Fekadu, 2013). Haricot bean is considered as the main cash crop and protein source of many lowlands and mid-altitude zones of Ethiopia. (Alemnezh *et al*., 2017; Abebe, 2009; Ferris and Kaganz, 2008). According to, Miklas *et al*, (2006) this crop has a high nutritional value with important protein contents (22%), minerals (Calcium, Copper, Iron, Magnesium, Manganese and Zinc), and vitamins necessary to warrant the food security of people in the developing countries. Haricot bean is an important income source; its straw serves as feed for livestock, and also improves soil fertility by its virtue of nitrogen fixation in the cropping system (Fekadu, 2013).

Although the area has got potential for the production of haricot bean, the crop hasn't been widely grown. Even if its production is concentrated at low land areas; but the extent of production of haricot bean in the target area especially in Godey and Kelafo is limited. low adoption and access to improved common bean varieties to specific growing conditions are the serious problems on the expansion of production and productivity of the crop (Amanuel and Girma, 2018). The lack of improved varieties is one of the top problems for low yield of common bean (Fekadu, 2007). Therefore, there is need to introduce the improved haricot bean varieties released in Ethiopia to the target area in order to improve the productivity of the crop in the study area. Therefore, the study was initiated with the objective of selecting the best performing haricot bean varieties in the study area in terms of seed yield and related attributes

Materials and Methods

The experiments were conducted in Godey and Kelafo, research stations in two years 2021 and 2022**.** The experiment was laid in a Randomized Complete Block Design (RCBD) with three replications. Six improved haricot bean varieties named: Awash-2, Tefach, Awash-mitin, Dimtu, Ada, Seri119 and Seri125 were used in the study. The varieties were obtained from Melkassa Agricultural Research Center. The plot size was 2 x 2.4 m (six rows on plots) with harvestable plot size of 1.6 x 2 m and a spacing of 0.40 m between rows and 0.10 m between plants was maintained. The spacing between replications, and plots within each block was 1.5 and 0.5 m, respectively. NPS fertilizer at the rate of 100 kg/ha was applied at the time of sowing. All agronomic managements were applied as per the recommendations made for eastern Ethiopia Haricot bean production.

Data collection

Traits such as days to flowering and days to maturity were recorded. Days to flowering was recorded by counting the number of days after emergence when 50% of the plants per plot had the first open flower. Days to maturity was recorded when 95% of pods matured per plot. Plant based data were collected from five randomly selected plants from four central rows, the first row and sixth rows excluded as border effect, to determine plant height and yield components like pods per plant and seed per pod. 100 seed weight was determined by taking a random sample of 100 seeds from the harvested yield of a plot. Four central rows were harvested for determination of grain yield and adjusted to 12% moisture content.

Data analysis

Collected data were subjected to the analysis of variance (ANOVA) using the statistical Software program of GenStat (15). Mean separation was carried out to determine significant differences among varieties using Fisher's Least Significant Difference (LSD) test at 5% probability level and Coefficient of Variance (C.V) was calculated to reveal the relative measure of variation that exists within data. Data from both locations were combined after testing for ANOVA assumptions such as, normality and homogeneity.

GGE- biplot: GGE-bi-plot methodology, which is composed of two concepts: the bi-plot concept. (Gabriel, 1971) and the GGE concept (Yan *et al.*, 2000), was used to visually analyze the METs data. This methodology uses a biplot to: show the factors (G and GE) that are important in genotype evaluation and that are also the source of variation in GEI analysis of METs data (Yan ,2001).The GGE-biplot shows the first two principal components derived from subjecting environment centered yield data (yield variation due to GGE) to singular value decomposition (Yan *et al*., 2000).

Results and discussions

Analysis of variance (ANOVA)

Combined analysis of variance showed highly significant (P≤0.01) differences for all the studied trait due to variety and location effect (Table 1). This indicates the presence of genetic variability for each of the characters among the tested varieties. Year also had highly significant (P≤0.01) differences on days to maturity, plant height and thousand seed weight; significant difference (P≤0.05) on number of seed per pod. The genotype*environment interaction showed highly significant (P≤0.01) differences on number of pods per plant, number of seed pods per plant, biomass yield and grain yield (Table 1). This indicates that the location has different impact on the yield potential of the genotypes while the varieties have different performance in the tested environments. Variety*year showed the presence of highly significant ($P \leq 0.01$) differences for the studied traits except thousand seed weight and biomass yield in which significant difference ($P \leq 0.05$) was observed (Table 1). Location*year*varieties showed highly significant ($P \leq 0.01$) differences on Number of pods per plant and grain yield but non-significant for other studied parameters Urgaya and Temesgen (2022). This implies that, varieties performance for these traits is not variety actual potential but it is cumulative effect of location, year and variety.

Table 1. Combined Mean Square values from ANOVA for Haricot bean Parameters at Godey and Qalafo research centers for two years (2021-2022)

Source of variation	**DF**	**Mean square**						
		DM	PH	NPPP	NSPP	TSW	BM	GY
Rep	2	4.04	16.19	1.488	0.1751	28.67	514399	140120
Variety	5	126.57**	324.97**	12.817**	1.4209**	61.83**	1673982**	2461817**
Environment	1	1012.50**	2291.65**	658.845**	6.7222**	28600.35**	7534746**	7423821**
Year	1	840.50**	4990.00**	1.681ns	1.0756*	139656.12**	190996ns	4441649**
V*E	5	9.63^{ns}	49.00^{ns}	8.175**	1.3149**	10.98^{ns}	3250950**	403022**
V*Y	5	123.97**	451.24**	29.940**	1.6882**	38.49*	1494006*	353768**
E*Y	1	1404.50**	1008.00**	7.347*	0.6422*	37128.12**	40533ns	4546578**
V*E*Y	5	14.23^{ns}	65.47^{ns}	17.181**	0.1036^{ns}	20.89^{ns}	410672^{ns}	118622*
Error	46	17.04	30.39	2.009	0.2196	11.22	474417	50280
Total	71							

Keys*: *, **: significant at 5% and 1% respectively, E=environment, L= year V * E=variety verses environment, V*L= variety verses year, E*Y= environment verses year, V*E*Y= variety verses environment and year, CV=coefficient of variation, DF=degree of freedom DsF=days to flowering, DM=days to maturity, PH=plant height, NPPP=number of pods per plant, NSPP=number of seed per pod, TSW=thousand seed weight, BM=biomass, GY= yield.*

Combined Mean Performance of the Varieties for the Characters

Days to maturity: A highly significance ($P \leq 0.01$) were exhibited among varieties for days to maturity (Table 1). Variety Seri125 was early (71.25 days) to mature while variety Seri119 was late (78.58 days) to mature compared to other varieties (Table 2). This finding is in agreement with Urgaya and Temesgen (2022) and Gebre-Egziabher *et al*., (2014); Dembele and Ashenafi (2018) and Wondimu et al, (2018). It was also reported that days to maturity varied considerably among bean varieties from 41.16 to 46.16 days (Beshir *et al*., 2021)

Plant height (cm): Haricot bean varieties were exhibited highly significantly ($P \leq 0.01$) variation for plant height (Table 1). Higher plant height (47.12 cm) was recorded from Awash-2 followed by Seri125 variety followed by N-26 (45.89cm) and Seri119 (45.41cm) (Table 2). significant differences are also reported for plant height Urgaya and Temesgen (2022) and Beshir *et al*. (2021).

Number of pods per plant: The haricot bean varieties tested had a s highly significantly ($P \leq 0.01$) variation among each other for number of pods per plant (Table 1). Seri119 had higher number of pods per plant (13.25) followed by Ada (13.13) and Seri125 (12.94) variety and lower number of pods per plant was recorded from Awash-mitin (10.78) (Table 2). Urgaya and Temesgen (2022. Beshir *et al*. (2021); Dembele and Ashenafi (2018) and Wondimu *et al*., (2018) reported similar finding. Similarly, it was observed a range of variation in number of pods per plant from 5.33 to 22.67 by Simon *et al*., (2020)

Number of seeds per pods: Haricot bean varieties showed highly significance ($P \leq 0.01$) variation on number of seed per pods (Table 1). Higher number of seed per pods (69.42) was recorded from Seri119, were statistically at par with Seri125 (69.42) while the lowest was recorded for Ada (63.58) (Table 2). It was also reported difference of number of seed per pods among haricot bean varieties Beshir *et al*. (2021); Dembele and Ashenafi (2018) and Wondimu *et al*., (2018). Similarly, it was observed variation of number of seed per pods from 3.00 to 5.72 by Simon *et al*., (2020).

Table 2. Combined mean of growth and yield parameters of Haricot bean varieties over locations and years

Varieties	DM	PH	NPPP	NSPP	TSW	BM
Ada	71.42^{b}	34.23^{c}	13.13^{a}	5.675^{a}	63.58^{b}	6510^{ab}
Awash-2	76.42^{a}	47.12^{a}	12.29^{ab}	5.592^{a}	67.83^{a}	6267^{abc}
Awash-Mitin	71.00^{b}	39.57^{b}	10.78^{c}	5.042^{b}	68.67^{a}	6788^{a}
SER119,	78.58^{a}	45.41^{a}	13.25^{a}	5.067^{b}	69.42^{a}	5969^{bc}
SER125,	71.25^{b}	45.89^{a}	12.94^{a}	5.508^{a}	69.42^{a}	6323^{abc}
Tafach,	71.83^{b}	37.90^{bc}	11.28^{bc}	4.850^{b}	69.33^{a}	5743^{c}
Mean	**73.42**	**41.69**	**12.28**	**5.289**	**68.04**	**6267**
CV%	**5.6**	**13.2**	**11.5**	**8.9**	**4.9**	**11.0**
LSD	**3.392**	**4.530**	**1.165**	**0.3851**	**2.752**	**566.0**

Keys: CV=Coefficient of Variation, LSD= Least Significant Difference. Means followed by different letters within columns are significantly different by Duncan's new multiple range test (P = 0.05), DF=days to flowering, DM=days to maturity, PH=plant height, NPPP=number of pods per plant, NSPP=number of seed per pod, TSW=thousand seed weight, BM (kg/ha) =biomass, GY (kg/ha) = grain yield

Biomass yield (kg/ha): The highly significance (P≤0.01) variation was observed among haricot bean varieties in their response to number of biomass yield. Awash-mitin variety had the highest biomass yield (6788 kg/ha) while the lowest was recorded from Tafach (5743 kg/ha) variety (Table 2). Tadesse *et al*. (2014) also reported significance difference among 11 common bean varieties in total biomass using over two years data. Also as reported by Simon *et al*., (2020) biomass yield ranged from 17670 kg/ha to 4333 kg/ha in their findings.

Yield performance across location and year

Grain yield (kg/ha): Grain yield is the result of dry matter production and its transformation in to economic value that takes place in the plant system. There was a significant difference (P≤0.01) on grain yield with the varietal effect on tested haricot-bean varieties across location and year (Table 1). Seri119 variety had higher grain yield (2127.4 kg/ha) in year 2021 and Seri125 (1775 kg/ha) in year 2022 at Godey station while in Qalafo station variety Seri199 (2544 and 2389 kg/ha) and Seri125 (2469 and 2222 kg/ha) in year 2021 and 2022 respectively in which both varieties performed best across year in which they were significantly at par with each other. While Tefach variety had lower grain yield across location and year as compared with other varieties (Table 3). This is in harmony with Takele *et al*, (2021) who reported maximum grain yield (1776.4 kg/ha) from Seri119 haricot bean variety followed by Seri125 (1504.00 kg/ha). Likewise, Beshir *et al*. (2021); Urgaya and Temesgen (2022; Motuma *et al*., (2022); Dembele and Ashenafi (2018) and Wondimu *et al*. (2018) reported a great variation of grain yield among studied haricot bean varieties.

Table 3. Means of grain yield (Kg/ha) of 6 Haricot-bean varieties across location and years

	Godey		**Qalafo**		
Varieties	2021	2022	2021	2022	Combined mean
Ada	1583^{c}	539.6^{b}	951^{c}	1294^{bd}	1092^{c}
Awash-2	2078^{ab}	550.7^{b}	1925^{b}	1736^{b}	1572^{b}
Awash-Mitin	1003^{d}	775.7^{a}	1411^{c}	1736^{bc}	1231^{c}
SER119,	2217^{a}	691.7^{ab}	2544^{a}	2389^{a}	1960^{a}
SER125,	1767^{bc}	824.3^{a}	2469^{a}	2222^{a}	1821^{a}
Tafach,	883^{d}	152.1^{c}	1067^{c}	1025^{d}	782^{d}
Mean	1588	589	1728.	1734	1410
CV	14.5	17.5	16.2	13.9	184.3
LSD	420.1	187.5	508.7	438.5	15.9

Keys: CV=Coefficient of Variation, LSD= Least Significant Difference. Means followed by different letters within columns are significantly different by Duncan's new multiple range test (P = 0.05).

Comparison plot for genotypes based on the concentric circle

The estimation of yield and stability of genotypes were done by using the Average Coordinates of the Environment (AEC) methods (Yan, 2001; Yan and Hunt, 2001). The average environment is defined by the average values of PC1 and 2 for the all environments, and it is presented with a circle. The Average Ordinate Environment (AOE) defines by the line which is perpendicular to the AEA (average environment axis) line and pass through the origin. This line divides the genotypes in to those with higher yield than average and in to those lower yield than average. By projecting the genotypes on AEA axis, the genotypes are ranked by yield; where the yield increases in the direction of arrow. In this case the highest yield had genotypes Seri119 and Seri125, but the lowers had Ada and Tefach (Fig1). Stability of the genotypes depends on their distance from the AE abscissa. Genotypes closer to or around the center of concentric circle indicated these genotypes are more stable than others. Therefore, the greatest stability in the high yielding group had genotypes Seri119 and Seri125 whereas the most stable and yielder of all was Seri119 (Fig1)

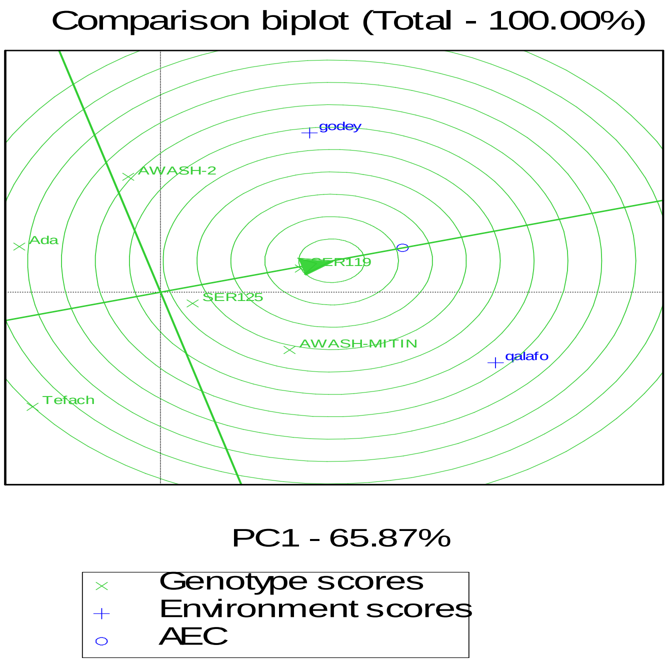

Figure 1; GGE bi-plot based on genotype-focused scaling for comparison of genotypes for their yield potential and stability of haricot bean varieties.

Conclusion and Recommendations

The genetic and environmental factors can cause a different level of variation of the tested characteristics of haricot bean. Testing of improved haricot bean varieties at different environment is Crucial for evaluating the performance and suitability of the varieties to be grown across agro-ecologies. Production of Haricot bean trough adaptation and selecting high yielding, improved varieties could provide an important contribution to change the livelihood of farmers in areas like SRS where there is low practice of producing improved varieties of common bean. The combined analysis of variance showed that there was significant variation at ($P \leq 0.05$ and $P \leq 0.01$) in all studied parameters as influenced by varieties, locations, and year main effect. There was also significant interaction effect of location by year, varieties by year and location by varieties by year on grain yield and other yield components. Seri119 variety had higher grain yield (1960 kg/ha): at par with Seri125 (1821 kg/ha) While Tefach variety had lower grain yield (782 kg/ha) as compared with other varieties. The varieties with constant high-yielding characteristics are considered stable and better varieties which are appropriate for the improvement of crop productivity. Therefore, Seri119 and Seri125 were recommended for the study area and similar agro-ecologies. Hence if the above-mentioned varieties are demonstrated and popularized to the small-scale holder farmers, they can boost the income of poor farmers.

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2.5. Performance Evaluation of three Improved Mung Bean (*Vigna radiata L.*) Varieties for growth and yield in Somali Region, Eastern Ethiopia

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Abstract

Mungbean (Vigna radiata (L.) Wilczek) is an important source of nutrients and income for smallholder farmers in dry-land areas of the country and in the study area. However, the productivity of the crop is constrained by biotic and abiotic factors, mainly lack of adaptable varieties, and peer agronomic practices. The experiment was conducted at Godey, Kalafo, Dollo-ado and Jarati of Somali regional state on station during the main cropping season under irrigation with the objective to investigate and select the best adapted mung bean variety for the study area. The experiment consisted of three mung bean varieties arranged in Randomized Complete Block Design (RCBD) with three replications. The genotype and environment main effects and genotype x environment interaction effect were significant on mung bean varieties. AMMI model shows varieties accounted 103.75%, GXE 17.42%, environment 6.12% of the total variation. The high percentage of varieties is an indication that the major factor that influence yield performance of soybean in the study area is the varieties. The first two IPCAs are the most accurate model that could be predicted the stability of the genotype and each explained 23.92% and 4.43% respectively of the total variation in GEI. According to the Combined mean yield and stability analysis revealed that NVL-1 variety is the most stable varieties and high yielding across test location. Therefore, NVL-1 was recommended for production in the study area and similar agro-ecologies.

***Key words**: haricot bean, Genotype by Environment Interaction, grain yield, AMMI, GGE-Biplot*

Introduction

Mung bean (*Vignaradiata*L.), which is introduced recently, is an annual herb of the legume family. It has green skin and is also called green bean (MoA, 2011). It is sweet in flavor and cold in nature (EPP, 2004). This crop is a rich source of protein which ranges from 19 to 29% and amino acid especially lysine which is the major limiting amino acid in cereal proteins for humans and mono gastric animals (Jood and Singh, 2001). This is particularly true for populations in the study area with their reliance on cereal-based diets. In addition, it is low in saturated fat and sodium, and very low in cholesterol. It is also a good source of thiamin, niacin, vitamin B6, pantothenic acid, Iron, magnesium, phosphorus and potassium, and a very good source of dietary fiber, vitamin C, vitamin K, riboflavin, folate, copper and manganese (Khalil and khan, 1994; Mohan and Janardhanan, 1993).

The crop matures early; special features include high yield, good nutritive value, the earliness, drought resistant features and the reasonable cost of production. It is a warm season annual grain legume and the optimum temperature range for good production is 27 to 30°C and requiring 90 to120 days of frost-free conditions from planting to maturity depending on the variety (Itefa, 2016). It uses as a source of proteins, micronutrient, income and as emergency crop in times of crop failures; as well as supplementary animal feed for fattening livestock (Mogotsi, 2006). Mung bean improves soil fertility through biological nitrogen fixation and is, therefore, used in crop rotations, mixed cropping and alley cropping systems (Heuzé*et al*., 2015).

Mung bean is the sixth product that Ethiopian Commodity Exchange trading next to coffee, sesame, white pea beans, maize and wheat. It mostly produced in Amhara regional state particularly in some areas of North Shewa and South Wollo as well as in some woreda's of Benishangul Gumuz regional state. Its demand in the international market is increasing from time

to time and there is a need supply to address the demand. Also, in Ethiopia's mung bean export has grown slightly from time-to-time Ethiopian commodity exchange (ECX, 2014). But supply is limited in Ethiopia since the production of mungbean is very low due to different factor. Availability and distribution of the varieties is one of factor which affects production of mungbean in Ethiopia particularly in East Shewa Zone. The study area is potential for lowland pulses like mung bean. But the improved varieties are not yet introduced to farmers in the study area. Therefore, this activity was carried out to identify and select the best adapted mung bean variety for the study area

Materials and Methods

The experiments were conducted in Gode, Kelafo, Dolo-ado and Chereti research stations. Three recently released varieties were tested (Arkebe (SML668), NVL-1 and N-26). The experiment was laid out in Randomized Complete Block Design. Each entry was planted in a plot having 4 rows of 3-meter length. Four rows were harvested and two border rows were left to exclude border effect. The row and plant spacing was kept at 40 cm and 10 cm, respectively. Plot size was 1.6 m x 3 m=4.8 m^2 having 1m and 1.5m between plot and block, respectively. 100kg NPS/ha fertilizer was calculated to plot and applied at the time of planting. All other agronomic managements were applied uniformly in all experimental plots as per national recommendation for the crop.

Data collection

The following data were collected during the experiment time both from the whole plot, net plot and sampled plants by random selection method from the middle of four rows of each plot.

Data recorded on plant basis

Plant height at harvest (cm): Height of five randomly taken plants during harvest period from each experimental plot was measured in centimeter from the ground level to top of the plants and the average height was recorded. Number of pods per plant: this was recorded as average total number of pods of five randomly selected plants from each experimental plot at harvest. Number of seeds per pod: The mean number of seeds per pod was obtained by counting the number of seeds collected from five pods from each five selected plants.

Data collection on plot basis

Days to 50% emergency: was recorded when 50% of the plant emerged in each plot**.** Days to Flowering: The numbers of days from the date of emergence to the date on which about 50% of the plants in each plot produce flowers. Days to maturity: The number of days from planting to the date when 90% of the morphological observation of the plant turned to yellow straw color. 1000-seed weight: It was recorded by counting 1000 seeds taken from the grain yield collected from the net plot and weighed using a sensitive balance. Biomass yield (kg/ha): the biomass yield from each plot was measured at harvesting time and converted in to kg ha^{-1}. Grain yield (kg/ha): Grain yield obtained from each plot was used to estimate grain yield (kilogram) per hectare.

Statistical analysis

Homogeneity of error variance was tested prior to combined analysis using Bartlett's test (Steel and Torrie, 1980) and statistical analyses was performed using GenStat statistical program version 18th edition. Means were separated using Fisher's Least Significant Difference (LSD) test at 5% level of probability as stated in Gomez and Gomez (1984).

The AMMI model: AMMI analysis was used for analyzing GEI to identify patterns of interaction and reduce background noise. It combines conventional ANOVA with principal component analysis. Besides, it provides more reliable estimates of genotype performance than the mean across sites as well as to identify target breeding environments and to choose representative testing sites in those environments. This model will also help to select varieties with good adaptation in targeted breeding environments (Angela et al 2016). The model used for this analysis is indicated below:

$$Y_{ij} = \mu + g_i + e_j + \sum_{1}^{N} \lambda_k \Upsilon_{ik} \delta_{jk} + \varepsilon_{ij}$$

Where Yij is the grain yield of the i-th genotype in the j-th environment, μ is the grand mean, gi and ej are the genotype and environment deviation from the grand mean, respectively, ʎk is the eigenvalue of the principal component analysis (PCA) axis k, Ɣik and δjk are the genotype and environment principal component scores for axis k, N is the number of principal components retained in the model, and Ɛij is the residual term.

GGE- biplot: GGE-bi-plot methodology, which is composed of two concepts: the bi-plot concept. (Gabriel, 1971) and the GGE concept (Yan *et al.*, 2000), was used to visually analyze the METs data. This methodology uses a biplot to: show the factors (G and GE) that are important in genotype evaluation and that are also the source of variation in GEI analysis of METs data (Yan, 2001).The GGE-biplot shows the first two principal components derived from subjecting environment centered yield data (yield variation due to GGE) to singular value decomposition (Yan *et al*., 2000).

Results and discussions

Analysis of variance

Combined analysis of variance revealed that varieties showed highly significant ($P \leq 0.01$) influence on the days to maturity, plant height, number of seed per pod, thousand seed weight and biomass yield; significant difference ($P \leq 0.05$) for grain yield (Table 1). The presence of significant differences among varieties indicates the presence of genetic variability for each of the characters among the tested varieties. Environment also showed highly significant ($P \leq 0.01$) differences among all agronomic parameters except days to emergency. The genotype by environment interaction showed highly significant ($P \leq 0.01$) differences among studied parameters except days to emergency. The non-significant response of varieties across environment indicated that varieties would behave similarly across locations.

Source of variation	**Mean square**									
	DF	DE	DsF	DM	PH	NPPP	NSPP	TSW	BM	GY
Rep	2	0.0000	0.194	0.778	3.488	1.156	0.5769	4.33	249213	557579
Variety	2	0.5833^{ns}	222.694**	186.861**	2248.361**	1.061ns	9.3644**	364.33**	18053494**	2319925*
Location	3	4.9167^{ns}	197.222**	1365.065**	75.027**	104.900**	88.4781**	3032.03**	62491636**	48814381**
V*L	6	0.3611^{ns}	20.028**	14.231**	222.321**	10.965**	1.7393**	161.44**	8125832**	1869723**
Error	22	0.3030	4.558	1.990	6.151	1.258	0.2951	11.03	380309	465849
Total	35									

Table 1. Combined analysis of mungbean varieties at SRS, Godey, Qalafo, dolo-ado and Jarati research station during 2022

Keys: *, **: significant at 5% and 1% respectively, S.V=source of variation, E=environment, V * E=variety verses environment, DF=degree of freedom DsF=days to flowering, DM=days to maturity, PH=plant height, NPPP=number of pods per plant, NSPP=number of seed per pod, TSW=thousand seed weight, BM=biomass, GY= yield

Growth and Phonological Parameters

The current study revealed that varieties have highly significantly ($p < 0.01$) influence on days to flowering, days to maturity and Plant Height (Table 1)**.**

Days to 50% flowering: Arkebe variety flowered relatively early (34.33 day), while NVL-1 variety was late flowering (41.92 days) compared to other varieties (Table 2). This finding was in line with result of Teame *et al*., (2017); Tadesse and Shashemene (2021); Temesgen *et al*. (2022)

Days to 90% Maturity: The lowest days to maturity was recorded for Arkebe (53.83 days); which, however, were statistically at par with the mean days to maturity recorded for variety N-26 (54.00) (Table 1), while the highest days to maturity was recorded for NVL-1 (60.75 days) (Table 2). The variation of days to flowering and maturity is due to their inherent genetic variation of varieties. similar Adhiena *et al*., 2015; Teame *et al*., 2017; Temesgen *et al*., (2022) reported a significance difference of maturity date among mungbean varieties.

Plant Height: Environmental factors and genetic traits play an important role in determining plant height. The highest plant height was in NVL-1 (65.88 cm) while the lowest plant height was recorded from N-26 (42.13 cm); which, however, were statistically at par with the mean plant height of variety Arkebe (42.22 cm) (Table 2). The difference in plant height between varieties is due to inherent genetic variation and environment. This finding was in line with result of Rasul, *et al*., (2012); Yoseph (2022) and Temesgen *et al*., (2022); Tadesse and Shashemene, (2021); Fantaye *et al*., 2019.

Table 2. Combined mean yield and agronomic traits of mung-bean varieties tested at SRS, Godey, Qalafo, dolo-ado and charati research centers for (2022)

Varieties	**DE**	**DF**	**DM**	**PH**	**NPPP**	**NSPP**	**TSW**	**BM**	**GY**
Arkebe	3.583a	34.33b	53.83b	42.22b	13.19a	9.95b	59.25a	4523b	2740b
N-26	3.667a	34.58b	54.00b	42.13b	13.00a	9.72b	48.42c	4789b	2818b
NVL-1	4.000a	41.92a	60.75a	65.88a	13.58a	11.35a	55.58b	6768a	3538a
Mean	3.750	36.94	56.19	50.08	13.26	10.339	54.42	5360	3032
CV%	14.7	5.8	2.5	5.0	8.5	5.3	6.1	11.5	22.5
LSD	0.4661	1.808	1.194	2.100	0.950	0.4599	2.812	522.1	577.9

Keys: NS= Not significant, CV=Coefficient of Variation, LSD= Least Significant Difference. Means followed by different letters within columns are significantly different by Duncan's new multiple range test (P = 0.05). DF=days to flowering, DM=days to maturity, PH=plant height, NPPP=number of pods per plant, NSPP=number of seed per pod, TSW=thousand seed weight, BM=biomass, GY= grain yield

Yield Components

Number of pods per plant: The number of pods per plant is the main factor determining the yield of legumes. The number of pods ultimately determines mung bean performance**.** Mean number of pods per plant was wasn't significantly influenced by varieties tested. The lowest statistical number of pods per plant (13.00) were recorded for variety N-26 followed by Arkebe (13.19) variety, while the highest (13.58) was recorded for variety NVL-1 followed by SERI119 **(**Table 2). Adhiena *et al*., (2015); Wedajo *et al*. (2015); Tadesse and Shashemene, (2021); Gezu *et al*., 2022; Yoseph (2022); Ahmad *et al*., (2015) and Rasul *et al*., (2015); Teame *et al*., 2017; Temesgen *et al*., (2022), stated that mung bean cultivars exhibited a significant variation on number of pods plant.

Number of seed per pod**:** Mean number of pods per plant was highly significantly ($p < 0.01$) influenced by varieties tested. The lowest number of pods per plant (9.72) were recorded for variety N-26, while the highest (13.35) was recorded for variety NVL-1 (Table 2). The difference in the number of seeds per pod mainly attributed difference in seed size among varieties and environment. The result was in-line with the report of Rasul, *et al*. (2012), who reported the difference of seed per pod among the varieties are due to the difference of genetic. Adhiena *et al*., (2015); Gezu *et al*., (2022); Ahmad *et al*., (2015) and Rasul *et al*., (2015); Teame *et al*., (2017); Temesgen *et al*., (2022), stated that mung bean cultivars had significant effect on number of pods plant.

Thousand seed weight (g)**:** Among the various parameters that contribute to final crop yield, 1000 seed weight is the most important. Data presented in Table 1 revealed that varieties had significant ($P \leq 0.05$) effect on the 1000-seed weight. The highest thousand seed weight (59.25g) were recorded for variety Arkebe followed by NVL-1 (55.58 g) variety while the lowest thousand seed weight (48.42 kg/ha) was recorded for variety N-26 (Table 2). Differences in 100-seed weight between cultivars could be due to differences in seed size that existed between cultivars and were indeed affected by the growing environment. Wedajo, (2015) also stated that**,** the difference in seed weight between the hundred-seeded mung bean varieties is due to harvest potential in terms of yield, growth rate, higher nutrient transfer, and genetic superiority. similarly, Wedajo *et al*., (2015); Tadesse and Shashemene, (2021); Yoseph (2022); Ahmad *et al*.,

(2015) and Rasul *et al*., (2015); Teame *et al*., (2017); Temesgen *et al*., (2022) reported variation of thousand seed weight among mungbean varieties.

Biomass yield (kg/ha): Crop productivity is primarily determined by biological yield and Production of large amounts of biomass is one of the attributes of seed yield**.** Data regarding biomass yield per hectare given in Table 1 revealed a significant (P≤0.05) variation was observed among varieties with respect to biomass yield of the haricot bean plants. The highest biomass value (6768 kg/ha) was recorded in variety NVL-1 followed by N-26 (4789) variety, while the lowest value (4523 kg/ha) for variety Arkebe followed by variety Ada (Table 2). Therefore**,** this variation could be attributed to the cultivar's genetic features in its response and adaptation to growing conditions**.**

Grain Yield (kg/ha): Dry matter production and its conversion to economic yields are the end result of various physiological, biochemical, phenological**,** and morphological events that occur in plant systems. Seed yield of a variety is the result of interplay of its genetic make-up and environmental factors in which plant grow

Table 3. Means of grain yield (Kg/ha) of 3 Mung bean varieties across location

			Locations		
Varieties	Godey	Charati	qalafo	Dollo-ado	Combined mean
Arkebe	982.3^{b}	1438^{a}	867^{c}	842^{c}	1032^{b}
N-26	876.0^{c}	1021^{b}	1158^{b}	1150^{b}	1051^{b}
NVL-1	1130.2^{a}	1562^{a}	1833^{a}	1692^{a}	1554^{a}
Mean	996.2	1340	1286	1228	1213
CV	1.5	9.3	6.9	10.7	11.2
LSD	34.06	281.4	200.6	296.7	114.9

The current study revealed grain yield was highly significantly ($p < 0.01$) affected by varieties and location (Table 1). Regarding grain yield NVL-1 were significantly higher yielder (1130.2, 1562, 1833, 1692 and 1554 kg/ha) for Godey, Jarati, Kelafo and Dollo-ado respectively and the combined mean being (3538 kg/ha) followed by N-26 variety, while the lowest grain yield was recorded from variety Arkebe for all locations (Table 3). The greatest yield of the varieties NVL-1 and N-26 could be due to their inherent genetic potential and growing environment. Adhiena et al., 2015; Temesgen *et al*. (2022); Tadesse and Shashemene (2021); Mequannit and Terefa (2020); Yoseph (2022); Gezu *et al*. 2022; Wedajo *et al*. (2015); Ahmad *et al*. (2015) and Rasul *et* *al*., (2015)**;** Teame *et al*. (2017) reported that mung bean varieties showed significant effect on grain yield across locations.

Additive Main Effects and Multiple Interaction (AMMI) model ANOVA

The AMMI analysis can be used to diagnose whether a specific sub-case provides a more appropriate analysis. AMMI has no specific experimental design requirements, except for a two-way data structure. The AMMI model ANOVA for grain yield is presented in Table 5. This

Source	Degree freedom	Sum Squares	Mean Squares	TSS explained %
Varieties	2	2105614	1052807**	103.75
Environment	3	618959	206320*	6.12
Block	8	269807	33726**	3.32
Interaction	6	1060905	176817**	17.42
PC1	4	970963	242741**	23.92
PC2	2	89942	44971*	4.43
Residual	16	162361	10148	

analysis also revealed the presence of highly significant (P< 0.01) differences among mungbean varieties for grain yield performance. The variation was largely due to varietal variation 103.75%. GEI and environment accounted 17.42% and 6.12% of the total variation, respectively. As indicated below, the high percentage of varietal variation is an indication that the major factor that influence yield performance of soybean is the variety. The result revealed that there was a differential yield performance among the varieties across testing environments and the presence of strong genotype by environment (G X E) interaction. Similar findings have been reported in previous studies (Kaya *et al*., 2006; Farshadfar *et al*., 2012).

Table 4. Additive main effect and multiplicative interaction analysis of variance (AMMI) for grain yield of 3 mung bean varieties.

As G x E interaction was significant, further calculation of genotype stability is possible. In the AMMI ANOVA, the GEI was further partitioned using PCAs scores. The result of ANOVA showed that the first two IPCAs were highly significant at (P<0.01) implying the inclusion of the first two interactions PCA axes in the model. Considerable percentage of GEI was explained by IPCA1 (23.92%) followed by IPCA2 (4.43%). This result revealed that there were differential yield performances among soybean varieties across testing environments due to the presence of GEI. The presence of GEI could complicate the selection process of superior varieties and might reduce the selection efficiency in a breeding program According to Gauch (2006).

Evaluation of varieties based on GGE-bi-plot model

The estimation of yield and stability of genotype were done by using the average coordinates of the environment (AEC) methods (Yan, 2001; Yan and Hunt, 2001). The average environment is defined by the average values of PC1 and PC2 for the all environments, and it is presented with a circle. The average ordinate environment (AOE) defines by the line which is perpendicular to the AEA (average environment axis) line and pass through the origin. This line divides the varieties in to those with higher yield than average and in to those lower yield than average. By projecting the varieties on AEA axis, the varieties are ranked by yield; where the yield increases in the direction of arrow. In this case the highest yielding variety is NVL-1 but the lower yielder varieties are N-26 and boreda (figure 1). Stability of the varieties depends on their distance from the AE abscissa. Varieties closer to or around the center of concentric circle indicated these varieties are more stable than others. Therefore, the greatest stability in the high yielding group had variety is NVL-26. The genotype ranking is shown on the graph of genotype so-called “ideal” genotype (Fig 1). An ideal genotype is defined as one that is the highest yielding across test environments and it is completely stable in performance that ranks the highest in all test environments; such as variety in this case was NVL-26.

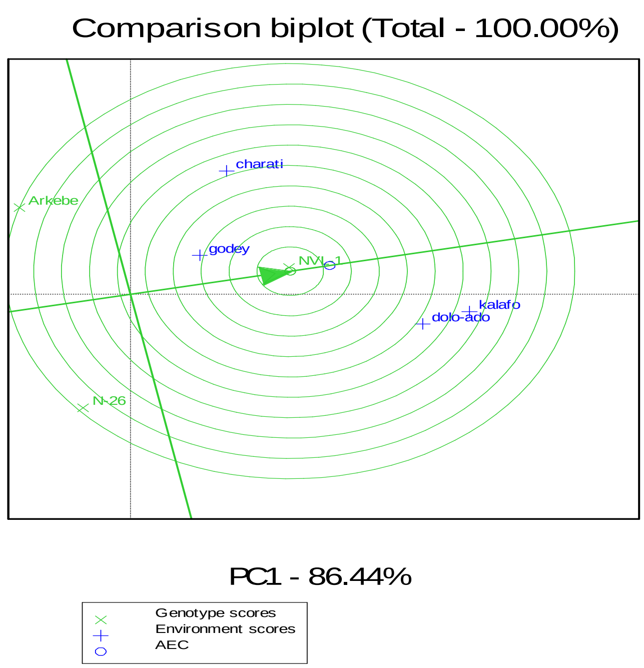

Figure 1. GGE bi-plot based on varieties focused scaling for comparison of varieties for their yield potential and stability

Evaluation of environments relative to the ideal environments

The average environment is defined by the average values of PC1 and PC2 for the all environments and it is presented with a circle (Purchase, 1997). The average ordinate environment (AOE) is defined by the line which is perpendicular to the AEA (average environment axis) line and pass through the origin. The ideal test environment should have large PC1 scores (more power to discriminate variety in terms of the genotypic main effect) and small (absolute) PC2 scores (more representative of the overall environments). Such an ideal environment was represented by an arrow pointing to it (Fig. 2). Actually, such an ideal environment may not exist, but it can be used as an indication for variety selection in the METs. An environment is more desirable if it is located closer to the ideal environment. Therefore, using the ideal environment as the center, concentric circles were drawn to help ideal test environment in terms of being the most representative of the overall environments and the most powerful to discriminate varieties (Fig.2).

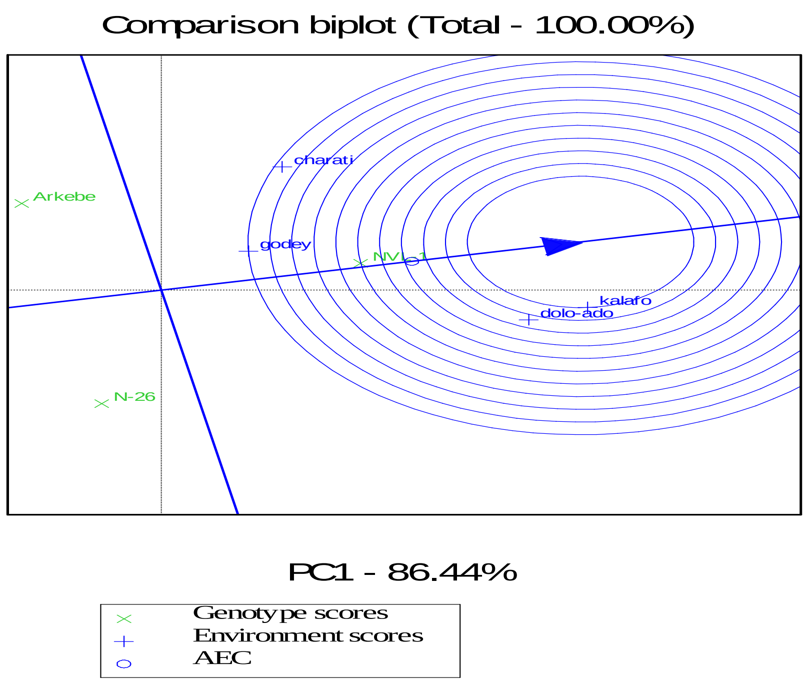

Figure 2. GGE bi-plot based on environment focused scaling for comparison of varieties for their yield potential and stability

From GGE-biplot comparison for environment under this study, G1 (Kelafo) and G2 (Dollo-ado) had the longest vector with small PCA2, and fell into the center of the concentric circles and is considered as an ideal environment in terms of being the most representative of the overall environments and the most powerful to discriminate genotypes (Figure 2). From figure 2, it shows that, 3 (NVL-1) was closer to the ideal environments and is considered as suitable to select widely adapted genotypes respectively. G3 (Godey) and G4 (Jarati) were far from the ideal environment and are considered to be unsuitable environments to select desirable genotypes

(Figure 2). This result is in line with the findings of Yan *et al*. (2000), Yan and Rajcan (2002) and Yan *et al*. (2007) and Fiseha *et al*. (2015).

Conclusion and Recommendations

Mung bean is an important pulse crop grown in drier areas for household consumption and as a source of family cash income. It is regarded as a poor man's crop because of its low input requirements, chief protein source, short duration, ease of production and ability to produce under adverse weather and soil conditions. combined analysis of variance (ANOVA) result revealed significant difference of grain yield and most of yield contributing traits among evaluated haricot bean varieties across locations, years and the interactions. This indicated that, the location and fluctuation of weather condition over the cropping season had affected performance of varieties.

Although the GEI of grain yield partitioned in to different IPCAs using AMMI model analysis, the first principal component axis for interaction alone explains most of the interaction sum of squares. The sign and magnitude of IPCA scores showed the relative contribution of each genotype and environment for the genotype and environment interactions. This helps to summarize the pattern and magnitude of GEI and main effects that reveal clear insight into the adaptation of genotypes to environments. This shows that, NVL-1 variety is fewer contributor to the interaction effect and have consistent performances across locations. Therefore, NVL-1 variety was identified as the best variety in terms of yielding ability and stability and better agronomic performance. Therefore, NVL-1 variety was recommended for the study area and similar agro-ecologies. Hence if the above-mentioned varieties are demonstrated and popularized to the small-scale holder farmers, they can boost the income of poor farmer

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2.6. Survey of Disease and Insect Pests of Cultivated Fruit and Vegetable Crops in Siti, Shebelle and Fafan Zones of Somali Regional State

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Abstract

The survey aimed at identifying and recording disease and insect pests that attack fruit and vegetable crops grown in three irrigation areas namely Siti, Fafen and Shebelle zone of Somali region was conducted. Totally eleven insect pests and seventeen diseases identified and recorded from three key vegetable crops grown in four districts of Somali regional state namely Godey, Gursum, Shebelley and Erar woredas. The highest disease incidence was receded from onion which is onion purple blotch across all location where the highest 64.47% were recorded from the Sheblle zone followed by Siti and Fafan zone 56.5 and 55.12% respectively. According to the result twelve disease and sixteen insect pests were identified and reordered from five major cultivated fruit crops in surveyed districts. The highest disease prevalence 100% was recorded from Siti zone fruit orchards for Anthracnose, Canker, Phytophtorarot and Dieback. The average higher fruit disease incidence 39 % was recorded from the dieback of citrus lowest was recorded from Citrus sudden death 1.7% among different locations. Majority of identified and recorded disease and insect pests were belonged to citrus fruits. Similarly, among major disease recorded from vegetables disease such as onion purple blotch, downy mildew and tomato leaf spot are major ones. The findings of current study could be useful as a baseline for further research on management of specific insect pests and disease on major cultivated fruit and vegetable crops.

Key Words: *identifying; recording; disease and insect pests of; fruit and vegetable crops*

Introduction

In Ethiopia Agriculture is the most important sector, crucial for the country's food security and the livelihoods of nearly 85% of its people, and serving as the engine for the country's development strategy (Driba *et al*., 2020). Horticulture is one of the sub-sectors of agriculture in Ethiopia have been benefiting a lot, not only for food self-sufficiency but also for sustainability of their economies (Ali, 2008; AgBit, 2015).

Horticultural crops are one of the most important agricultural commodities produced in Ethiopia for both commercial and consumption purposes (Driba *et al*., 2020). Various types of fruits and vegetable crops are grown in Ethiopia under rain-fed and/or irrigation systems (Alemayehu *et al.,* 2010). Horticultural crops play a significant role in a developing country like Ethiopia, both in improving income and social spheres for the fulfillment of human nutrition. In addition, they help in maintaining ecological balance since they are so diverse. Furthermore, the sector provides employment opportunities for their management being too intensive. Particularly the sub-sector of fruits and vegetables in Ethiopia has a high potential for domestic, regional and international markets. In Ethiopia majority of horticultural production particularly fruit and vegetables production is concentrated in the lowland areas, with most households producing vegetables.

Somali region is one of major fruit and vegetable production areas of Ethiopia particularly areas like Erar, Fafen and Godey are well known for tire fruit and vegetables production mainly through irrigation. In these areas fruit and vegetable production play important role in poverty alleviation through employment generation, agricultural transformation and capital flows. Most of the products including tomato, onion sweet orange, lemon, water melon are marketed in local, domestic and also exported to neighboring countries line Djibouti and Somali.

Somali region has favorable climate and edaphic conditions for the production of wide range of fruit and vegetable crops. Despite the potential of the area, several constraints hampered the development of the sector and the expected contribution to regional and national economy and food security. Therefore, having any rich resource and potential only would not be enough unless constraints and limitations are solved (Getu *et al*., 2020). Major fruit and vegetable production sector constraints include pests, drought, and shortage of inputs, machineries and finances. In Ethiopia over past 30 years fruit exports amount have dropped due to poor quality delivered on to the market, which is mainly due to lack of improved production practices and technology transfer has hampered industry growth (Tamesse, 2009; Yosef *et al*., 2014). Diseases are often the most important constraint to the production of tropical fruit. They indirectly reduce yields by debilitating the plant, and directly reduce the yield or quality of fruit before and after they are harvested (Minyahil, 2015). The damage ranges from esthetic problems that lower the marketability of the harvested product to lethal problems that devastate local or regional production.

Apart other challenges fruit and vegetable crops in Somali regional state are attacked by numerous insect pests and diseases which has been one of the challenges in the development of the sector. As compared to other parts of Ethiopia extremely low information is available on the diversity abundance, prevalence and status fruit and vegetable disease and insect pests in fruit and vegetable growing areas of the regions. However, this information is perquisites to develop sound pest management as well as for preventive approaches. Therefore, field assessment was carried out to asses current status disease and insect pests of cultivated fruit and vegetable crop in for three zones of Somali region of Ethiopia and to categorize pests and disease fruit and vegetable crops based on their importance.

Materials and method

Description of Study Area

Field survey was conducted in three zones of Somali region which are major fruit and vegetables crop production areas namely Siti, Fafm and Sheble zones of Somali regional state. The districts were, Godey, Shebeley, Gursum and Erar. Siti zone have a rainfall pattern characterized by main rains in summer (*i.e.* from June to September) preceded by small rainfall peak in spring or by prolonged period of moderate rainfall. The mean annual rainfall varies from 500 to 800mm.the zone woreda is located at geographical location of longitude 9:14 .4 E latitude 40:45:00E l 1400 m.a.s.l. Much of the areas exhibit the highest mean temperature during the growing period within the mean temperature during the growing period exceeding 25.1 to 27.5 ^{o}C. Generally, the areas constitute elevation range of from less than 500 to 900 m.a.s.l. Fafan zone have the altitude ranges between 950-1350 meters above sea level. There are two rainy seasons in the Zone *Gu* and *karan*, both of which are almost equally important. The *gu* falls between late March and late May while the *karan* season is between late July to late September. In recent years, the *karan* has shown better reliability. Whereas, Shebele zone is located at an elevation of 300 m.a.s.l with latitude of 5°57’ N and longitude of 43°27’E. The climate of the zone is characterized as arid to semi-arid agro- ecology. Rainfall pattern is characterized by main rainy season of *Gu’* that extends from April to June and the short rainy season (*Deyr*) from October to December with mean annual rainfall of the area ranges from150 to 340 mm. The soil texture of the area is silt-loam to silt- clay loam in the top and becoming clay with depth. But, the textural class of the experimental soil is clay (SCF-UK DPPA, 2003; Ayale, 2005).

Survey and Sample Collection

Field surveys was conducted in aforementioned six districts of three zones of Somali regional state during 2021 cropping season to assess and identify major cultivated fruit and vegetable crops disease and insect pests. The distracts were, Godey, Shebeley, Gursum and Erear. Multistage sampling techniques that consisting random and purposive was used. At the first stage, three fruit and vegetable crop production zones were selected then from these three zones based on the same criteria two woredas were selected. Using similar selection criteria, thee kebeles were selected purposively based on their fruit and vegetable crop production. After kebeles were systematically selected for survey, based on the number of farms and their distribution further farmer selection was done. Finally, farmers' sampling and selection was done using the formula indicted below.

Where :
n= sample size required
N = number of farms in the population
e = allowable error (%)

$n = \frac{N}{1 + N(e)^2}$ Yamane, 1967.

After farms were systematically selected sapling for disease and insect pest within the selected farms were done through 'zigzag' and 'X' depending on the field and targeted crops. All sampled plants parts leaves, stems, fruits, flower were examined for insect pests and disease. Pest damages. Arthropod pests (insects and mites) will be counted. Magnifying hand lens 10^X was used in case of small Arthropods such as trips and mites etc.

Disease/pest incidence

$$\text{Disease Incidence (\%)} = \frac{\text{No. of diseased plants}}{\text{Total no. of plants observed}} \times 100$$

Disease/pest severity

Severity on leaves was estimated using the percentage leaf area infected based on a one-to-five scoring scale where 1 = no symptoms, 2 = 1-25%, 3 = 26-50%, 4 = 51-75% and 5 = above 75% (Amadi, 2008; Ezeibekwe, 2011). A similar scoring system was used for fruit severity, where 1 =

healthy, 2 = less than 5%, 3 = 5-20%, 4 = 21-50% and 5 = above 50% of fruit surface affected (Seif and Hillocks, 1999).

$$\text{Severity (\%)} = \frac{\text{Proportion of diseased plants part}}{\text{Total of plants part observed}} \times 100$$

$$\text{Density of insect/plant} = \frac{\text{Total number of insects count}}{\text{Total number of sample plants}} * 100$$

$$\text{Incidence (\%)} = \frac{\text{No. of diseased plants}}{\text{Total no. of plants observed}} \times 100$$

Furthermore, diseases and insect pests were categorized as major, intermediate, and minor considering their relative occurrence, incidence, severity, and seasonal distribution.

Identification of disease and insect pests

Identification of disease and insect pest were made both at field and laboratory. During field sample collection insect and disease samples were identified using different manuals such as keys (Overholt *et al*., 2001; The CIMMYT Maize Program. 2004; Agrios, 2005; Gibb and Oseto, 2006; ACES, 2008). Further sample identification was made at JJU crop Science laboratory for those specimens' identification was difficult at field level.

Data Analyses

Data on insect pest and disease prevalence, incidence and severity were summarized using Microsoft excel. The surmised data was analyzed through descriptive statistics using IBM SPSS Version 23. Then the result presented in Tables.

Results and Discussions

Major Fruit and Vegetable Crops under Production

Various fruit and vegetable species under cultivation across surveyed areas were recorded. The result in table 1 and 2 revealed that in surveyed districts framers predominantly cultivated five vegetables and six fruit species. Majority of farmers farm multiple spices of fruit and vegetables within their farms. According to the result of this study a total of five different vegetables species which are under production recorded from six woreda of Somali regional state. Framers in surveyed districts predominantly grow citrus major vegetables such as onion, tomato, water melon and hot pepper. However, there some very minor vegetables such as cabbage, parsley have been recorded from extremely limited farms at Dhagale area. In general majority of farmers in study area grow multiple vegetables such as onion, tomato and water melon chilly to some extent. Similarly, other leafy vegetables including lettuce, parsley and cabbage production also noticed in maller areas.

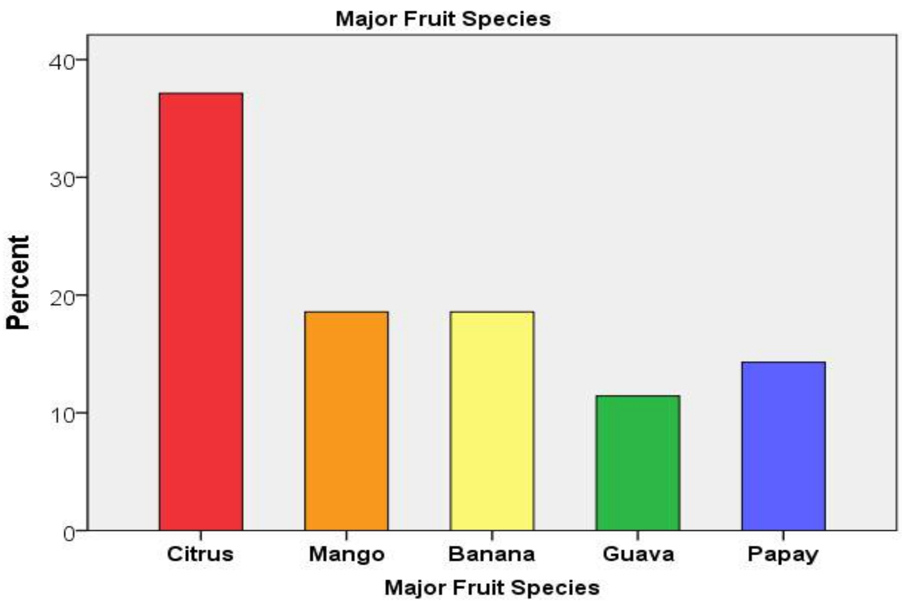

Figure 1 Major cultivated fruit crop species in surveyed districts

Table 1 Types of Vegetable Crop Cultivated by the Farmers in Surveyed areas

Types of cultivated vegetables	**Siti**		**Fafan**		**Shebele**	
	No. of farms	Percent (%)	No. of farms	Percent (%)	No. of farms	Percent (%)
Onion	7	17.07	16	50	19	30.64
Tomato	4	9.56	2	6.25	4	6.45
Water melon	3	7.31	2	6.25	10	16.12
Onion Tomato	9	21.9	3	9.37	6	9.67
Onion watermelon	5	12	2	6.25	9	14.51
Tomato and water melon	3	7.31	2	6.25	3	4.83
Tomato onion water melon and capsicum	6	14.63	2	6.25	7	11.29
Capsicum and water melon	4	9.75	3	9.37	4	6.45
Total (N)	41	100	32	100	62	100

Status of Disease and Insect pests of Cultivated Fruit and Vegetables

Status of Cultivated Vegetable Disease and Insect Pests

Totally eleven insect pests and seventeen diseases identified and recorded from three key vegetable crops grown in four districts of Somali regional state namely Godey, Gursum, Shebelley and Erar woredas. The result in table 2 and 3 revealed that different diseases and insect pests were identified and recorded from vegetable crops predominantly tomato, onion and water melon. Out of totally recorded 12 insect pest species majority of insect pests (75%) of them were recorded from tomato followed by water melon and onion. Similarly, out of identified diseases 43% of the diseases were identified and recorded form water melon followed by tomato 39% and the rest was recorded from onion. Among insect pests identified and recorded across surveyed area the highest prevalence was recorded from tomatoes *i.e.* sweet potato whitefly, followed by Ahids (*Aphis gossypii)* on water melons and tomato leaf miner and fruit borer *Tuta absoiluta and Helicoverpa armigera* respectively. However, interms of damage severity severity recoreded from tomato fruit borere and tomato leaf miner was significantly higher that other recovered insect pests. In current file survey compared to onion tomato and water meleon sustained significant damage due to insect pests.

Despite their higher prevalence and incidence values insect pests like *Aphis gossypii* and *Bemesia tabaci* the severity values of both insect pests remain minimum. In terms of location there were slight differences on prevalence, incidence and severity of identified and recorded insect pests. On average vegetable farms located in Erar woreda in Sist zone had relatively higher prevalence, incidence and severity values while farms in Fafan zone at Gursum and Shebele wored was relatively lower than both Shebele and Siti zones. The result on abundance and distribution of different vegetable disease presented in table 4 according to the result at total of 16 diseases were identified and recorded from three major cultivated vegetable crops from surveyed areas. The highest disease incidence and severity values were recovered from onion purple blotch and onion mildews followed by early blight and blossom end rot of tomato. Among all the disease occurred on vegetables, some were due to fungal, some were caused by bacteria and viral infections and a few such as blossom end rot were affected by physiological disorders.

According to the result of the study in Table-4 all surveyed districts showed 100% prevalence of recorded disease and insect pests. Despite similarities in the prevalence of disease and insect pests there were variations among surveyed areas on percent of severity of each disease and insect pests. Accordingly, the highest disease incidence was receded from onion which is onion purple blotch across all location where the highest 64.47% were recorded from the Sheblle zone followed by Siti and Fafan zone 56.5 and 55.12% respectively. Similarly, from the recorded disease the lowest disease incidence was recorded from onion root rot followed by downy mildew and water melon mosaic disease. The findings of current survey is in line with Oluwasogo (2015) and Keinath *et al*., (2017) who reported, fusarium wilt (41.3%) and powdery mildew (38.8%) phytophtora rot and leaf spot disease in water melon (Salome *et al*., 2020). Wilt complex of hot pepper, downy mildew of Onion, Purple blotch of Garlic and Cercospora leaf spot of Hot pepper (Adina et al., 2020; Hailu, 2021). During the survey, early blight was 100% prevalent septoria leaf spot was another important disease. In addition, tomato septoria spot was found economically important in all the surveyed area (Hailu, 2021).

Table 3 Status of insect pests of vegetables

Crops		**Siti**			**Fafen**			**Shebelle**		
		DP (%)	**DI (%)**	**DS (%)**	**DP (%)**	**DI (%)**	**DS (%)**	**DP (%)**	**DI (%)**	**DS (%)**
Tomato	Leaf miner Tuta *absoluta* Lepidoptera: Gelechiidae	100	61.06	22.50	100	29.74	18.01	100	37.51	12.01
	Fruit borer, *Helicoverpa armigera*	100	50.42	29.77	100	31.60	19.03	100	43.60	27.14
	Aphids *Aphis gossypii*	100	53.19	10.43	100	41.21	5.75	100	67.67	9.92
	Sweet potato whitefly *Bemesia tabaci*. Alyerodide Homomptera	100	81.47	11.01	100	67.19	9.77	100	92.19	13.77
	Trips *Thrips tabaci*	100	40.32	15.63	100	36.85	9.35	100	66.05	3.75
	Spider mites *Tetranychus cinnabarinus*	100	23.27	13.52	100	7.27	1.92	100	10.21	6.88
Onion	Onion trips Thrips tabaci	100	43.39	16.33	100	38.13	12.05	100	51.13	29.33
	Aphids	100	36.87	1.66	100	11.07	2.66	100	10.07	4.71
Watermelon	Aphids	100	100	13.53	100	55.42	5.77	100	78.42	15.31
	Whitefly	100	100	12.21	100	100	3.31	100	100	9.21
	Melon Flies	74.41	36.41	9.23	23.41	3.36	1.37	74.41	18.36	3.37

P=% of prevalence; I=% incidence; S=% severity

Status of Insect Pest and Diseases of Cultivated Fruit Crop

The results regarding the major insect pests and diseases of fruit crop of surveyed district are presented in table *4 and 5*. According to the result twelve disease and sixteen insect pests were identified and reordered from five major cultivated fruit crops in surveyed districts. Citrus armoured scale (*Aonidiella auranti* and *Coccus hesperidu*), Citrus aphid (*Aphis gossypii)*, Citrus trips (*Scirtothrips citri)*, citrus fruit fly *Bactrocera dorsalis*, Citrus white fly (*Orchamoplatus citri*), Citrus Mealybug *(Planococcus citri)*, Orange dogs *(Papilio demoleus)*, Citrus leaf minor (*Phyllocnistis citrella)*, Cottony cushion scale (Icerya purchase), Papaya mealy bugs (*Paracoccus marginatus*), Papaya fruit fly (*Toxotrypana curvicauda*), and Banana mealy bugs. The result revealed that majority of insect pests about 80% were identified and recorded from citrus fruit species including sweet orange, mandarin, lemon and lime. The insect pests identified and recorded from banana and papaya was very low compared to citrus fruit crops.

Insect pest identified and recorded across surveyed districts were presented in varying prevalence abundance and severity despite their differences in intensity, their distribution was the same and present on all surveyed districts. Among identified and recorded insect pests citrus fruit fly *Bactrocera dorsalis* followed by citrus armored scale (*Aonidiella auranti* and *Coccus hesperidu* had the highest prevalence, damage incidence and severity. The highest incidence and severity of these insect pests was recorded from citrus farms located at siti zone in Erar district followed by Godey. Citrus whitefly *Orchamoplatus citri* relatively abundant and wide spread but the level of damage was very low. Similarly, citrus aphid *Aphis gossypii* also showed wide distributions and abundance but the direct damage recorded for the citrus aphid was minimum. The survey also revealed that the lowest pest intensity from banana mealy bugs *Pseudococcus elisae,* and Papaya fruit fly *Toxotrypana curvicauda.*

Table 4 Status of vegetable diseases in Shebele zone

Crops	Major Diseases	Siti			Fafan			Shebele		
		DP (%)	DI (%)	DS (%)	DP (%)	DI (%)	DS (%)	DP (%)	DI (%)	DS (%)
Tomato	Early blight *Alternaria sp.*	100	77.86	19.14	89.41	12.86	8.14	100	25.10	11.19
	TYLC	100	19.3	8.23	13.00	11.3	0.21	100	18.6	13.04
	Bacterial wilt	100	7.05	13.11	37.71	7.05	1.25	43.81	13.05	3.87
	Septoria leaf spot	100	23.18	15.52	68.28	8.66	14.59	100	25.23	12.58
	Powdery mildew	37.49	6.63	2.55	75.00	18.63	4.27	53.00	12.63	1.74
	Blossom end rot	63	12.14	23.41	22.41	6.14	0.17	100	19.73	16.97
Onion	Purple blotch *Alternaria parii*	100	47.14	66.42	100	63.66	44.58	100	51.14	49.93
	Downy mildew *Peronospora distructor*	100	24.14	29.08	100	16.14	22.18	100	14.14	4.87
	Fusarium basal rots *Fusarium sp.*	49.36	16.72	1.17	28.22	12.72	1.31	56.55	19.81	8.02
Watermelon	Phytophtora rot	67.37	10.23	3.98	21.13	10.23	2.21	100	7.73	3.14
	Leaf spot	100	9.14	6.04	60.11	11.14	2.07	100	16.30	3.33
	Water melon fruit split	25.32	3.22	9.33	25.17	13.61	3.14	100	16.44	4.37
	Cercospora leaf spot	43.64	17.32	11.75	9.11	5.27	0.11	22.74	15.13	3.14
	Water melon mosaic virus	53.55	7.17	8.20	12.25	2.74	0.14	29.11	10.14	11.7
	Cucurbit yellow vine disease	47.26	2.74	1.74	6.74	2.47	0.7	35.27	9.74	2.67
	Blossom-end rot	17.61	8.84	32.39	0	0	0	40.47	12.84	1.62

DP Prevalence (%); DI=Incidence (%); DS= (%) Severity According to the result in table 4 a total of 10 major diseases were identified form six fruit crops. Majority of identified disease were belonged to citrus fruits including sweet orange, mandarin, lemon followed by banana and papaya. Some of the diseases were recorded from citrus such as citrus dieback; citrus sudden death the cause of the disease has not been demined yet since these diseases can be caused by both biotic and abiotic factors or both of them. Among identified disease of fruit crops of surveyed districts, the highest disease intensity was recovered from leaf and fruit anthracnose *Colletotrichium Spp* followed by leaf and fruit canker of citrus and die back. The result also revealed that among surveyed districts fruit farms in Erar district showed very high intensity of variety of disease.

The results of the existing surveys were also consistent with these previous reports. Asmare *et al*., (2014) reported that fruit orchards in Erar and Shinile districts highly infected with wide range of disease particularly citrus Tristeza, Greening, Nutrient imbalance, Unknown disease reported at Erer Gota, Hurso, Tony (Asmare *et al* 2014; Ajene *et al* 2020). The presence of Asian citrus psyllid which is responsible for citrus greening disease known for its transmission of *Candidatus liberibacter* the causal bacterium of huanglongbing (Ajene *et al*., 2020). On field observations citrus producers had reported 13.6% of citrus trees dieback due to virus problems and over 35% citrus attack by other plant pathogens in the major citrus farms across Ethiopia (Sisay, 2007). Corroborates with Asmare *et al*., (2014) who reported nearly 63.3% of the orchards surveyed were infected with the multiple disease. Asmare *et al.*, (2014) also reported 100% incidence and 43% and 65% severity on leaves and fruits, respectively.

Similarly, two well-known banana disease recorded were in conformity with previous findings. Fusarium and bacterial wilt disease were were widely distributed in most of the areas assessed with an infection varying from 0 to 75 % for fusarium wilt and 100% for Segatoka (Getachew, 2016). Insect pests on citrus were found to be equally important to diseases and leaf miner (77.6%), red scales (57.1%), citrus thrips (24.5%),cottony cushion scales (16.3%), Mediterranean fruit fly (14.3%), and woolly whitefly (10.2%) were reported as the major insect pests on citrus in the orchards surveyed (Asmare *et al* 2014).

Table 5 Status of fruit disease

Major Diseases		**Siti**			**Fafan**			**Shebele**		
		DP (%)	DI (%)	DS (%)	DP (%)	DI (%)	DS (%)	DP (%)	DI (%)	DS (%)
Citrus (sweet orange, mandarin, lemon and lime)	Leaf and fruit Anthracnose Colletotrichium Spp	100	43.31	14.51	100	17.11	10.51	100	19.16	16.35
	Canker (leaf and fruit) *Xanthomonas citri*	100	32.39	22.84	100	10.39	12.84	100	12.09	21.24
	Phytophtora foot rot *Phytophthora* sp	100	22.14	13.19	100	3.14	0.87	100	10.84	10.16
	Die back	100	23.17	-	100	18.17	-	100	22.31	-
	Sudden death	82.85	12.25	-	19.74	4.43	-	100	2.75	-
	Citrus greening *Candidatus spp*	100	22.18	19.45	100	11.18	22.10	100	9.12	-
Papaya	Pytophtora fruit and root rot *Phytophthora palmovora*	85	36.66	13.87	38.94	6.36	8.27	100	22.24	3.59
	Black Spot *Asperisporium caricae*	29.17	6.16	0.38	18.09	1.18	0.81	27.65	3.14	0.11
Banana	Bacterial wilt *Xanthomonas vasicola*	100	20.39	2.26	57.41	9.39	0.53	77.51	9.78	4.03
	Banan fusraium wilt *Fusarium oxysporum f. Sp.* cubensev	22.45	4.57	4.4	17.82	2.02	0.19	61.57	9.92	10.29

DP=% of disease prevalence; DI=% of disease incidence; S=% of disease severity

Table 6 Status of fruit insect pests

Crops	**Insect pests of cultivated fruit crops**	**Siti**			**Fafan**			**Shebele**		
		P (%)	I (%)	S (%)	P (%)	I (%)	S (%)	P (%)	I (%)	S (%)
1	**Armord scale (Aonidiella auranti and Coccus hesperidu*)* Homoptera: Diaspididae**	100	89.80	72.42	36.12	9.11	0.42	100	19.80	8.42
2	Citrus Aphid *Aphis gossypii* (Aphididae: Hemiptera)	100	47.28	10.50	100	13.28	7.51	100	19.11	12.50
3	Citrus trips *Scirtothrips citri* (Thripidae: Thysanoptera)	100	51.27	17.26	29.61	6.27	1.21	100	33.17	12.26
4	Fruit fly *Bactrocera dorsalis* (Tephritidae: Diptera)	100	72.41	59.48	100	34.45	19.48	100	50.31	19.28
5	**Citrus white fly Orchamoplatus citri Hemiptera: Aleyrodidae**	100	67.28	9.17	100	39.28	1.15	100	41.75	6.82
6	**Asian citrus psyllid *Diaphorina citri* Hemiptera: Psyllidae**	86.87	57.63	-	64.59	31.57	-	37.86	12.18	-
7	Citrus Mealybug, *Planococcus citri* (Pseudococcidae: Hemiptera)	66.47	22.22	13.53	27.19	10.22	0.69	51.9	4.22	22.53
8	Orange dogs *Papilio demoleus* (Papilionidae: Lepidoptera)	100	16.29	9.51	52.52	6.16	0.29	67.19	3.74	1.19
9	Citrus leaf minor *Phyllocnistis citrella* Gracillaridae: Lepidoptera)	100	67.49	9.11	100	12.27	1.11	100	7.18	1.05
10	Cottony cushion scale *Icerya purchase* Hemiptera: Margarodidae	100	18.24	3.19	100	6.61	1.19	100	21.25	9.19
11	Papaya mealy bugs Paracoccus marginatus	63.79	16.07	7.39	13.79	3.05	9.36	100	24.11	12.39
12	Papaya fruit fly Toxotrypana curvicauda Diptera: Tephritidae	43.52	16.11	3.62	31.37	2.81	0.92	67.32	12.09	1.78
13	Banana mealy bugs *Pseudococcus elisae,*	19.91	3.42	1.82	26.17	9.80	7.42	33.72	6.80	2.42

P=% of prevalence; I=% incidence; S=% severity

Conclusion and Recommendations

A survey was conducted during November to March 2021 to find out status of disease and insect pests of major cultivated fruit and vegetable crops of Somali regional state. The survey was conducted in three major fruit and vegetable crop production areas of Somali region namely Siti, Fafen and Shebelle zone in Erar, Gursum and Shebeley, and Godey districts. The study raveled more than 40 diseases and insect pest form 10 major cultivated fruit and vegetable crops across three different zones. The current survey of pests and diseases on fruit and vegetable crops in three zones provides baseline information regarding the infestation levels of major pests. Based on the field assessment and coverage and status of identified disease and pests' further categorizations of diseases and insect pests were ma*d*e. Accordingly, four insect pests and four diseases were categorized as major and critical. Furthermore, based on the impact and devastations two of them designated as critical namely Armord scale /brown scale of citrus and tomato fruit worm, onion purple blotch and downy mildew designated as major pests.

Timely and regular survey of insect pest and disease should be observed by the government and or concerned bodies to update pest and disease status and for immediate and timely intervention. Farmers should be encouraged to apply good agricultural practices including crop rotation technique, which is an effective measure for minimize pest outbreak and buildup. The findings of current study could be useful as a baseline for further research on management of specific insect pests and disease on major cultivated fruit and vegetable crops.

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2.7. Screening of potato Germplasms for Heat Stress at lowland, Fafen, Somali Region, Ethiopia

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Abstract

Potato is an important food security crop and a major source of household income for smallholder farmers in Ethiopia. Potato (Solanum tuberosum L.) produces more nutritious food on less land with time, but the production in lowland areas is limited by the temperature. The production of potato at lowland areas demands to develop heat tolerant cultivars adaptable specific to high temperatures. thus, it is very important to evaluate such genotypes, which have high yield potential and are suitable to our local environmental conditions. A field experiment was conducted at Fafen Research Station, during 2021 and 2022, to evaluate the performance of fifty potato genotypes for plant, and tuber yield characters. The experiment was laid out in a randomized complete block design with three replications. The genotypes and year showed highly significant difference for all the traits except flowering and days to maturity. The interaction between genotypes and years revealed significant differences in all the studied parameters except days flowering, maturity, plant vigor and plant height. Genotype CIP312923.522 and CIP312906.575 produced more marketable tubers for category I and II (>80g and >30g tuber[1]) and total tuber yield than all other genotypes respectively. Thus, the genotypes are recommended to be promoted to variety verification trial in the coming year for further evaluation at on-farm and on-station in the study area and similar agro ecologies.

Keywords: *screening, heat tolerance, germplasm, potato, yield*

Introduction

Potatoes are a precious source of food for many low-income people in both urban and rural areas. Potato is the world's third most important food crop in overall production after rice and wheat, and is a food security crop in Ethiopia (Devaux *et al*., 2014). It is mainly used as vegetable and available in the market throughout the year with reasonable price and has great importance in rural economy of the country as compared to other vegetables crops in Ethiopia. It can be consumed in different forms, such as boiled, roasted, fried and chipped (Kibar, 2012). Potatoes provide different types of nutrients and vitamins (Kärenlampi and White, 2009). They are source of different minerals like iodine (I), copper (Cu), iron (Fe), potassium (K), manganese (Mn), phosphorous (P), zinc (Zn), magnesium (Mg) and calcium, (Ca) (USDA, 2014). It is also an important food security crop in eastern Ethiopia in particular and in Ethiopia in general (Tewodros and Belay, 2015).

In Ethiopia, potatoes are mostly cultivated in the central, north western, southern, and eastern parts of the country (Semagn *et al*., 2016). The crop has potential for improving the livelihoods of millions of smallholder farmers in the high lands area of the country. The potential for higher yield per unit area, early maturity, and excellent food value give the potato crop greater potential for improving food security, increasing household income, and reducing poverty than other crops (Semahagn Asredie *et al*., 2015).

It is important crop in Somali region also however there is no production potato in the region any were all potato consumed in the region comes from the neighboring region. The absence of potato production in the region could be due the unavailability of potato variants suitable for the Somali region. variety adaptability trial will able to determine the different varieties that are suitable for each location in which farmers will be able to choose which of the introduced varieties are suited for their needs. Therefore, to introduce potato technology in the region varieties adaptability trial project was required that which help selection of suitable variates. Therefore, the objective of this study was to evaluate the performance of potato genotypes for their tuber yield and yield related traits at Fafen research center, Somali regional state.

Materials and Methods

Experimental Materials, Design and Procedure

A total of 15 potato genotypes were used (CIP312921.550, CIP312926.502, CIP312923.522, CIP312923.562, CIP312920.538, CIP312927.550, CIP312916.591, CIP312897.548, CIP312898.640, CIP312911.508, CIP312906.575, CIP312896.509, CIP312905.530, CIP312901.638 and Belete (St.ck). The genotypes were arranged in Randomized Complete Block Design with two replications due to seed shortage and each gross plot were 3 m x 3 m = 9 m^2 consisting of four rows, which accommodated 10 plants per row and thus 40 plants per plot. The spacing between rows and plants were 0.75 m and 0.30 m, respectively. The spacing between plots and adjacent replications were 1 m and 1.5 m, respectively. The two middle rows were used for data collection. The experimental field was cultivated to a depth of 25-30 cm by a tractor and ridges were made manually after leveling. The planting depth was maintained at 10-15 cm. All other agronomic practices such as weeding, cultivation and spraying Redomil chemical were kept uniform for all treatments in each plot.

Data collection and Statistical Analysis

Days to 50% flowering: The number of days from planting to flowering of 50% of plants in each plot was recorded. Days to 50% maturity: This was registered by counting the number of days taken from planting to 50% of plants in each central two row per plot showed yellowish haulms. Plant height: The height of the plants recorded from at least eight plants in the central two rows by measuring from the ground surface to the tip of the main stem in centimetre and averaged to get the mean plant height in centimetre. Number of plants harvested: This was recorded by counting the number of plants harvested from the central two rows. Number marketable tubers category I/plot: Recorded by counting the number of marketable tubers for category I with weighing between >80 g or tubers of 40-60 mm from the central two rows. Number marketable tubers category II/plot: Count the number of marketable tubers category II weighing between 30-80 g or tubers between 20-40 mm from the central two rows. Number of non-marketable tubers/plot: Count the number of non-marketable tubers with weighing less of 30 g or less of 20 mm from the central two rows. Marketable tuber weight category I/plot was recorded by Weighing marketable tuber category I/plot. The unit of measure is in Kilograms. Marketable tuber weight category II/plot was recorded by Weighing the marketable tuber category II/plot. The unit of measure is in Kilograms. Non-marketable tuber weight/plot was recorded by Weighing the non-marketable tuber/plot. The unit of measure is Kilograms. Total tuber yield (kg ha -1): the total tuber yield was obtained by adding marketable and unmarketable tuber yields. Collected data was subjected to analysis of variance (ANOVA) for RCBD using GenStat 18th edition software. Means that are significantly different were compared using Least Significant Difference (LSD) at 5% level of significance.

Results and discussions

Genotypes and year had significantly affected all measured plant characters except days to flowering and maturity (Table 1). The presence of significant differences between varieties indicates the presence of genetic variation for each of the genotypes tested**.** The interaction between genotypes and year exhibited a significant variation on the studied parameters except days flowering, maturity, plant vigor and plant height. this may be due to the genetic trait of the genotypes as well as the changing weather pattern in the experimental location.

Table 1: Combined Mean square values of plant characters and yield components of potato genotypes for combined analysis of variance over two years (2021 and 2022) at Fafen, research stations

Source of variation	**DF**	**Mean square**												
		DsF	PU	PV	DM	PH	AvSN	NMTCI	NMTCII	NNoMTP	MTWCI	MTWCII	NoMTWP	TTY
Rep	1	112.07	0.2667	0.267	0.267	228.74	14.2009	3.267	36.817	12.15	0.998	0.299	0.5419	1.412
Genotype	14	21.59ns	6.2571**	5.429*	4.245ns	151.48**	0.7671ns	413.874**	529.493**	322.62**	157.888**	19.314**	0.7590**	227.671
Year	1	4.27ns	41.6667**	17.067**	8.067ns	218.62*	1.2760ns	1401.667**	13053.750**	5208.02**	1136.897**	798.766**	2.6014**	4044.10
G*Y	14	21.80ns	6.2381**	2.781ns	2.602ns	78.24ns	0.6426ns	237.774**	138.036**	318.98**	111.525**	5.312**	0.8960**	125.962
Error	29	14.51	0.4046	2.198	9.749	45.73	0.5150	9.336	9.093	12.63	6.404	1.436	0.1056	7.891
Total	59													

Keys: *, **: significant at 5% and 1% respectively, Rep= replication, Y= year, V * Y=variety verses year, DF=degree of freedom DsF=days to flowering, DM=days to maturity, PH=plant height, PU- plant uniformity, PV= plant vigor, NMCTI=Number marketable tubers category I, NMCTII= Number marketable tubers category II, MNoMTP= Number of non-marketable tubers/plot, MTWCI= Marketable tuber weight category I, MTWCII= Marketable tuber weight category II, NoMTWP= Non-marketable tuber weight, TTY(kg/ha)=total tuber yield

Growth and Phonological Parameters

Plant uniformity: The analysis of variance showed that genotypes had highly significantly at ($p<0.01$) on number of plant uniformity (Table 1)**.** The best/optimum plant uniformity was recorded from CIP312921.550 (7.500); which was significantly at par with CIP312911.508 (7.500) genotype and the lowest plant uniformity was recorded from CIP312920.538 (3.500) genotype followed by CIP312898.640 (4.000) genotype (Table 2). The variation in plant uniformity of the potato genotypes was reported by previous researchers too Luitel *et al*. (2016) and Tessema *et al*. (2020) that Genotypes differ genetically in their growth habit.

Plant vigor: The result of statistical analysis showed that genotypes had highly significantly ($p<0.01$) effect on plant vigor (Table 1)**.** The best plant vigor was obtained from CIP312901.638 (3.500) genotype while the lowest plant vigor was from CIP312923.562 (7.500) genotype (Table 2).

Days to 50% Maturity: The effect of different potato genotypes on days to maturity was in-significant (Table 1). genotype CIP312901.638 matured early (111.8 days) while genotypes CIP312923.562 matured lately the other tested genotypes (109.0 days) and the grand mean being 109.87days (Table 2).

Plant height (cm): The result of analysis of variance showed the effect of different genotypes on plant height was found highly significantly ($p<0.01$) (Table 1). Plant height ranged from 65.50 cm to 43.95 cm with an over mean of 58.41cm. Genotypes CIP312923.562 produced longer stem (65.73 cm) genotype; at par with CIP312923.522 genotype, while genotype CIP312901.638 produced shorter stem (43.95 cm) (Table 2). Differences in plant height between genotypes may be related to genetic differences, which can lead to variable growth and development performance. also, many authors in different part of the world have found that potato genotypes had significant variation of plant height Aweka *et al*. (2021); Abebe Chindi *et al*. (2021) Abebe Chindi *et al*. (2020); Binod *et al.* (2020), Arifa *et al*. (2018), Eaton *et al*. (2017) and Getachew *et al*. (2016).

Yield component

Number of marketable tubers for category I (>80g tuber[1]**)**: The result of analysis of variance revealed that genotypes highly significant ($p < 0.01$) difference on the number of marketable tubers for category I (>80g **tuber**[1]) in both of the cropping seasons (Table 1). CIP312923.522 genotype produced maximum number marketable tubers category I (>80g **tuber**[1]) **(**64.00g **tuber**[1]**)** followed by CIP312897.548 (53.00 tuber) while the minimum was recorded from CIP312901.638 (26.00g **tuber**[1]) genotype, which was statistically at par with CIP312927.550 (27.75g **tuber**[1]) (Table 2)**.** a study by Binod *et al*. (2020) described highly significant differences among potato genotypes for marketable tubers.

Number of marketable tubers for category II (>30g tuber[1]**)**: The result of analysis of variance revealed that genotypes highly significant ($p < 0.01$) difference on the number of marketable tubers for category II (>30g **tuber**[1]) in both of the cropping seasons (Table 1). the maximum Number of marketable tuber category II (>30g **tuber**[1]) was from CIP312911.508 (51.75g **tuber**[1]) genotype followed by CIP312923.522 (47.75g **tuber**[1]) and the minimum was from CIP312901.638 (12.50g **tuber**[1]) genotype, which was statistically at par with CIP312926.502 **(16.00**g **tuber**[1]**)** (Table 2). Similarly, other researchers also investigated that marketable yield was significantly varied by genotypes Abebe (2020); Binod *et al*., (2020) and Raphael (2022)

Number of non-marketable tuber category (<30g tuber[1]**)**. There was a highly significant ($P< 0.01$) variation among the tested genotypes with respect to number of non-marketable tuber category (<30g **tuber**[1]) (Table 1). The maximum Number of non-marketable tuber category (<30g **tuber**[1]) of tested genotype was obtained in CIP312898.640 (51.75g **tuber**[1]) genotype followed by CIP312923.522 (47.75g **tuber**[1]) and the minimum was in CIP312901.638 (18.00g **tuber**[1]) genotype (Table 2). The variation of number of tubers per plant is due to genetic traits of genotypes, canopy development and study area conditions. Our results are in line with Aweko *et al*. (2021); Binod *et al*. (2020); Abebe Chindi *et al*. (2021) Abebe Chindi *et al*. (2020); Getachew *et al*. (2016); Getie *et al*. (2018) and Ebrahim *et al*. (2018); Eaton *et al*. (2017); Kena (2018); Abebe *et al*. (2020) who reported high variation among potato genotypes with respect to tuber number.

Marketable tuber weight category I, II (>80 and 30 kg/ha). In potatoes, weight of tubers has an important role in tuber yield. The result of analysis of variance revealed that genotypes highly significant ($p < 0.01$) difference on the marketable tubers weight category I and II (>80g and 30 **kg/ha**) in both of the cropping seasons (Table 1). In the present study, maximum Marketable tuber weight category I (>80 g) of tested genotype was produced by CIP312923.522 (35.25

kg/ha) genotype followed by CIP312906.575 (32.90 kg/ha) and the minimum was obtained from **CIP312927.550** (13.98 kg/ha) genotype (Table 2). Moreover, the maximum Marketable tuber weight category II (>30 g) of tested genotype was obtained from CIP312911.508 (10.133 kg/ha) genotype followed by CIP312923.562 (9.582 kg/ha) and the minimum was recorded from CIP312901.638 (2.706 kg/ha) genotype. This is in agreement with Binod *et al*. (2020) and Raphael (2022)

Non-marketable tuber weight (<30 kg/ha): The result of analysis of variance revealed that genotypes highly significant ($p < 0.01$) difference on the non-marketable tuber weight (<30 kg/ha) in both of the cropping seasons (Table 1). the maximum non-marketable tuber weight (<30 kg/ha) of tested genotype was from CIP312897.548 (3.25 kg/ha) genotype followed by CIP312911.508 (3.144 kg/ha) and the minimum was from CIP312901.638 (1.83 kg/ha) genotype. The variation in tubers weight may be attributed to inheritability of genotypes and season.

Total tuber yield (kg/ha). The result of analysis of variance revealed that genotypes highly significant ($p < 0.01$) difference on Total tuber yield in both of the cropping seasons (Table 1). Regarding of Total tuber yield, the yield performance of genotype (CIP312923.522) showed the highest (41/51 kg/ha) total tuber yield followed by CIP312906.575 (42.83 kg/ha) and CIP312897.548 (41.51 kg/ha) while the lowest total tuber yield was recorded from CIP312901.638 (19.99 kg/ha) genotype (Table 2). **Yield** differences **among** these **genotypes** may **therefore** be related to genetic makeup in efficient **use** of inputs **such as nutrients**. Accordingly, Raphael (2022), Abebe Chindi *et a*l. (2021) Abebe Chindi *et al*. (2020); Awoke *et al*. (2021), Binod *et al*. 2020, Getachew *et al*. (2016), Getie *et al*. (2018) and Ebrahim *et al*. (2018) reported a significant variation of potato genotypes for their total tuber yield.

Table 2. Combined mean of potato genotypes on agronomic traits and tuber yield of over two years.

Genotype	PU	PV	DM	PH	NMTC1	NMTCII	NNoMTP	MTWCI	MTWCII	NoMTWP	TTW
CIP312921.550	7.500^{il}	6.500^{c}	110.5^{a}	63.56^{cde}	47.00^{c}	39.25^{de}	45.25^{bc}	20.68^{fg}	8.228^{bcd}	2.568^{c-f}	31.48^{ef}
CIP312926.502	4.500^{bc}	5.000^{abc}	110.2^{a}	52.42^{abc}	33.50^{f}	16.00^{h}	26.50^{f}	23.18^{def}	3.377^{hi}	1.884^{hi}	28.44^{f}
CIP312923.522	6.500^{hi}	7.000^{c}	110.0^{a}	65.66^{e}	64.00^{a}	44.50^{bc}	47.75^{ab}	35.25^{a}	9.196^{abc}	2.969^{abc}	47.41^{a}
CIP312923.562	5.000^{cde}	7.500^{c}	109.0^{a}	65.73^{e}	34.50^{ef}	48.25^{ab}	39.50^{de}	19.76^{fg}	9.582^{ab}	2.011^{ghi}	31.35^{ef}
CIP312920.538	3.500^{a}	5.500^{abc}	109.5^{a}	55.13^{b-e}	39.75^{d}	28.00^{fg}	39.50^{de}	29.65^{bc}	6.002^{fg}	2.531^{c-f}	38.19^{cd}
CIP312927.550	6.000^{gh}	5.000^{abc}	111.0^{a}	62.53^{b-e}	27.75^{g}	37.25^{e}	40.75^{cd}	13.98^{i}	7.276^{def}	2.796^{a-e}	24.05^{g}
CIP312916.591	6.500^{g-j}	6.500^{c}	110.0^{a}	60.32^{b-e}	41.25^{d}	25.25^{g}	36.00^{de}	24.93^{de}	5.388^{g}	2.260^{f-i}	32.58^{ef}
CIP312897.548	5.500^{c-g}	7.000^{c}	108.8^{a}	64.05^{de}	53.00^{b}	41.00^{cde}	37.50^{de}	29.58^{bc}	8.678^{a-d}	3.258^{a}	41.51^{bc}
CIP312898.640	4.000^{ab}	6.500^{c}	108.0^{a}	60.22^{b-e}	40.75^{d}	42.25^{cd}	51.75^{a}	17.93^{gh}	7.784^{cde}	2.924^{a-d}	28.64^{f}
CIP312911.508	7.500^{ijl}	7.000^{c}	111.2^{a}	58.05^{b-e}	52.25^{b}	51.75^{a}	45.50^{bc}	26.66^{cd}	10.133^{a}	3.144^{ab}	39.93^{bc}
CIP312906.575	4.500^{bcd}	6.500^{c}	109.8^{a}	54.18^{a-d}	46.50^{c}	31.75^{f}	35.25^{de}	32.90^{ab}	7.466^{c-f}	2.467^{d-g}	42.83^{b}
CIP312896.509	6.500^{g-k}	4.000^{ab}	110.0^{a}	51.63^{ab}	37.75^{def}	24.00^{g}	34.75^{e}	25.55^{de}	6.098^{efg}	2.759^{b-e}	34.41^{de}
CIP312905.530	7.000^{h-l}	6.500^{bc}	108.5^{a}	56.18^{b-e}	50.50^{bc}	36.75^{e}	37.00^{de}	30.00^{bc}	8.044^{bcd}	2.517^{c-f}	40.56^{bc}
CIP312901.638	5.000^{b-f}	3.500^{a}	111.8^{a}	43.95^{a}	26.00^{g}	12.50^{h}	18.00^{g}	15.45^{hi}	2.706^{i}	1.831^{i}	19.99^{h}
Belete (St.ck	6.000^{e-h}	6.000^{bc}	109.8^{a}	62.56^{b-e}	39.00^{de}	26.25^{g}	24.75^{f}	22.59^{ef}	5.002^{gh}	2.351^{e-h}	29.94^{ef}
Mean	5.700	6.00	109.87	58.41	42.23	33.65	37.32	24.54	7.00	2.55	34.09
CV%	11.2	24.7	2.8	11.6	7.2	9.0	9.5	10.3	17.1	12.7	8.2
LSD	0.9199	3.032	4.516	9.780	4.419	4.361	5.140	3.660	1.733	0.470	4.062

Keys: DM=days to maturity, PH=plant height, PU- plant uniformity, PV= plant vigor, NMCTI=Number marketable tubers category I, NMCTII= Number marketable tubers category II, MNoMTP= Number of non-marketable tubers/plot, MTWCI= Marketable tuber weight category I, MTWCII= Marketable tuber weight category II, NoMTWP= non-marketable tuber weight

Conclusion and Recommendations

Screening helps in ongoing efforts to select the best genotypes**.** In order to increase the productivity of potatoes in research and similar agroecological fields**,** it is recommended to consider the characteristics of the best varieties with high yields and market dominance. In this study, genotypes showed a significant difference in most of the studied parameters. the yield performance of genotype (CIP312923.522) showed the highest (47.41 kg/ha) tuber yield followed by CIP312906.575 (42.83 kg/ha) and CIP312897.548 (41.51 kg/ha). Hence this implied that, both genotypes were recommended to be promoted to variety verification trial in the coming year for further evaluation at on-farm and on-station in the study area and similar agro ecologies.

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2.8. Adaptability and Performance Evaluation of Hot Pepper (capsicum species) varieties for Growth and Pod Yield in Dollo-ado district, Somali region, Ethiopia

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Abstract

Hot pepper is one of the most important vegetables and spice crops cultivated in many parts of the country. Despite its economic, nutritional, and medicinal purposes, no research was done so far on this crop in the study area. Therefore, this study was initiated to investigate the performance of different varieties of hot pepper for growth and green pod yield at the study area. a field experiment was carried out in Dollo-ado, Eastern Ethiopia during 2021. The experiment was laid out in a randomized complete block design with three replications. Treatments included five hot pepper varieties (Melka Zala, Melka Awaze, Melka Shote, Oda Haro and Kume) varieties against one Commercial variety (HarbadF1)). Analysis of variances (ANOVA) revealed that varieties differed significantly ($P \leq 0.05$) in number of branches per stem, fruit diameter, fruit length, number of pods per plant, marketable green pod yield, un-marketable green pod yield and Total green pod yield but had no significant effect on days to first harvest and number of flowers per plant. As a result, the highest number of branches per stem attained was from Kume, while the highest number of pods per plant was recorded in Oda haro. The highest fruit length attained was from Melka awaze variety. On the other hand, the widest fruit diameter was recorded at HarbadF1 varieties; where the thinnest fruit size of was attained at Melka Shote. the highest marketable green pod yield(kg/ha) of hot peppers was recorded in Oda haro, Melka Shote, and HarbadF1 respectively. The highest un-marketable green pod yield(kg/ha) observed was from Kume variety; while the lowest was from Oda haro variety. the highest total green pod yield was exhibited by Oda haro (5033kg/ha) followed by Melka Shote (4183 kg/ha) variety. So, varieties Oda haro and Melka Shote were high yielder under the study area, so it would be highly recommended under irrigation conditions at Dollo-ado as well as similar growing vicinity. Since this study was done one seasons at one location; it would be advisable to conduct further research across location and year.

Keywords: *adaptability, Hop pepper, green pod yield*

Introduction

Pepper (Capsicum spp) is a spice crop and one of the most important spices in terms of world trade. It is a pungent spice and a stimulant which has been cultivated due to its high value for centuries (Poulos, 1993). Pepper is known with the famous scientific name; Capsicum and it belongs to the genus of flowering plants. Pepper originated from America with their cultivation now grown all around the world because they are widely used as food and medicine (Mazourek *et al*., 2009). Capsicum has two important species: Capsicum annum (sweet pepper) and Capsicum frustescens (Hot pepper).

Capsicum is a high value crop used as vegetables and spice in Ethiopia. Different pepper types such as bell (sweet) pepper which is non -pungent, chili (mitimita) and hot pepper (berbere) which is pungent are produced in which hot pepper is dominantly produced. The pungency is due to high capsaicin (C 18 H 27 O 3 N) content in the fruit. It is important in local dishes, karia, berbre and processing industries (coloring agent); it is exported in the form of oleoresin (red pigment) and ground powder in different forms (Girma *et al*., 2001). Capsicum is grown in most part of the county. Peppers are a warm-season crop and require similar growing conditions as tomato and eggplant. The crop grows at wide range of altitudes with rainfall between 600-1250 mm per annum. Seeds germinate best at 25-30°C. Optimal temperatures for productivity range between 18-30°C.

Peppers are tolerant to a wide range of soil conditions. Peppers are very important in fresh and processed forms along with different spices for daily consumption (Dessie and Birhanu, 2017). Pepper requires a hot and dry climate free of frost and suitable agroecological areas. The ideal altitude range for pepper production is between 1000 and 1800 metres above sea level (m.a.s.l.). However, fertile medium loams and well-drained soils with a pH of 5.5-6.8 are generally considered most suitable (Brandenberger *et al*., 2012).

In Ethiopia, it has a great economic importance both for small holder farmers and export earnings (Beyene and David, 2007). It is a high value crop used as vegetable and spice crops around the world for its pungent flavor and aroma (Obidiebub *et al*., 2012). Because it is wide accepted in the Ethiopian diet, it is an essential traditional crop mainly used for its pungency and color (Molla e*t al*., 2019). Hot pepper is the second most important vegetable in the world next to tomato (Berhanu *et al*., 2011). It is a great source of vitamins and minerals, including vitamins A, E, and C, which are essential for human health (Bosland and Votava, 2000).

The present situation indicates that in study area there is no improved hot pepper varieties but there is one local variety named "*Qaji*" by local growers, as a result, varietal information for the improvement of the crop for high fruit yield and quality in the existing agro-ecology is insufficient. There has also been no research on evaluation of hot pepper which enables the growers to select the best performing varieties in the study area. Introduction and selection for best adaptable varieties with high yield and quality as well as resistant to major diseases is therefore a priority and quick approach to contribute towards alleviating the existing problems of obtaining the desired varieties. Better adaptable and well performing variety (varieties) with improved cultural practices could be a possibility to boost quality and marketable production of the crop, so that the farmers benefited by cultivating those adaptable improved verities in the study area. Therefore, present study was initiated with the objectives of investigating the performance of different varieties of hot pepper for growth, green pod yield and recommend adaptable and high yielding variety/ies for the study area.

Materials and Methods

Experimental Location and Experimental Material

The experiment was conducted in Dollo-ado Agricultural Research Center during 2021 main cropping season. five improved large pod hot pepper varieties collected from Melkassa and Bako Agricultural Research Centers viz Melka Zala, Melka Awaze, Melka Shote, Oda Haro and Kume varieties were evaluated against one Commercial variety (Harbad F1) .

Experimental design and management

The experiment was laid out in randomized complete block design (RCBD) with three replications. The seed of all pepper varieties was sowed on nursery bed size (1 m x 5 m) separately, the seed bed was covered with a dry grass for 20 days. Then, beds covered by raised shade to protect the seedling from strong sun shine and heavy rainfall until the plants was ready for transplanting. Agronomic practices were done as crop requirement in the nursery. The seedlings were transplanted and planted at spacing of 30 cm x 70 cm between plant and row respectively to the main field after attaining stage for transplanting on (12-15 cm height and or at 45-60 days after sowing) with 10 plants per row. The plot size was 3 m x 3 m = 9 m^2 with a total of 40 plants per plot. The spacing of 0.5 m and 1.5 m was used between plots and between blocks respectively. Field layout was done according to treatments and design. DAP was applied at the rate of 200 kg/ha before transplanting and urea at the rate of 100 kg/ha was side dressed in split application where 50% of urea was applied after 21 days of transplanting and the other 50% at one and half month after transplanting. Other pertinent agronomic and horticultural practices applicable to hot pepper were also followed in the field based on the recommendation. Harvesting was done when the green pods have got firm green mature pods from two middle rows. After harvest, the pods were weighed immediately before shrinking and then yield and quality data was recorded.

Data Collection and Data Analyses

Ten plants were randomly sampled from middle three rows. The number Days to 50% emergence was recorded when half of the seedlings per net plot area emerged. The number of days where 50% of the selected plants started blooming beginning from the days of transplanting was used to measure days to 50% flowering. Number of flowers per plant was recorded when the 10 sample plants attained 100% flowering stage from each plot. Number of branches per stem was recorded randomly from primary, secondary and tertiary branches per stem of the selected 10 middle row plants at final harvest stage. While, the remaining measurements were taken on plot basis. The numbers of days from transplanting to the date of first harvest was recorded from 10 sample plants selected from two central rows to measure Days to first harvest. Mean number of red ripe fruits of individual plants from two central rows for each plot at each harvest was recorded to measure Number of pod per plant. Pod length (cm) and Diameter was taken as Average fruit length and diameter on 10 plants from two middle rows per plot respectively. Marketable green pod yield (MGPY) (kg/ha) was determined at each harvesting by sorting green pods according to color, shape, shininess, firmness and size of the fruits. After drying, the green marketable pods will be separated, the weight of the respective categories was recorded and converted to tone per hectare. Unmarketable green pod yield (uMGPY) (kg/ha) was obtained by sorting the diseased, discolored, shrunken shape and small sized, totally unwanted pods by consumers from randomly sampled and pre-tagged marketable dried pods was recorded at each harvest and converted to tone per hectare. Total green pod yield (TGPY) (kg/ha) was taken as Weight of total (marketable and unmarketable) pods harvested at each successive harvesting from randomly sampled and pre-tagged plants was recorded and summed up to estimate yield per hectare.

The collected data were subjected to analysis of variance using GenStat computer software (15) and Least Significant Differences (LSD) was used to compare the varieties using the procedures of Fishers protected at the 5% level of significance.

Results and discussion

Growth and Phonological Parameters

Days to 50% flowering: From analysis variance, the six tested hot pepper varieties didn't significantly affected days to flowering (Table 2). The maximum days to flowering was recorded for variety Melka zala (102.7 days) and the minimum days to flowering observed was from haybard F1 variety (102.0days) and the grand mean being 102.11 days (Table 1).

Number of flowers per plant: From analysis variance, Number of flowers per plan was non-significantly influenced by varieties (Table 2). The maximum Number of flowers per plant of tested varieties was 7.200 for 'Melka awaze' and the minimum was 6.267 for 'Oda hara' (Table 1).

Number of branches per stem: the analysis of variance revealed that variety showed highly significantly ($P \leq 0.01$) difference on Number of branches per stem (Table 2). the highest Number of branches per stem (7.167) was obtained from 'Kume' variety followed by 'Melka awaze' (6.533), while the lowest was recorded for HaybardF1 (4.133) variety. Higher branch counts mean more potential fruit production opportunities**.** This may be due to different plant canopy and growth habits among the same crop varieties**.** This is in line with the previous findings of Shamil and Merga (2022); Melaku *et al*. (2015) and Kibiru *et al*. (2021), who reported a significance variation of number of branches per plan among studied hot pepper varieties.

Days to first harvest: regarding, days to first harvest varieties exhibited non-significant affect (Table 2)**.** The longest days to first harvest was obtained from Melka awaze (180.3 days) and the fastest days to first harvest was from Melka zala (179.0 days). the major difference between cultivars in terms of days to maturity may be genetic factors that advance or delay the crop life cycle**.** This is in line with the work of Munda and Shumbulo (2020), that reported variation maturity date on hot pepper varieties.

Table 1. Mean phonological, growth traits and yield component as affected by different hot pepper varieties at dollo-ado research center (2022).

Varieties	DF	NFPP	NBPS	DFH	NPPP	PL	PD	MGPY	UMGPY	TGPY
HarbadF1	102.0^{a}	6.067^{a}	4.133^{c}	180.0^{a}	10.90^{c}	7.033^{a}	2.867^{a}	3752^{b}	131.7^{b}	3884^{b}
Melka zala	102.7^{a}	7.033^{a}	6.267^{ab}	179.0^{a}	12.80^{b}	6.033^{cd}	2.300^{bc}	3143^{c}	71.4^{c}	3214^{c}
Oda haro	102.0^{a}	6.267^{a}	4.767^{bc}	178.3^{a}	15.30^{a}	6.900^{ab}	2.633^{ab}	4978^{a}	55.6^{c}	5033^{a}
Kume	101.3^{a}	6.667^{a}	7.167^{a}	180.0^{a}	14.77^{a}	5.500^{d}	2.167^{c}	2892^{c}	190.5^{a}	3083^{c}
Melka awaze	102.3^{a}	7.200^{a}	6.533^{a}	180.3^{a}	14.40^{a}	7.533^{a}	$2.367b^{c}$	2714^{c}	177.8^{ab}	2892^{c}
Melkashot	102.3^{a}	6.967^{a}	5.900^{ab}	180.0^{a}	12.20^{bc}	6.600^{bc}	$2.267b^{c}$	4041^{b}	141.3^{b}	4183^{b}
Mean	102.11	6.70	5.79	179.61	13.39	6.600	2.433	3587	128.0	3715
CV%	1.0	9.1	15.5	0.7	5.9	5.6	9.6	8.9	20.0	9.0
LSD	1.839	1.111	1.637	2.245	1.427	0.6701	0.4267	578.7	46.48	608.8

Keys: CV=Coefficient of Variation, LSD= Least Significant Difference. Means followed by different letters within columns are significantly different by Duncan's new multiple range test (P = 0.05), DE=days to emergency, DF=days to flowering, DFH=days to first harvest, NFPP= number of flowers per plant, NBPS= number of branches per stem, PL= pod length, PD= pod diameter, MGPY= marketable green pod yield, UMGPY= un-marketable green pod yield, TGPY= total green pod yield.

Yield Components

Number of pods per plant: The analysis of variance revealed that, varieties had highly significantly ($p<0.01$) influence on number of pods per plant. The highest number of pods per plant (15.30) was recorded in 'Oda haro' variety followed by 'Kume' and 'Melka awaze' while the minimum number of pods per plant recorded was (10.90) for 'HarbadF1' variety and the mean being (13.39) (Table 1). Differences in the number of pods per plant between cultivars may be due to cultivar differences. Shamil and Merga (2022); Munda and Shumbulo (2020); Melaku *et al*. (2015) and Kibiru *et al*. (2021), also reported difference of pods per plant in studied hot pepper varieties

Pod length (cm): According to the analysis of variance, number of pod length was highly significantly ($p<0.05$) influenced by the tested varieties (Table 3). The mean separation indicated that, the maximum pod length (7.533 cm) recorded was for 'Melka awaze' variety followed by 'HarbadF1' (7.033 cm) and the minimum was obtained in 'Kume' (5.500 cm) and the mean bieng (6.600 cm). The significant difference in fruit length between pepper cultivars could possibly be attributed to genetic traits. This result corroborated the findings of Shamil and Merga (2022); Kahsay (2017); Haileslassie *et al*. (2015); Seleshi *et al*. (2014); Munda and Shumbulo (2020); Melaku *et al*. (2015); Yemane (2017); Shushay and Haile (2019) and Kibiru *et al*. (2021)

Pod diameter (cm): Effect of variety showed highly significant difference ($p<0.01$) on Pod Diameter (Table 3). The mean separation indicated that, the maximum pod diameter was observed in 'harbadF1' (2.867 cm) followed by 'Oda haro' (2.633 cm) and the minimum was recorded in 'Kume' (2.167 cm) and the mean being (2.433 cm). Shamil and Merga (2022); Shamil and Merga (2022); (Kahsay, (2017); Munda and Shumbulo (2020); Yemane (2017); Shushay and Haile (2019) also reported similar results.

Marketable green pod yield (kg/ha): Table 2 revealed that Marketable green pod yield was highly significantly ($P<0.01$) influenced by the tested varieties. Accordingly, the highest Marketable green pod yield was observed in 'Oda haro' (4978 kg/ha) followed by 'Melkashot' (4041 kg/ha) and the lowest Marketable green pod yield was obtained from 'Melka awaze' (2714 kg/ha); which was significantly at par with 'Melka zala' and 'kume'. Variation in market yields of these cultivars may be due to differences in genetic traits. this result was in agreement with the finding of likewise, Munda and Shumbulo (2020); Yemane (2017); Melaku *et al*. (2015); Yemane (2017) and Shushay and Haile (2019).

Un-Marketable green pod yield (kg/ha): As that of the Un- Marketable green pod yield of the hot pepper varieties revealed highly significantly (P<0.01) difference (Table 2). The highest un-Marketable green pod yield was observed in 'Kume' (190.5 kg/ha) followed by 'Melka awaze' (177.8 kg/ha) and the lowest un-Marketable green pod yield was from 'Oda haro' (55.6 kg/ha). This current result was supported by the findings of Melaku *et al*. (2015) and Yemane (2017).

Total green pod yield (kg/ha): Analysis of variance showed that total green pod yield was highly significantly (P<0.01) influenced by the tested varieties. The highest mean of total green pod yield **(**5033 kg/ha) was recorded from 'Oda haro' variety followed by 'Melka shot' and 'Harbad F1' and the lowest mean of total green pod yield was obtained from 'Melka awaze' (2892 kg/ha); which was significantly at par with 'Kume' and 'Melka zala' variety. This is associated with excellent vegetative growth such as number of branches, pod length, pod diameter and pod number**.** etc. This result also supported by Dessie & Birhanu (2017); Shamil and Merga (2022).

Conclusion and Recommendations

Variety evaluation for adaptation is one of the most important mechanisms to select best varieties and demonstrate and disseminate the technology to the farmers easily. The results of the study showed that almost all parameters considered were significantly affected by variety, with the exception of days to flowering and days to first harvest.Yield-related traits were also greatly influenced by certain cultivars in the growing environment. Oda haro' (5033 kg/ha**)** followed by 'Melka shot' (4183 kg/ha) and 'Harbad F1' (3884 kg/ha) achieved the highest total green pod yield record and the lowest mean of total green pod yield was obtained from 'Melka awaze' (2892 kg/ha**)**. Therefore, we have concluded that, variety Oda haro and Melka shot has adapted in the study area compared to other varieties. Therefore, until other or new varieties introduced to the areas, variety Oda haro and Melka shot is recommended for production to the farming community in the study areas. Further study should be carried out with other varieties, years and location in order to improve hot pepper production under the study area and similar agro-ecological areas.

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3. Soil and Water research directorate




3.1. Performance Evaluation of Gully control Measures implemented at Karamarda Watershed, South Jigjiga District, Somali Region

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Abstract

Land degradation in the form of soil erosion is a serious global, regional, national, and local challenge to agricultural productivity and overall economic growth for which immediate and long-term control mechanism is momentous by using various interventions including physical structures like check-dams and weir structures. Such interventions require continuous evaluation of theirbiophysical, technical, and socio-economic performance. Hence, study was aimed to evaluate the biophysical and technical performance of the gully control measures implemented at Karamarda watershed, South Jigjiga district. Due to lack of sufficient bench mark data the study subjected to use a participatory approach of data collection through field measurement and observations, focus group discussions, and key informants' interviews (KIIs). In addition, performance indicator criterion approach was applied. The study revealed that the amount of soil deposited behind the structure's ranges between0.2-0.90 m and 0.4 -1.5 m depth in hilly grazing land and cultivated land respectively. in addition,crop yield was increased by 15%. Similarly, surface water availability, moisture retention, and vegetation cover were increased. Furthermore, the soil erosion was decreased and gullies stabilized and changed into cultivated land. However, ground water utilization showed no change indicating that there was no wells and irrigation schemes available in the study area. From the technical parameters, vertical interval between every two successive check-dams exceeded the standard mean layout that showed p-value of 0.002. Moreover, there was limitation of repair, maintenance, and management of the implemented structures in the study area. Based on the finding of this study, the implemented Control measures were effective if properly managed and maintained.

Key words: *land degradation, performance evaluation, gully control measures, Karamarda watershed, Eastern Ethiopia.*

Introduction

Land degradation is a serious global constraint. Globally, 2 billion ha of agricultural land, pasture, and forest and woodland have been degraded since 1950 (Scherr and Yadav, 1996), and 5-10 million ha of global arable landare lost every year to severe degradation. With this regard, 1.4-2.8% of the total agricultural, pasture and forest land will be lost by 2020 If such a trend remains the same (Scherr and Yadav, 1996). In addition, estimates declared that that degradation of crop land and pasture seems to be most extensive in Africa, affecting 65% of crop land area and 31% of pasture land, compared to 51% and 14% in Latin America and 38% and 20% in Asia respectively (Scherr and Yadav, 1996).

The immediate consequence of land degradation is reducing crop yields, which leads to economic decline and increasing social stress (Mekuria *et al.*, 2007). Periodic low soil moisture due to erratic and poorly distributed rainfall, severe soil loss by run-off and resultant low soil fertility are the prominent factors associated with land degradation causing low agricultural production (Hurni *et al*., 2005). In addition, subsistence agriculture that has extended into marginal lands due to increasing population is also aggravating land degradation as well as damaging and threatening the long-term viability of the environment and agricultural production. Land degradation in the form of soil erosion and declining soil quality seriously challenges agricultural productivity and overall economic growth of the country (Mekuria *et al*., 2009).

In order to alleviate both the erosion and low crop productivity constraints various SWC measures have been implemented in Ethiopia since the 1970s. The impacts of physical SWC measures can be classified into short- and long-term effects based on the time needed to become effective against soil erosion (Mekuria *et al*., 2009). According to Bosshart (1997), the short-term effects of stone bunds are the reduction in slope length and the creation of small retention basins for run-off and sediment. These reduce the quantity and eroding capacity of overland flow. Such effects appear immediately after construction of the stone bunds and reduce soil loss. The medium- and long-term effects include the reduction in slope angle by formed bench terraces, development of vegetation cover on the bunds and gullies, and change in land management (Mekuria *et al*., 2009). Based on the studies of the soil conservation research project in other parts of Ethiopia, Herweg and Stillhardt (1999) stated that well-established mechanical SWC measures retain most of the soil eroded in between the structures. Such studies, however, may not be applicable to old conservation measures on a catchment scale as most of these studies were conducted on erosion plots that concerned well-managed and young structures. In addition, different gully control structures have been implemented at Karamarda watershed, however their performance status have still remained unstudied. Therefore, this study was investigated the biophysical and technical performance of the gully control measures implemented at Karamarda watershed, South Jigjiga district Somali region. Hence, this project is aimed to evaluate biophysical and technical performance of gully control measures implemented in the study area.

General methodology of the study

Location of the study

The study was conducted at Karamarda Watershed, South Jigjiga district, Somali region. The watershed drains from the ridge of Karamarda mountain, west of Jigjiga city and continues until it joins to the upper Jarer Valley. The watershed encompasses two Kebelles of Shabelley district known as Bolidid and Amadle.

Data sources and methods of data collection

Since, sufficient benchmark data was not available before implementing the project in respect to Karamarda watersheds; it was decided to adopt a participatory approach of data collection and performance indicator criterion. Both primary and secondary data were collected. The primary data/information was collected based on field measurement, observations during the field visit (kind of topographic transect walk), focus group discussions (FGDs) with local community and key informants ’interviews (KIIs) with all the stake holders and staffs of the project implemented institutions/organizations. In addition, performance indicators were used to evaluate the impacts of the implemented interventions on biophysical aspects. Furthermore, the secondary data/information was collected from available published and unpublished documented related to the subject matter of the study.

Field observations and transect walk

Topographic transect walk method was employed for the assessment of natural resources and existing conservation measures in the watershed. During the transect walk, observations and appraisals of the impact of the existing SWC measures, level of erosion, and types of conservation measures implemented at different land use types were recorded.

Field measurements

The field measurement was undertaken to collect the data related to the amount of sediments deposited behind the structures and the construction dimensions of the structures by using tape meter.

Interviews

Focus discussion groups comprised of twelve individuals having various social groups including elders, women, and youth were selected from upper, middle, and downstream and then interviewed. In addition, key informants (woreda experts, kebele developmental agents and administrators, and NGO staffs were interviewed.

Performance Evaluation of biophysical Indices

Biophysical indicators such as reduction of soil loss and inflow runoff water, and increasing moisture retention, surface/ground water availability, increased cultivable land, and crop yield improvement were used to evaluate the performance of the implemented structures as applied by Kirubel and Gebreyesus (2011).

Table 1. Performance evaluation criterion

Performance criterion	Performance indicators	Indicators used for this study
Extent of soil loss and runoff	Measurement of erosion and associated yield loss Sediment deposition rate Presence, expansion and development of new active erosion features by slope, soil and land use types	Sediment deposition rate Presence, expansion and development of new active erosion features.
Soil moisture retention	Relative change in yields and biomass. Time series, intra- and inter year variations in soil moisture using measuring instruments. Laboratory analysis before and after implementation	Relative change in yields.
Surface/ground water availability	Surface water storage	Surface water storage

	Number of wells Existence of ground water sources irrigation schemes	Number of wells dug Existence of ground water sources irrigation schemes
Change of land use, biomass, and yield	Using land use change dynamics Relative change in farm land area Change vegetation cover Gully stabilization	Relative change in farm land area Change in vegetation cover by using interviews Gully stabilization

Data analysis

The data related to the layout of the implemented conservation measures were compared with stand layout of check-dam design and analyzed by using one sample t-test in SPSS 23.0 version software. Moreover, the qualitative data was summarized and interpreted qualitatively.

Results and Discussions

Typical gully control measures implemented in the study area

Various types of gully control measures have been implemented at the study watershed since 2012 without enough participation of the local community. The implemented measures were gabion check-dams and weir Structures. According to FGD, the employed interventions were executed by SRS, Bureau of agriculture and GIZ through top-down approach with no much consideration bottom-up community-initiated approach. The gabion check-dams were implemented at the upper watershed from the head cut across the gullies, where weir structures were installed across the gullies in the cultivated land. Nevertheless, the structures have great visible impacts along with their variation in age and need for further management as witnessed during field observation. Yet, the local farmers believed that they benefited from the structures in reducing soil loss and runoff, increasing soil moisture thereby improved crop yield and livestock.

Biophysical performance of the implemented gully control measures

In this study, the consequences of implemented measures in the study area were assessed to evaluate the impacts on soil, water (moisture), reduction of soil and water losses with run-off by using performance indicators due to lack of enough data before the implementation of the project. The study revealed that soil accumulated along the check dams was up to 0.9m and 0.4 to 1.5 m in deep gabions and weirs respectively (table 2). It was also observed that the sediment depth varied according to the typical check-dam applied, slope and sediment source area. For instance, the soils accumulated in check-dams in down watershed cultivated land were deeper than that of upper watershed. Similarly, moisture retention in gully bed increased as indicated by the different plant species spread and filled on the gully floor behind the gabion check-dams and the increment of yield by 15% in the gully bed installed with weir structures while rainfall was same as before the implementation (table 2).

Likewise, the Erosion channels treated gabions were covered by vegetation and changed to grazing area with diversified plant species revealing that gully channels were changed vegetative grazing area. Also, the deep gullies treated with weir check dams became stabilized and changed to rainwater harvesting schemes and cultivated land. According to key informants the weircheck dams store water during first two years than filled by soil and became cultivated land that is grown various annual crops like maize and sorghum (table 2). According to focus group discussion, such structures increased their cropping pattern so that crops grown twice a year without use of irrigation showing that the moisture retention of the structures is high. Yet, implemented structures reduced the creation of new erosion channels within the treated gullies and to the sides for further expansion of the gully, which were good indicators for the performance of installed structures for reducing gully erosion (table 2).

Table 2. Performance of gully control measures in conserving soil, retaining moisture, reducing soil erosion, increasing yield and biomass, and changing land use pattern at land use types.

Land use types	**Soil conserved**	**Soil moisture retention**	**Soil erosion reduction**	**Change in land use type and increased biomass and vegetation cover**
Hilly grazing land	Gully bed behind the check-dams filled by soil ranging from 0.2-0.90 m	Different plant species spread and filled on the gully floor behind the check dams	Little gully expansion and development	Erosion channels covered by vegetation and changed to grazing area with diversified plant species
Cultivated land	Accumulated soil ranges 0.4-1.5 m depth.	Yield increased by 15% while rainfall is similar as before	No further new erosion channels are created or expanded within the gullies.	Gullies stabilized and changed to water harvesting schemes and cultivated land.

The implemented structures particularly weirs also increased the availability of water for rain-fed crops, and domestic and livestock consumptions. According to FGDs and KIIs, the water storage capacity was also increased storing the water around 6 to 8 consecutive months. In addition, the farmers were convinced that rehabilitated gullies greatly increased the amount of surface water. As shown by the qualitative result of this study, there was no change in ground availability after the rehabilitation of gullies and also irrigated agriculture was not conducted in the watershed (table 3). The increases in crop yield, biomass and diversity are due to more water availability and soil fertility restoration after the SWC measures for rain-fed crops. The rain-fed crops and grass cover is also prolonged by improvement in soil water content as witnessed by the farmers in the area. Additional indicators of the positive effects of the gully control measures are the rapid recharge of the water. This is because the time for infiltration has increased after installation check dams, which raises the water table level.

Table 3. Effectiveness of check-dams for water resources development

Performance standard	Water availability situation in the study area
Surface water availability and storage capacity	Increased surface water availability Rehabilitated gullies stored huge amount of water
Increased irrigated land	No irrigation used in the study area
Increased wells for ground water utilization	No wells available in the study area

Technical viability of check-dam structures

Evaluation of the fitness of implemented check-dams to the standard layout of the structure was done based on the data obtained from field measurement so as to confirm their technical viability. As indicated in table 4, Result showed that there was no significance mean difference between the measured design parameters (thickness, height, and widthof the spillway) of the installed check-dams and the mean of standard design except vertical interval between the check-dams, which had shown significant mean difference between the two layouts with the p-value of 0.002. If the vertical interval between every two successive check-dams exceeds the standard, the effectiveness of the structures might not as viable as expected.

Table 4. Technical viability of the implemented check-dams

Implemented Structure	SDM in meter	MDM in meter	T-test	P- value
Gabion check-dam				
Thickness	1.8	1.6	6.8	0.17
Height	1.8	1.5	-12.2	0.06
Vertical Interval	5	10	8.1	0.002
Width of the spillway	0.5-1	1.2	4.7	0.12

SDM is Standard design mean, MDM is measured design mean

Maintenance and management of structures

Regular maintenance and management are vital after the implementation SWC measures for ensuring their effective functioning. Though, majority of the implemented check-dams particularly upper watershed installed gabions accomplished their standard age of eight years, they still exist, but needs urgent maintenance for retaining their proper functionality. However, majority of the weir check-dams were still young and purely sustain their function. In addition, focus group discussants disclosed that the weir check dams in the cultivated land had better consideration in supervision and management of the initiatives compared to the gabions. As shown in figure 3, the gabion check-dams begun to destroy with absolute termination of their physical appearance and functionality. According to FGD, the weir structures in the cultivated land had better consideration in supervision and management of the initiatives compared to the gabion check-dams. However, the local beneficiaries have not endeavored any maintenance and believed that such activities are responsible by the government. Hence, there was limitation of repair, maintenance, and management of the implemented structures in the study area. Similar finding was reported by Yericho and Bena (2015) in Chena woreda, Ethiopia.

Conclusion and recommendations

This study evaluated the biophysical and technical performance of implemented Check-dams at Karamarda Watershed by using performance indicators and standard layout comparison techniques respectively. From the biophysical prospect, conserving soil, surface water availability, retaining moisture, crop yield, and vegetation cover were increased. Moreover, the soil erosion was decreased and gullies stabilized and changed into cultivated land. However, ground water utilization showed no change indicating that there was no wells and irrigation schemes available in the study area. From the technical parameters, vertical interval between every two successive check-dams exceeded the standard mean layout that showed the p-value of 0. 002.In addition, there was limitation of repair, maintenance, and management of the implemented structures in the study area. Based on the finding of this study, the implemented Control measures were effective if properly managed and maintained.

Therefore, the study suggested the following recommendation:

- Biological conservation measures should be implemented along with the physical measures

- Additional conservation measures like terraces, soil bunds, and fanajuu should be applied at the upper watershed, so that the groundwater availability can be increased.
- The vertical interval between every two successive check-dams should be decreased and reconstruct according to the standard interval.
- The soil and water conservation measures should be implemented through active community participation
- Additional study is required assessing the socio-economic performance of the implemented control measures in the study area.

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3.2. Evaluation of Furrow Irrigation Methods on Water Use Efficiency and Yield of Maize in Shebelle and Ganale Rivers of Somali Region

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Abstract

Water scarcity is a major constraint for the production of food in arid and semi-arid areas. Therefore, method of irrigation systems are important concerns to improve water use efficiency without significant yield loss. The objective of an experiment was evaluating the performance of furrow irrigation methods on Maize yield and water use efficiency. The treatments were three furrow irrigation systems and laid out randomized complete block design (RCBD) with three replications. The result revealed that, maize grain yield responded differently significantly across locations to different irrigation methods. The highest grain yield and water use efficiency were obtained from CFI and AFI respectively. from the result obtained highest yield was scored in conventional furrow irrigation water management method at Gode (1777.80kg/ha), Kalafo (2292.4 kg/ha) and Dolo-Addo (1805.30 kg/ha) and it has a significant difference with alternative furrow irrigation and fixed furrow irrigation water management methods. Maximum WUE was observed at Kalafo (7.64 kg/ha/m^3), Gode (4.17 kg/ha/m^3) and Dolo-ado (3.3 kg/ha/m^3) alternate furrow method was statistically higher than both conventional and fixed furrow methods. Therefore, it can be decided that Alternative furrow irrigation increased water use efficiency without significant yield reduction and it can solve the poor irrigation water application in the study areas. As well it will be solution for the environmental problems experienced in the study areas.

Key words: *Alternate Furrow; Crop Water Requirement; Maize; Water Use Efficiency*

Introduction

The rapid exponential inclination of population growth worldwide in general and in developing countries is forcing the environment to produce more food and cash crop to feed and enhance the economic development of the people. Water is an important factor for agricultural sustainability, financial development and environmental security. Water has been identified as one of the scarce inputs, which can severely restrict agricultural production and productivity unless it is carefully conserved and managed. There is a growing recognition that increases in food production will largely have to originate from improved productivity per unit water and soil (Hofwegen van and Svendesen, 2000). One of the limits in exploiting the water is the fact that though water looks cheap renewable natural resource, it is very expensive to transport it. Investment is required to convey water from where it is obtainable to where it is desired. Among all irrigation methods surface irrigation methods have a tendency to be require less assets but intensive labor. Along with the different surface irrigation methods, furrow irrigation is known to have high potential in conditions where water is scares.

According to (Michael, 1996) furrow irrigation dictates providing water to crops using narrow ditches running between rows of crops. As compared to other surface irrigation methods, furrow irrigation has many advantages, such as water contacts only one half to one fifth of the land surface there by reducing peddling and crusting and evaporation losses, possibility of earlier cultivation (a distinct advantage in heavy soils), reducing labor requirements in land preparation. These advantages make the system appealing to the farmers who are suffering from shortage of irrigation water, erosion problem, and labor shortage.

Most crops can be irrigated by furrow irrigation method except those grown in pounded water such as rice. The furrow method is particularly suitable for irrigating crops subject to injury if water covers the crown or stem of the plants, as the crops may be planted on beds between furrows (Michael, 1997). Furrow irrigation is characterized by low application efficiency (45-60%) and causes significant water losses, mainly due to excess application leading to deep percolation from the irrigated area (Raine and Bakker, 1996; Smith *et al*., 2018). The amount of water loss in furrow irrigation can be extensive under farmer's management. Water is lost in furrows as deep percolation or runoff as tail water.

Kang *et al*. (2000) conducted a field experiment on soil water distribution, irrigation water advance and uniformity, yield production and water use efficiency with a new irrigation method for maize in an arid area with seasonal rainfall. Irrigation will be applied through furrows in three ways: alternate furrow irrigation (AFI), fixed furrow irrigation (FFI), and conventional furrow irrigation (CFI). For alternate furrow irrigation one of the two neighboring furrows will be alternately irrigated during consecutive watering. For FFI, irrigation will be fixed to one of the two neighboring furrows. Every furrow will be irrigated during each watering for furrows using CFI. Each irrigation method will be further divided into three treatments using different irrigation amounts.

However, the amount and distribution of rainfall are not sufficient to sustain crop growth and development in Somali region. For this reason, river is used as a source of irrigation water. Community desires to irrigate extra lands under limited water resource. Therefore, in the arid and semi-arid area application of deficit irrigation could provide greater economic returns than maximizing yields per unit of water. The deficit irrigation could be considered as a way of maximizing water use efficiency (WUE) by applying a reduced amount of irrigation water, which has no significant impact on yield. Yet, there is a lack of studies about the application of deficit irrigation and the performance of irrigation systems in the region. Hence, this study aimed to investigate the performance of alternate furrow irrigation, fixed furrow irrigation and conventional furrow irrigation system on Maize (Malkas-2) yield in the Lower Shebelle and Ganale Rivers.

Materials and Methods/ Research Methodology

Description of the study areas

The study was conducted in Shebelle and Ganale-dawa riparian districts (Gode, Kalafo and Dolo-ado). The study was carried out at Gode, Kalafo and Dolo-ado experimental sites (5^o 94`N Latitude and 43$^o$ 56`E longitude; 5^o 58`N latitude and 44$^o$ 19`E longitude; and 4^o 24`N Latitude and 41$^o$ 24`E longitude) respectively. The annual average rain of the study areas ranges between 130-500mm. There are two main rainy seasons: *Gu* (April to early June) and *Deyr (*September to early November). The Agricultural production of the area is mainly dependent upon the rivers` water. Sandy clay loam soil textures are the dominant soils of the areas. The main crops mostly cultivated in the areas are Maize, Onion, Sesame and sorghum. In addition to tomato, hot paper and fruit crops are cultivated in the areas.

Treatments, experimental design, and field management procedures

Treatments were included three furrow irrigation methods (Conventional, Alternative & Fixed Furrow irrigations). The experimental treatments were design in Randomized complete design (RCBD) with three replications, in which furrow irrigation methods was randomly assigned to the experimental plots. The Maize seeds were planted at a spacing of 75cm and 25cm between and within rows. The blocks and plots were separated by 1m and 0.5 m. respectively.

Data Collection and Analysis

Growth Parameters of Maize

Plant height (cm): The height of five randomly select plants from each row was measured and the mean value was recorded as plant height.

Yield and Yield Components

Grain yield (kg ha^{-1}): This refers to the weight of grain harvested from the central three rows of the net plot. Grain yield was then converted in to adjust yield for the analysis by using this formula. **Adjusted yield=AGY-(AGY*0.1)**

Aboveground biomass (kg ha^{-1}): This was measured based on central three rows of the net plot plants at harvest time after sun drying, and was changed to per hectare using respective plant weight for each treatment.

Crop Water Requirement

Metrological data (minimum and maximum, temperature, relative humidity, wind speed and daily sunshine hours) was used to determine reference crop evapo-transpiration using modified FAO penman mountienth method. Therefore, CROPWAT 8.0 was used for the computation of the reference crop Evapo-transpiration (ETo) and crop water requirement (CWR) of maize in the study area (Gode, Kalafo and Dolo-ado). The reference crop evapo-transpiration (ETo) and Crop Water Requirement (CWR) of Maize for the selected areas were prepared. The Net irrigation water requirement was calculated by subtraction effective rainfall from the estimated crop water requirement. ETo was computed on monthly basis and CWR was computed for the growing period of the corresponding crops. Since there was no determined crop coefficient (Kc) so far in the region and particularly the study areas, the FAO recommended Kc values for Maize growth stages are used to calculate CWR. The local planting date of the crop had been used for the computation.

CWR=ETo*KC ………………………………………………………………….……… (1)

Effective rainfall was determined using USDA soil conservation service method to compute net irrigation requirement:

IR=CWR-Peff…………………………………………………………….…………… (2)

Water Use Efficiency

The discharge was measured using partial flumes installed at the entrance of the supply ditch channel and the upstream of inlet of the experimental furrows and the water application duration and amount were recorded:

T=Dap*l*w/60Q

WHERE: -T= water application depth (min), Dap = gross water application depth (mm), L= furrow length (mm), W=furrow width (m), Q=Discharge (l/s^{-1}). Similarly, the water use efficiency was calculated by using the following equation:

WUE= (Y/I) ……………………………….……. (3)

Where: WUE=Water use efficiency (kg/m^3) is the amount of Maize grain yield per meter cubic of irrigation water applied, Y=Yield of Maize (kg/ha) and I= Total irrigation water applied (m^3/ha).

Statistical Data Analysis

Soil and water analysis were determined according to Laboratory procedures. Analysis of variance (ANOVA) was used for agronomic and water use efficiency data. Irrigation water methods were interpreted and compared with Least Square of Differences (LSD) and 95% confidence level was considered statistically significant. Results of Growth, Yields and Yield parameters were analyzed using statistical GenStat software.

Result and Discussions

Soil chemical and physical characteristics of the experimental site

The textural class of Gode, Kalafo and Dolo-Addo were Sand clay, Sand clay loam and Sand clay loam respectively, according to the USDA soil textural classification. The Nitrogen, phosphorus and Available potassium of the experimental sites indicated low to moderate ranges (Table 1).

Table 1 Soil physical and chemical properties of the experimental sites

Soil property	**Experimental sites**		
Particle size distribution	**Gode**	**Kalafo**	**Dolo-Addo**
Sand (%)	50	50	56
Silt (%)	35	32	26
Clay (%)	15	18	18
Textural class	Sand clay	Sand Clay Loam	Sand Clay Loam
Bulk Density (gm/cm^{-3})	1.12	1.14	1.11
Organic matter (%)	1.45	1.38	1.67
pH	7.62	7.59	7.9
EC(dS/m)	0.07	0.05	0.10
Nitrogen (%)	0.11	0.10	0.12
Phosphorus (mg/kg)	6.51	5.58	7.74
Potassium (cmol/kg)	0.45	0.58	0.61

Source: Own survey

Effect of irrigation methods on Maize yield and yield components

Plant Height

The analysis of the variance revealed that Plant height was not significantly affected the different irrigation water management methods and experimental location (Table 2). The maximum plant height was observed for conventional furrow method in Gode (189.20cm) and Dolo-ado (166.07cm), in contrast Kalafo result indicated the highest plant height (138.33) was recorded in alternative furrow.

Whereas the minimum result was observed at fixed furrow method at Gode182.33 cm Kalafo 124.37 cm and Dollo-ado 151.73 cm. The maximum plant height recorded at conventional furrow method was not statistically superior to both fixed and alternate furrow methods in all locations (Table,6). This study supports the findings of Jemal and Berhanu, (2020), Gelu (2018), Meskelu*et al.* (2018), and Zelalem (2017), who found that conventional furrow irrigation leads to higher yield components and plant heights than alternate and fixed furrow irrigation methods.

Above Ground Biomass

The different types of furrow irrigation water management methods on maize at Gode have shown statistically significant ($p<0.05$) influence on aboveground biomass production. But, the alternative and fixed furrow water management method at Gode was not significantly different. However, Furrow irrigation water management methods on maize at Kalafo and Dolo-ado shown non-significant influence on aboveground biomass (Table 2). The highest aboveground biomass was observed at Gode (8018.90, kg/ha), Kalafo (5370.40kg/ha) and Dolo-ado (6518.50 kg/ha) on conventional furrow method. The maximum aboveground biomass obtained at conventional furrow method was statistically superior to both alternate and fixed furrow methods at all experimental locations (Table 2).

Contrary to this, minimum aboveground biomass was obtained at Gode (4370.40 kg/ha), Kalafo (3240.70 kg/ha) and Dolo-ado (5129.60 kg/ha) on fixed furrow irrigation method in all sites. The minimum aboveground biomass obtained at fixed furrow was statistically similar with that of alternate furrow irrigation method at Kalafo and Dolo-ado. The highest aboveground biomass of maize obtained at conventional furrow irrigation method lead to an improvement of 56.2% compared to the fixed furrow method. The result was in agreement with those reported by Bayisa (2021) and Mulugeta and Kannan (2015) on maize in which highest aboveground biomass and grain yield obtained under conventional furrow irrigation than the alternate and fixed furrow irrigation method.

Grain Yield

The furrow irrigation methods have significantly influenced the grain yield of maize per hectare production ($P<0.05$) from the result obtained highest yield was scored in conventional furrow irrigation water management method at Gode (1777.80kg/ha), Kalafo (2292.4 kg/ha) and Dolo-ado (1805.30 kg/ha) and it has a significant difference with alternative furrow irrigation and fixed furrow irrigation water management methods (Table 2). Contrary to this, minimum grain yield was obtained at fixed furrow irrigation method. The minimum grain yield obtained at fixed furrow irrigation water management method was not statistically similar with that of alternate furrow irrigation method which was attained high yield compared to the fixed furrow.

The highest grain yield of maize obtained at conventional furrow irrigation method led to an improvement of 55.1% than the fixed furrow method. The water application in alternative furrow irrigation treatments, showed the less reduction on yield, while that of water application in fixed furrow irrigation treatments showed the greatest reduction of yield 52%. The current finding is in line with Jemal and Berhanu (2020), Meskelu, *et al*. (2018) and Zelalem (2017), who found that conventional furrow irrigation leads to higher yield components than alternate and fixed furrow irrigation methods on Maize crop.

Effect of irrigation methods on maize water use efficiency

The result of furrow irrigation water management methods on maize have shown a very highly significant ($p<0.05$) influence on water use efficiency (WUE) (Table 2) in all locations. Findings indicated that the WUE of maize was higher under alternate furrow irrigation method as compared with conventional and fixed furrow method.

Maximum WUE was observed at Kelafo (7.64 kg/ha/m^3), Godey (4.17 kg/ha/m^3) and Dollo-ado (3.3 kg/ha/m^3) alternate furrow method was statistically higher than both conventional and fixed furrow methods. The pooled mean (5.1 kg/ha/m^3) of the locations recorded at alternative furrow irrigation method. While the minimum WUE (3.2 kg/ha/m^3) was observed at fixed furrow irrigation methods and, it was statistically lower to both alternate and conventional irrigation methods during growing season (Table 4). Some authors, like Kassaw (2011) and Jemal and Mukerem (2017), reported that alternate furrow irrigation has the highest irrigation water use efficiency of every furrow irrigation system.

Table 2 Analysis of Variance in Irrigation Methods Effect on Maize Crop Height, Biomass, Grain Yield and Water Use Efficiency at Godey, Kelafo and Dollo-ado, Somali Region.

		Plant Height (cm)			**Biomass (kg/ha)**			**Grain Yield (kg/ha)**			**WUE (kg/ha/m^3)**		
TRT	**Loc.**	Gode	Kalafo	Dolo	Gode	Kalafo	Dolo	Gode	Kalafo	Dolo	Gode	Kalafo	Dolo
CFI		189.20	126.80	166.07	8018.90^a	5370.40	6518.50	1777.80^a	2292.4^a	1805.30^a	3.6^a	5.09^b	3.25^a
AFI		182.47	138.33	158.4	5874.10^b	4518.50	5888.90	1537.00^a	1526.9^b	1758.50^a	4.87^a	7.64^a	3.34^a
FFI		182.33	124.37	151.73	4370.40^b	3240.70	5129.60	1074.10^b	1341.7^b	1357.80^b	2.52^b	4.47^b	2.51^b
CV (%)		4.99	5.97	4.77	13.68	17.27	20.36	12.5	11.73	5.33	12.52	11.73	5.36
LSD (0.05)		20.88	17.56	17.165	1888.2	1713.5	2697.6	414.52	457.32	198.2	0.97	1.52	0.36
MEAN		184.6	129.83	158.73	6087.8	4376.5	5845.7	1463	1720.3	1640.5	3.4322	5.7333	3.0356
P-VALUE		NS	NS	NS	**	NS	NS	**	**	**	**	**	**

Note: CFI, AFI, FFI, WUE, Trt, & NS, represents conventional, alternative, fixed furrow irrigations, water Use Efficiency, Treatment, & Non-Significant, ** implies 5% P level of significant difference. Means followed by the same letter within a column or row are not significantly different at 5% P level within parameter. Own Source (2022).

Interaction effect of different furrow irrigation methods on Maize grain yield and Water use efficiency

According to the result in table (3) there was a highly significant interaction effect irrigation method across locations at ($P<0.05$). The result revealed that, maize grain yield responded differently significantly across locations to different irrigation methods. Accordingly, the highest grain yield was obtained at Kelafo center when maize was irrigated with conventional irrigation method followed by Dollo-Addo location with the same irrigation method and the grain yield obtained at Godey was lower than both locations. Grain yield at Kelafo location increased by 23% compared to Godey and 21.2% compared to Dollo-Addo. However, the grain yield showed reduction at Kelafo center with alternative furrow irrigation at this irrigation method maize grain yield showed significant increment at Dollo-Addo center and increased grain yield by 12.5% compared to Kelafo.

Even though, grain yield increased at Godey center due to alternative furrow irrigation compared to Kelafo the increment was not statically significant. Grain yield recorded due to fixed irrigation was lower than both alternative and conventional furrow irrigation methods. The current finding is in agreement with Kedir and Getachew, (2020) who reported that grain yield of maize differed highly significantly ($p< 0.001$) among different types of furrow irrigation water management methods, where the highest grain yield of 9004 kg ha-1 was recorded from conventional furrow irrigation water management method. Similarly, Ekubay (2020) also reported the same result that conventional furrow irrigation resulted in higher grain yield compared to fixed and alternative furrow irrigation systems.

Table 3 The interaction effect of furrow irrigation methods with location on mean of Grain Yield and WUE of Maize

		Grain Yield (kg/ha)			***WUE (kg/ha/m3)***		
Treatment	**Location**	**Gode**	**Kalafo**	**Dolo**	**Gode**	**Kalafo**	**Dolo**
CFI		1777.8[b]	2292.4[a]	1805.3[b]	3.60[de]	5.09[b]	3.25[ef]
AFI		1537[bc]	1526.9[bc]	1758.5[b]	4.17[cd]	7.64[a]	3.34[e]
FFI		1074.1[d]	1341.7[cd]	1357.8[c]	2.52[f]	4.47[bc]	2.51[f]
LSD		281.85			0.81		
CV		10.13			11.57		
Mean		1607.90			4.06		
P (<0.05)		**			**		

Note: WUE=Water Use Efficiency, CFI, AFI, FFI= conventional, alternative, fixed furrow irrigations

The result on water use efficiency presented in table 8 according to the result water use efficiency (WUE) was highly and significantly affected by the irrigation method and locations (P<0.05). The maximum WUE was rerecorded from Kelafo center with alternative furrow irrigation systems while the minimum was recorded from Dolo-Addo center with fixed irrigation systems. Across three locations, WUE obtained from Kelafo was better and higher than both Gode and Dolo-Addo centers. WUE increased by 29.27 and 36.14% at Kelafo center with conventional furrow irrigation compared to Godey and Dolo-Addo centers respectively. Similarly, using alternative furrow WUE reduced by 45.41 and 56.28% at Gode and Dolo-Addo centers respectively compared to Kelafo center. The maximum water productivity of 2.43 kg/m3 observed at alternate furrow method was statistically superior to both conventional and fixed furrow irrigation methods (Kedir and Getachew, 2020).

Generally, alternate furrow irrigation system increased water use efficiency (WUE) with minor or no yield reduction as compared to conventional furrow irrigation method. The finding of this study similar to the result of the studies that concluded alternate furrow irrigation increases water use efficiency with minor or no yield reduction and save a substantial quantity of irrigation water (Nouri and Nasab, 2013; Ekubay, 2020). Results indicated that the water productivity of maize was higher under alternate furrow irrigation method than conventional and fixed furrow irrigation method (Kedir and Getachew, 2020).

The analysis of variance indicated that interaction effect of furrow irrigation methods had a significant effect at ($P<0.05$) with location on Grain yield and WUE of Maize (Table 3). Mean of Grain Yield (kg/ha) for each interaction of irrigation methods was shown increase as goes from CFI, AFI and FFI respectively. The highest of 2292.4 kg/ha 1805 kg/ha and1777.8 kg/ha and lowest 1074.1 kg/ha, 1341.7 kg/ha and1357.8 kg/ha were recorded by treatment combination CFI and FFI respectively as shown (Table 3).

Interaction effect of ANOVA Indicated that WUE was statistically significant at ($P \leq 0.05$) by interaction effect of furrow irrigation methods with locations. The highest WUE 7.64 kg/ha/m^3, 4.17 kg/ha/m^3 and 3.3 kg/ha/m^3 and the lowest 2.52 kg/ha/m^3, 2.5 kg/ha/m^3 and 4.47 were observed under AFI method in all location.

Conclusion and recommendations

Limited water resources availability is becoming the main challenge for sustainable crop production in arid and semiarid regions such as Somali region. Alternate furrow irrigation has been considered as a valuable and sustainable production strategy to improve maize yield and WUE in these regions. The CFI water management resulted in significant yield and Biomass improvement compared to AFI & FFI. While AFI water management resulted higher water use efficiency (42.3%) than CFI (32.1%) and FFI (25.6%). However, the yield recorded from CFI was not significantly greater than the AFI. Therefore, under no water scarce condition irrigation water could be used in conventional irrigation method to improve maize biomass and grain yield. Whereas, under limited irrigation water conditions alternate furrow could be practiced, which is found to be water use efficiency feasible for improving maize and water productivity in the study area and similar agro-ecology. Furthermore, Research about furrow irrigation methods and water application level should be undertaken.

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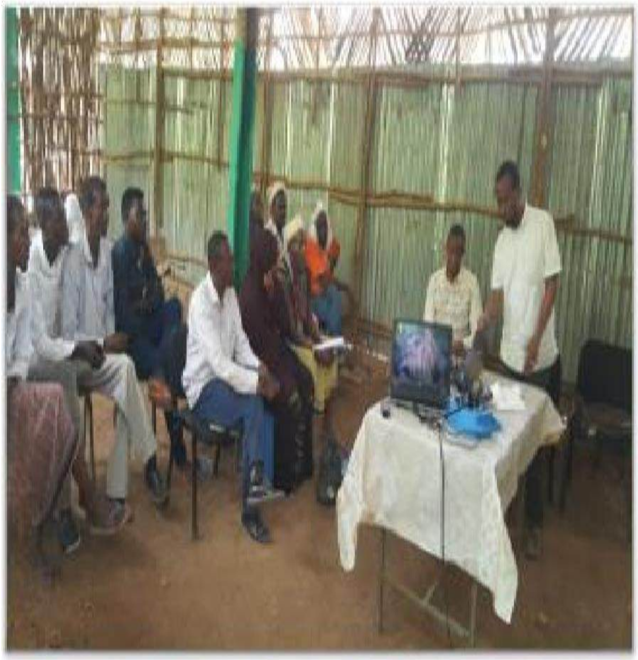
4. Agricultural Mechanization Research Directorate




4.1. Pre-extension Demonstration and Evaluation of Engine Driven Maize Sheller in Kelafo and Dollo Ado Woredas, Somali Region, Ethiopia

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Abstract

The pre-extension demonstration of engine driven maize Sheller helps to separate maize from the cob. The fabricated design consists of a body casing, drum, shelling unit, grain and cob discharge unit, air blower part, machine frame, hopper (Feeding chute), bearing as some of the major component. It is powered by diesel engine motor connected the shelling unit by B-belt. SoRPARI-Agricultural Mechanization research directorate were demonstrated the maize sheller and found to be about 97.54-98.76% efficient with output capacity of about 26.530 Qu/hr. The machine is relatively cheap, simple and portable when compared to imported product of similar capacity and other internal manufacture. 20 agro-pastoralists from each Kelafo and Dollo Ado woredas were selected for the maize Sheller demonstration and two machines were provided for both woreda to create wider awareness. The cost benefit analysis of the maize sheller machine was conducted using the payback period and the benefit-cost ratio. It calculated the machine cost benefit ratio and payback period is 1.15 and 1.94 this indicate that the machine is cost effective to popularization and scaling.

Keywords: *Maize Sheller, Engine driven, Demonstration, Kelafo and Dollo Ado, Cost Benefit Analysis*

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops in the world's agricultural economy (Win *et al*., 2019). It is called as "Queen of cereals" and "King of fodder" due to its great importance in human and animal diet (Teha and Nur, 2020). Maize is next to *rice and wheat with* regard to area and production. It is being used for manufacturing industrial products like starch, syrup, alcohol, acids, etc. It is a rich source of starch (60-80%), protein (8-12%), fat (3-5%), and minerals (1-2%) (Langyan *et al.,* 2021). In Ethiopia, maize grows from moisture stress to high rainfall areas and from lowlands to highlands. It is one of the most important cereal crops grown in the country and is the main staple food in rural areas. It accounts over 14 % and

18% in terms of land area coverage and productivity respectively with a higher annual growth rate (Teha and Nur, 2020). The overall productivity of maize is affected by many factors including a lack of post-harvest technologies, such as shelling. Shelling/Threshing assumes considerable importance in post-harvest operations because; the crop has to be shelled as early as possible to make way for sowing of another crop in the field. Sometimes, shelling time may also coincide with heavy rainfall. In view of these situations, suitable technology is necessary for reducing the threshing/Shelling time and safe storage of grains at farm level. A more efficient shelling is achieved when the grain has been suitably dry to 13 to 14 % moisture content (Hamzah *et al.,* 2021). Maize shelling in Ethiopia is mainly carried out using traditional methods. The most commonly employed methods include manual rubbing maize cobs against one another, using human finger, stone, biting the cob with wooden plank, treading with animal and wire mesh by using iron cylinder (EIAR, 2003). All these are time-consuming methods involving drudgery and exposure of crop over a time leads to natural hazards like rain, fire and loss of grains to animals, birds and insects. It is also highly tedious, inefficient; do not support large-scale shelling of maize requiring a lot of labor and time with low productivity as a worker can only shell a few kilograms per hour (Teha and Nur, 2020). Therefore, this project initiated to demonstrate motorized maize sheller technology that contribute for minimize the agro-pastoralist/farmers problems of traditional Maize shelling technologies in Kelafo and Dollo Ado woreda of Somali region Ethiopia. This study was conducted with the objectives to contribute in the enhancement of agro-pastoralist maize production through the application of engine driven maize Sheller technologies, to demonstrate and evaluate engine driven Maize Sheller, and to create awareness among agro pastoralist/farmers, developmental agents, subject matter specialists and other participant stakeholders on engine driven Maize Sheller technology.

Materials and Methods

Description of the study area

Pre-extension demonstration of Maize Sheller technology was conducted in Kelafo and Dollo Ado Woredas, Somali Region, Ethiopia. Kelafo is a town in eastern Ethiopia. Located in the Shebelle Zone of the Somali Region, this town has a latitude and longitude of 05°35′20″N 44°12′20″E and an elevation of 233 m.a.s.l. Based on figures from the Central Statistical Agency in 2005, this town has an estimated total population of 14,242, of whom 7,522 are men and

6,720 are women. Dolo Addo is one of the woredas in the Somali Region of Ethiopia. Part of the Liben Zone, Dolo Ado is located in the angle formed by the confluence of the Ganale Dorya with the Dawa River, and bordered to the northwest by Filtu, on the northeast by Afder Zone, on the southeast by Somalia, and on the south by Kenya. Towns in Dollo Ado include Bekol May, Dolo and Suftu. Dolo Addo is one of the woredas in the Somali Region of Ethiopia. Part of the Liben Zone, Dolo Ado is located in the angle formed by the confluence of the Ganale Dorya with the Dawa River, and bordered to the northwest by Filtu, on the northeast by Afder Zone, on the southeast by Somalia, and on the south by Kenya. Towns in Dollo Ado include Bekol May, Dolo and Suftu.

Agro-pastoralist/ Farmers Selection

Farmers were selected purposively based on their interest, innovation he/she has in using maize Sheller technology, willingness to use the technology, common shelling problem, share information and capable to manage the ordered activity in collaboration with the Dollo Ado and Kelafo woredas SoRPARI center and sub center. 20 agro-pastoralists from each woredas were selected. The selected agro-pastoralist was divided in to two sub-group having 2 members in each sub-group in consideration of gender issues (women, men and youth). The training was provided in the established group containing of 20 participants (15 male and 5 female) and two maize Sheller technologies was delivered for each woredas.

Table 1: Summary of selected woredas and number of agro-pastoralist

District	Type of machine	Qt of machine	Number of participants	Male	Female
Kelafo	Maize Sheller	1	20	15	5
Dollo ado	Maize Sheller	1	20	20	

Technology evaluation and demonstration methods/technique

The evaluation and demonstration of the technology was conducted on Kelafo sub-center and Dollo-ado center fields to create awareness about the maize Sheller technology operation and preventive maintenance.

Cost-Benefit Analysis of Engine Driven Maize Sheller

Cost-benefit analysis is an imperative part of the process for this study. In the making of any machine, the economics related to it have to be carefully considered to analyze the costs and go ahead to compute the profit.

The cost-benefit analysis of the maize Sheller was conducted using the payback period and the benefit-cost ratio.

Payback Period

The payback period is the length of time it takes to recover the invested capital or until the net benefits equal the investment cost.

$$\text{PBP} = \frac{\text{Initial Investment nital (Birr)}}{\text{Annual Profit }(\frac{\text{Birr}}{})} \tag{1}$$

Yr.

$$\frac{\sum_t \text{Revenu}\left(\frac{}{\text{Yr}}\right) - \text{Total cost}\left(\frac{}{\text{Yr.}}\right)^n}{n}$$

Birr Birr

Where Annual profit =; n = number of years of benefits. The acceptability of the project is determined by comparison with the project-required payback period (RPP). Accept the project when the PBP< RPP, otherwise reject the project (Mottalib *et al.*, 2019).

Benefit-Cost Ratio

The benefit-cost ratio is the ratio of the present worth of the benefit stream to the present worth of the cost stream. (Gittinger, 1994).

$$\text{BCR} = \frac{\sum \text{Present worth of Benefits (PWB)}}{\sum Present\ worth\ of\ Cost\ (PWC)}$$

The investment is said to be profitable when the BCR is greater than one. Depreciation and interest of investment are not included in the costs to prevent double accounting. Depreciation is accounted for by the inclusion of the investment cost while interest of investment is accounted for by the discount factor (Bd *et al*., 2020).

Data Collection

Quantitative data Output capacity (Qu/h), threshing efficiency (%), cleaning efficiency, grain damage (%), number of agro-pastoral participated in the training, number of stakeholders participated on the training and qualitative data were collected through personal field observation, individual interview, Focus Group Discussion by using checklist and data sheet tools. While qualitative data were farmers' perceptions towards the new technology and ranked using pair, wise ranking and Matrix ranking.

Data analysis

Quantitative data was summarized using simple descriptive statistics (Mean, Frequency and Percentage) while the qualitative data collected using group discussion and field observation and oral histories was analyzed using narrative explanation. Finally, data from different sources was triangulated to get reliable information.

Results and Discussion

Results

Training of farmers and other stalk holders

Multidisciplinary research team; Agricultural mechanization and extension research team and other stakeholders actively participated the theoretical and practical focus training by sharing their experience and knowledge on shelling maize.

Table 2: Type of profession and number of participants during the training at the two Districts

		Kelafo		**Dollo-Ado**		
No.	**Participants**	**Male**	**Female**	**Male**	**Female**	**Total**
1	Agro pastoralist	15	5	20		40
2	Agricultural experts	4	1	5		10
	Total	19	6	23	2	50

Among the training participant stakeholders, 80% were Agro-pastoralist. From those, 14.3% are female agro pastoralist participant. Different extension materials were utilized and distributed for the participants. For those individuals, 50 leaflets and 40 small manuals about maize Sheller technology that are prepared in Somali and English languages were distributed. During the training different questions, opinions and suggestions were raised and reacted from the concerned bodies. Most agro-pastoralist/farmers showed high interest towards the technology. Therefore, all concerned bodies were shared their responsibility for the future intervention and wider reach out of the technology.

Table: 3. The performance of engine driven maize Sheller machine

No	**Performance Indicators**	**Unit**	**M Sheller**
1.	Overall Dimension		
	• Length	Mm	1300
	• Width	Mm	1200
	• Height	Mm	1550
2.	Net Weight	Kg	150
3.	Power source		Petrol Driven Engine
4.	Power Requirement	Hp	7.5-10
5.	Fuel Consumption	Lit/hr	1
6.	Drum Type		Cylindrical
7.	Blower Type		Centrifugal
8.	Output Capacity	Qu/hr	26.5-30
9.	Threshing Efficiency	%	97.54– 98.76

10.	Cleaning efficiency	%	>95
11.	Grain Damage	%	<0.1

Agro-pastoralist/Farmer Opinion/Perception

The opinion of those farmers on the maize Sheller performance was collected from participants during machine demonstration. The major criteria used by farmers were the machine capacity, threshing efficiency, cleaning efficiency, grain damage, reduce labor, minimize human effort/tiredness and reduce time of thrashing. Therefore, most farmers preferred engine driven maize Sheller than traditional shelling methods.

Table 4: Ranks of the varieties based on farmers' selection criteria.

Implements	**Agro-pastoralist/farmers rank**	**Reasons**
Engine Driven maize Sheller	1^{st}	High Machine capacity, high threshing efficiency, high cleaning efficiency, low grain damage, reduce labor, minimize human effort/tiredness and reduce time of thrashing.
Traditional Maize shelling	2^{nd}	Low threshing capacity, low threshing efficiency, high grain damage, maximizes human effort/tiredness and increase time of thrashing.

Table 5: Pair-wise ranking matrix result to rank variety traits.

M ac hi ca pa cit | T hr es hi | Ef fi ci en | Cl ea ni | Ef fi ci en | M in i m | hu m an ef f | R ed uc e ti | of th ra sh | R ed uc e gr | da m ag

no ōd C | Fr eq ue nc

Tr ait | R an

1	Machine capacity	2	1	1	4	2nd		
2	Threshing efficiency		2	2	5	1st		
3	Cleaning efficiency		4	2	4th			
4	Minimize human effort/tiredness				5	5	1	5th
5	Reduce time of thrashing				5	3	3rd	
6	Reduce grain damage				0	6th		

Based on the result of pair wise ranking matrix the agro-pastoralist/ farmers highly preferred the maize Sheller with high threshing efficacy.

Cost-benefit analysis of Maize Sheller

The results of the benefit-cost analysis of the engine driven maize Sheller technology presented in Table 6 and Table 7.

Table 6: Various costs for maize Sheller

Cost Description	Cost (Birr)
Fixed Cost (cost of the Sheller)	155,000.00
Annual variable cost	55,000.00
Annual gross income from shelling	135,000.00
Annual net returns	80,000.00

Table 7: Payback period and benefit-cost ratio of maize Sheller

Description	Details
Payback Period (years)	1.94
Benefit-Cost Ratio	1.15

The benefit-cost ratio and payback period of the shelling technology were 1.15 and 1.94 years respectively. These results were in agreement with Milufarzana *et al*. (2015) who observed a benefit -cost ratio of 2.34 for a maize Sheller for which is required to be greater than one. In addition, the Sheller investment would pay back itself within 2 years or approximately four growing seasons, a relatively short payback period. Hence maize shelling using modified maize Sheller is a profitable venture for the entrepreneurs.

Discussion

The demonstration of engine driven maize Sheller reducing human interaction with the process. The machine has a great future scope for farmers due to its ease of use and cost effectiveness. The main advantage is its low operating costs, tame and energy saving. Savings of money resulting from the use of machine can pay for itself within the short period.

Conclusion and Recommendations

Maize harvesting and post-harvest operation usually consist of a series of operations comprising removal of kernel from cob. Traditionally maize shelling carried out manual rubbing maize cobs against one another, using human finger, stone, biting the cob with wooden plank, treading with animal this is inefficient; do not support large-scale shelling of maize requiring a lot of labor and time with low productivity and also it is one of the major problems which facilitate physical damage. Hence, the available engine had driven maize Sheller important to harvest maize and the technology on farm evaluation and demonstration best solution for minimizing maize post-harvest loss, increase production and productivity constraint under smallholder. In addition, less labor and time consumption were observed when compared with manual shelling and the machine is cost effective with short period of return. Therefore, based on farmer's idea and importance of this technology the following recommendations were drawn:

- More popularization and scaling up is necessary.
- Capacity building (training) could be required for farther promotion.

- More Effort is required on availability, distribution and demonstration of the technology should be made on.

Future study could require on technology in different area for more post-harvest loss minimization and busting production and productivity.

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4.2. Pre-extension Demonstration and Evaluation of Horizontal Hay Baler Machine in Kelafo and Dollo Ado Woredas, Somali Region, Ethiopia

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Abstract

The pre-extension demonstration of hay baller machine helps the pastoral and agro-pastoral community to prepare feed for their livestock easily that used during dry season. Only one person operates the horizontal hay baler. SoRPARI-Agricultural Mechanization research directorate were demonstrated the hay baler and found the output capacity of the hay baler about 15-20 kg per baled (1000 kg/hr). The machine is relatively cheap, simple and portable when compared to other internal manufacture. 20 agro-pastoralists from each Kelafo and Dollo Ado woredas were selected for the hay baller machine demonstration and two machines were provided for both woreda to create wider awareness. The cost benefit analysis of the baler machine was conducted using the payback period and the benefit-cost ratio. It calculated the machine cost benefit ratio and payback period is 1.43 and 1.5 this indicate that the machine is cost effective to popularization and scaling up.

Keywords: *Horizontal hay baler machine, Demonstration, Kelafo and Dollo Ado, Cost Benefit Analysis*

Introduction

Livestock is a major source of livelihood base for the population of Somali Region. According to the livestock census of CSA (CSA, 2013), the region is estimated to have 23.6 million heads of livestock comprising of Cattle (20%), Sheep (33%), Goat (36%), Camel (10%) and Equines (1%). Improving livestock productivity and production is crucial to accelerate growth, ensure food security and expand agricultural export. The government has accordingly paid due attention to improving the productivity of the sector. Grazing lands are the main source of livelihood to many pastoralists and agro-pastoralist providing year-round feed supporting livestock. As green plants availability is seasonally in most area, the provision of feed for deficit seasons has always been the major concern in many livestock production system (Valley *et al*., 2021). Therefore, hay is the most important conserved fodder used for this purpose. Many small-scale farmers/agro-pastoralist in Somali region by their own method make hay and store crop residues to carry livestock through periods of feed shortage. It can be prepared at household level using simple techniques. Hay making is traditional in most parts of Ethiopia especially, in our region there is no wide practice of making or storing hay and straw in bale, rather most agro-pastoralist/farmers and small-scale dairy holders store hay traditionally by making heap. However, the conventional method of haymaking has some drawbacks, such as feed loss; maintain low nutrient content, not convenient in transporting and storing. These drawbacks confirm that farmer's lacks knowledge about forage conservation, improvement of low-quality feed and using of proper technology for haymaking and storing resides. Studies indicate that, baling of hay by pressing helps to feed animals with little or no wastage, conserve its nutrient for a long time, simplifies the transport and storage condition and preparation of feed rations (Tekeste, 2020). The average weight of a bale from natural pasture and crop residues can be 15-20 and 8-15 kg, respectively (Addah and Ayantunde, 2021). But tractor assisted baler, can press in to bales up to 200-300 kg/ m^3 density when its moisture content is between 18-30% and in to briquettes of up to 700 kg/m^3 density when the moisture content is between 10-12% (Tekeste, 2020). Therefore, this project initiated to demonstrate horizontal hay baller technology that contribute for minimizing feed shortage during dry season in Kelafo and Dollo Ado woreda of Somali region, Ethiopia. The study was conducted with objective of to contribute in the enhancement of pastoralist and agro-pastoralist feed preparation through the application of hay baller technologies, to demonstrate and evaluate horizontal hay baler and to create awareness among agro pastoralist/farmers, developmental agents, subject matter specialists and other participant stakeholders on hay baller technology.

Materials and Methods

Description of the study area

Pre-extension demonstration of Maize Sheller technology was conducted in Kelafo and Dollo Ado Woredas, Somali Region, Ethiopia. Kelafo is a town in eastern Ethiopia. Located in the Shebelle Zone of the Somali Region, this town has a latitude and longitude of 05°35′20″N 44°12′20″E and an elevation of 233 meters above sea level. Based on figures from the Central Statistical Agency in 2005, this town has an estimated total population of

14,242, of whom 7,522 are men and 6,720 are women. Dolo Addo is one of the woredas in the Somali Region of Ethiopia. Part of the Liben Zone, Dolo Ado is located in the angle formed by the confluence of the Ganale Dorya with the Dawa River, and bordered to the northwest by Filtu, on the northeast by Afder Zone, on the southeast by Somalia, and on the south by Kenya. Towns in Dollo Ado include Bekol May, Dolo and Suftu. Dolo Addo is one of the woredas in the Somali Region of Ethiopia. Part of the Liben Zone, Dolo Ado is located in the angle formed by the confluence of the Ganale Dorya with the Dawa River, and bordered to the northwest by Filtu, on the northeast by Afder Zone, on the southeast by Somalia, and on the south by Kenya. Towns in Dollo Ado include Bekol May, Dolo and Suftu.

Agro-pastoralist/ Farmers Selection

Farmers were selected purposively based on their interest, innovation he/she has in using maize Sheller technology, willingness to use the technology, common shelling problem, share information and capable to manage the ordered activity in collaboration with the Dollo Ado and Kelafo woredas SoRPARI center and sub center. 20 agro-pastoralists from each woredas were selected. The selected agro-pastoralist was divided in to two sub-group having 2 members in each sub-group in consideration of gender issues (women, men and youth). The training was provided in the established group containing of 20 participants (15 male and 5 female) and two maize Sheller technologies was delivered for each woredas.

Table 1: Summary of selected woredas and number of agro-pastoralist

District	Type of machine	Qt of machine	Number of participants	Male	Female
Kelafo	Hay baler	1	20	15	5
Dollo ado	Hay baler	1	20	20	

Technology evaluation and demonstration methods/technique

The evaluation and demonstration of the technology was conducted on Kelafo sub-center and Dollo ado center fields to create awareness about the hay baller technology operation and preventive maintenance.

Cost-Benefit Analysis of Engine Driven Maize Sheller

Cost-benefit analysis is an imperative part of the process for this study. In the making of any machine, the economics related to it have to be carefully considered to analyze the costs and go ahead to compute the profit.

The cost-benefit analysis of the maize Sheller was conducted using the payback period and the benefit-cost ratio.

Payback Period

The payback period is the length of time it takes to recover the invested capital or until the net benefits equal the investment cost.

$$\text{PBP} = \frac{\text{Initial Investment nital (Birr)}}{\text{Annual Profit } (\frac{\text{Birr}}{\text{Yr.}})} \qquad (1)$$

Where Annual profit = $\frac{\sum_t^n \text{Revenu} \left(\frac{\text{Birr}}{\text{Yr}}\right) - \text{Total cost } (\frac{\text{Birr}}{\text{Yr.}})}{n}$; n = number of years of benefits. The acceptability of the project is determined by comparison with the project-required payback period (RPP). Accept the project when the PBP < RPP, otherwise reject the project (Mottalib *et al.*, 2019).

Benefit-Cost Ratio

The benefit-cost ratio is the ratio of the present worth of the benefit stream to the present worth of the cost stream. (Gittinger, 1994).

$$\text{BCR} = \frac{\sum \text{Present worth of Benefits (PWB)}}{\sum Present\ worth\ of\ Cost\ (PWC)}$$

The investment is said to be profitable when the BCR is greater than one. Depreciation and interest of investment are not included in the costs to prevent double accounting. Depreciation is accounted for by the inclusion of the investment cost while interest of investment is accounted for by the discount factor (Bd *et al*., 2020).

Data Collection

Quantitative data hay balling capacity (kg/h), baling efficiency (%), human labor requirement, number of agro pastoral participated in the training, number of stakeholders participated on the training and qualitative data were collected through personal field observation, individual interview, Focus Group Discussion by using checklist and data sheet tools. While qualitative data were farmers' perceptions towards the new technology and ranked using pair, wise ranking and Matrix ranking.

Data analysis

Quantitative data was summarized using simple descriptive statistics (Mean, Frequency and Percentage) while the qualitative data collected using group discussion and field observation and oral histories was analyzed using narrative explanation. Finally, data from different sources was triangulated to get reliable information.

Results and Discussion

Training of farmers and other stalk holders

Multidisciplinary research team; Agricultural mechanization and extension research team and other stakeholders actively participated the theoretical and practical focus training by sharing their experience and knowledge on haymaking.

Table 2: Type of profession and number of participants during the training at the two Districts

		Kelafo		**Dollo Ado**		
No.	**Participants**	**Male**	**Female**	**Male**	**Female**	**Total**
1	Agro pastoralist	15	5	20		40
2	Agricultural experts	4	1	5		10
	Total	19	6	23	2	50

Among the training participant stakeholders, 80% were Agro-pastoralist. From those, 14.3% are female agropastoral participant. Different extension materials were utilized and distributed for the participants. For those individuals, 30 leaflets and 20 small manuals a bout hay baller technology that are prepared in Somali and English languages were distributed. During the training different questions, opinions and suggestions were raised and reacted from the concerned bodies. Most agro-pastoralist/farmers showed high interest towards the technology. Therefore, all concerned bodies were shared their responsibility for the future intervention and wider reach out of the technology.

Table: 3. The performance of indicator of hay baller machine

Performance Indicators	**Machine Specification**
Machine Function	Used in baling different types of grass for Livestock folder.
Power Requirement	Manual (Operated by 1 person)
Capacity	15-20kg per baled (1000kg/hr.)
Weight	75kg
Remark	Machine include two wheels

Agro-pastoralist/Farmer Opinion/Perception

The opinion of those farmers on the hay baller machine performance was collected from participants during machine demonstration. The major criteria used by farmers were the machine hay balling capacity, balling efficiency, minimize human effort/tiredness and reduce time of hay balling. Therefore, most farmers preferred the improved hay-balling machine than traditional methods.

Table 4: Ranks of the varieties based on farmers' selection criteria.

Implements	**Agro-pastoralist/farmers rank**	**Reasons**
Improved hay baller machine	1st	Minimize feed loss, conserve its nutrient, simplifies the transport and storage condition and preparation of feed rations.
Traditional haymaking	2nd	Feed loss; maintain low nutrient content, not convenient in transporting and storing, labor intensive and time of time taking.

Table 5: Pair-wise ranking matrix result to rank variety traits.

1	Hay balling capacity	2	1	4	2nd		
2	Balling efficiency		2	5	1st		
3	Reduce labor						
4	Minimize human effort/tiredness		2	4th			
					5	1	5th
5	Reduce time of balling				3	3rd	

Based on the result of pair wise ranking matrix the agro-pastoralist/ farmers highly preferred the hay baller with high hay baller efficacy.

Cost-benefit analysis of Maize Sheller

The results of the benefit-cost analysis of the hay baler technology presented in Table 6 and Table 7. Table 6: Various costs for maize Sheller

Cost Description	Cost (Birr)
Fixed Cost (cost of the Sheller)	150,000.00
Annual variable cost	3,500.00
Annual gross income from sealing of baled hay	105,000.00
Annual net returns	101,500.00

Table 7: Payback period and benefit-cost ratio of maize Sheller

Description	Details
Payback Period (years)	1.47
Benefit-Cost Ratio	1.43

The benefit-cost ratio and payback period of the shelling technology were 1.43 and 1.5 years respectively. This result is accepted for which greater than one. In addition, the investment would pay back itself within one and half years or approximately three growing seasons, a relatively short payback period.

Discussion

The demonstration of hay baller machine reducing human labour with the process. The machine has a great future scope for farmers due to its ease of use and cost effectiveness. The main advantage is its low operating costs, tame saving. Savings of money resulting from the use of machine can pay for itself within the short period.

Conclusion and Recommendations

Livestock feed preparation is one of the main operations for pastoral and agro-pastoral community. From the training and demonstration of the mechanical hay-balling machine, farmers developed knowledge about the importance of baling of hay. They said that the use of these machines would help them to minimize feed loss, conserve the feed nutrient that can store and use it for dry period. The traditional feed loss; maintain low nutrient content, not convenient in transporting and storing, labor intensive and time of time taking. Therefore, based on farmer's idea and importance of this technology the following recommendations were drawn:

- More popularization and scaling up is necessary.
- Capacity building (training) could be required for farther promotion.
- More Effort is required on availability, distribution and demonstration of the technology should be made on.

Future study could require on technology in different area for more post-harvest loss minimization and busting production and productivity of livestock feed.

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5. Food Science and Nutrition Research Directorate

5.1. Proximate and Functional Properties of Different Sorghum Varieties Produced in Somali Regional State Ethiopia

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Abstract

Sorghum is one the staple food or crop that widely consumed in Somali community. The study was conducted in Somali Regional state with objective to analyze proximate, functional and physical of different sorghum varieties produced in Somali reginal state. Six different types of samples such as Dekeka, AdoKaye, ESH-1, Melkam, ASSO-1 and JLM control as control sample were collected. The collected sorghum samples were individually grounded to a fine powder (30 mesh size), packed in air tight polyethylene plastic bags and were stored at 4°C until further analysis. Proximate composition such as crude Protein, crude Fat, crude fiber, moisture content, carbohydrate, total energy, different minerals like Calcium, Iron, Magnesium and Total phosphorous were determined by AOAC. The functional and physical properties of the sorghum were determined different standard procedures. Based on the result all locally adapted those sorghum varieties adapted by the Somali region research institute were better in both macro and micro nutrients especially when it comes fiber, total ash, moisture content as compared to the control sample with brand name JLM control which imported from abroad. All sample's protein content is very low which in the range 5.23 to 6.50%. There is significant different in different components of sorghum between different varieties at $p<0.05$. Significance difference were also observed at $p<0.05$ in minerals content such as Calcium, zinc, iron and Total Phosphorous. The functional and physical properties of different sorghum varieties under study are almost not significantly different at $p<0.05$. Overall, from the finding we conclude that, almost all locally adapted sorghum varieties have better in nutritional content especially moisture, ash and fiber and very poor in protein content. Therefore, all actors on sorghum should apply fortification especially bio-fortification to enhance the nutrient content in particular the protein content as sorghum is one of the staple crops in Somali region.

Key words: *Sorghum, Proximate composition, Functional Properties, Physical properties.*

Introduction

Judging from the 2017 available data from FAOSTAT, Africa is the largest contributor to world sorghum production, with a production quantity of approximately 29.7 million tones [1]. Sorghum grains are a widely adaptable species and mostly cultivated in tropical, subtropical and temperate regions [2]. It is said to have originated from the Northeast quadrant of Africa [3]. Millet, barley, teff and wheat are also members of the Poaceae family [4] and are likewise known for their ecological dominance in many ecosystems, as well as their capacity to grow in low rainfall and harsh environmental extremes conditions [5]. As indicated by Ratnavathi and Komala [6], over 20 sorghum species are known.

In developing countries, especially in Africa, over 78% of the sorghum produced is used for food, with about 14% for animal feeding and 7% for other uses [7]. Proximate composition of sorghum from earlier studies has indicated that its protein content ranges from 6.2% to 14.9%, carbohydrates (54.6%-85.2%), fat (1.3%-10.5%), ash (0.9%-4.2%) and fiber (1.4%-26.1%). The variations in these values might possibly be related to the genotypes of the grains and growth conditions, as well as other cultivar specific differences. Sorghum contains fairly high levels of potassium (K) (900-6957.67 mg/kg), and phosphorus (P) (1498-3787.25 mg/kg), minerals known to assist with muscle movement, keeping the nervous system healthy and building strong bones and teeth [8,9].

Sorghum (*Sorghum bicolor* L) Mönch is the world’s fourth major cereal in terms of production with annual production volume of about 60million MT from land cover of over 40million hectares. Sorghum is a staple food for over 500 million people in Africa, Asia and Latin America [10]. Ethiopia is one of the major producers of sorghum, ranking 7th in the world and third in Africa contributing 12% and 5% of African and world annual production respectively. Sorghum in Ethiopia accounts for about 18% of annual production and 16% of land cover allocated for the entire grain crops including cereals, pulses and oilseeds [11].

In Ethiopia, sorghum is the third (3rd) most important staple cereal crop after teff and maize [12]. Sorghum crop is grown in almost all regions of Ethiopia and used as a staple food crop on which the lives of millions of poor Ethiopians depend on it. Sorghum is used in various ways in our country; the grain is used for human foods such as injera, bread, porridge, Nifro, infant food, syrup, and also, the leaf and stalk are used for animal feed, and further, the stalks are used for the construction of houses and fences and as fuelwood. Different research centers under Somali region pastoral and Agro-pastoral research institute (SoRPARI) have been working on the sorghum over the last many years; during this period, varieties of sorghum have been released. The released varieties had different specific qualities such as disease resistance, malt quality, and earliness. However, none of the varieties had no comprehensive nutritional profile data let it be macro-nutrient, micronutrient and other content, since the quality of sorghum produced worldwide is affected by biotic and abiotic constraints [13]. Therefore, the aim of the present study was to profile the nutritional value, antinutritional value, mineral contents, functional and physical properties of sorghum varieties adapted and released by SoRPARI and grown in different parts of Somali region of Ethiopia.

Materials and Methods

Materials and Equipment Used

Five different sorghum varieties produced/adapted under SoRPARI were collected from Dolo-Ado research center and one popular widely marketed variety as a control was purchased from the local market in Jigjiga. The five varieties produced or adapted under SoRPARI that were going to use for this study includes *Dekeka, AdoKaye, ESH-1, Melkam, ASSO-1,* whereas the control sorghum type might be the one with most likely used by local community named *JLM-Control* for this particular study. Only whole sorghum grains without any physical damage or insect infestation were selected for analysis. All equipment used in sample preparation were expected to be obtained from SoRPARI laboratories and missed equipment can be used from local institutes Further, after bringing to the laboratory, sorghum samples were individually ground to a fine powder (30 mesh size), packed in air tight polyethylene plastic bags and were stored at 4 °C until further analysis.

Proximate Composition

The proximate composition of sorghum flours was determined using the standard AOAC methods [13]. Moisture content was done by the gravimetric method in a hot air oven at 105 ºC until constant weight, and the quantity of ash was analyzed using a muffle furnace at 550 ºC. Crude protein content was measured by a standard Kjeldahl method using 5.95 as the conversion factor. Flour lipids were analyzed by the solvent extraction procedure. The content of total carbohydrates was determined by difference from the analysis of moisture, ash, protein and lipids. Whereas, gross energy was determined by calculation from fat, carbohydrate and protein contents using at water's conversion factors: 16.7 KJ/g (4 kcal/g) for protein, 37.4 KJ/g (9 kcal/g) for fat and 16.7 KJ/g (4 kcal/g) for carbohydrates and expressed in calories (AOAC, 2000).

Mineral analysis

The mineral contents were determined by the procedure of AOAC [14]. Calcium, iron, and zinc were determined according to AOAC 2000 official methods of 985.35 using an Atomic Absorption Spectrophotometer while phosphorous was determined by official method of 986.24 using calorimetric method using ammonium molybdate.

Hundred (100) kernel weight and bulk density

One hundred sorghum kernels were randomly selected and weighed separately. For bulk density, 50 g of sorghum grains was weighed and will be dropped into a graduated glass measuring cylinder from a constant height (approximately 30 cm). The volume occupied by sorghum samples were recorded and bulk density were calculated as g/ml ratio [15, 16].

Oil and Water Absorption Capacity Determination

For this 2 g of the samples was mixed with 10 ml of distilled water for five minutes respectively on a magnetic stirrer. The mixture was centrifuged at 3500 rpm for 30minutes and the volume of the supernatant was measured by using 10 ml measuring cylinder on each of the sample. The water density was taken to be 1g/ml.

$$\text{WAC}=volumeofwaterabsorbed/\text{Weight of the sample used}\times 100$$

Statistical analysis

All the analysis was performed in duplicate (unless stated otherwise) and presented as mean ± standard deviation. Statistical significance of the data obtained was analyzed by One-way analysis of variance (ANOVA) followed by Duncan test by using GenStat version 18.0. The level of significance was considered at P < 0.05.

Results

Table 1: Proximate composition of different Sorghum Varieties

Key: Same letter in the same column is not significantly different from each other at p<0.05

Varieties	Results in (%) (100g)						
	Moisture	Ash	C.Fiber	C.Protein	C.Fat	CHO	Energy
JLM Control	11.61 ± 0.24^{cd}	2.330 ± 0.01^{a}	2.720 ± 0.11^{b}	6.320 ± 0.24^{bc}	6.570 ± 0.14^{c}	70.45 ± 0.31^{ab}	366.2 ± 0.55^{b}
AdoKaye	12.51 ± 0.11^{d}	2.910 ± 0.02^{b}	2.840 ± 0.02^{bc}	6.210 ± 0.23^{b}	5.500 ± 0.23^{b}	70.03 ± 0.46^{a}	354.5 ± 0.98^{a}
Dekeka	9.63 ± 0.22^{ab}	3.110 ± 0.11^{bc}	2.410 ± 0.03^{a}	6.490 ± 0.11^{c}	5.165 ± 0.31^{a}	73.19 ± 0.34^{c}	365.2 ± 0.87^{b}
ESH-1	10.65 ± 0.12^{bc}	3.260 ± 0.21^{cd}	2.410 ± 0.12^{a}	6.240 ± 0.12^{bc}	8.270 ± 0.25^{f}	69.17 ± 0.12^{a}	376.1 ± 0.94^{c}
Asso-1	10.07 ± 0.31^{ab}	3.410 ± 0.08^{d}	2.910 ± 0.03^{bc}	6.500 ± 0.21^{c}	7.270 ± 0.34^{e}	69.84 ± 0.48^{a}	370.8 ± 0.84^{bc}
Melkam	9.36 ± 0.23^{a}	3.830 ± 0.10^{e}	3.000 ± 0.14^{c}	5.230 ± 0.14^{a}	6.940 ± 0.26^{d}	71.64 ± 0.51^{b}	369.9 ± 0.96^{bc}

JLM: The control sorghum sample
CHO: Carbohydrate,
Energy: Energy in Calory unit obtained from consuming 100g of these sorghum varieties

The proximate composition of different sorghum varieties has been depicted in table 1 above. Melkam variety has the lowest in moisture content while Adokaye is the highest. No significance difference was observed between Melkam, Asso-1, Dekeka varieties of sorghum under study at P<0.05. JLM control has the lowest in ash content while Melkam has the highest. When it comes crude fiber content, Melkam has the highest while (Ash-1 and Dekeka) has the lowest. The crude fiber content was significantly different between Melkam and (Ash-1 and Dekeka) and JLM control sample at P<0.05. With respect to crude protein content, Melkam has the lowest while Asso-1 variety has the highest in crude protein content. There is no significance difference in between JLM control, Adokaye and Esh-1 samples at P<0.05. Dekeka has the lowest while Esh-1 has the highest in crude fat content. The crude fat content was significantly different among all varieties of sorghum under study at P<0.05.

When it comes carbohydrate content, all sorghum varieties have high amount of carbohydrate as shown in table 1. Dekeka variety has the highest while Esh-1 has the lowest in carbohydrate content. There is no significant difference in carbohydrate among Asso-1, Esh-1, Adokaye and JLM control samples at $P<0.05$. There is also no significance difference in between Melkam and JLM control samples. The energy in calory unit were also calculated and depicted as shown in table 1 above. Adokaye variety has the lowest while Esh-1 has the highest in energy obtained from consuming 100g of each sample. The energy obtained is significantly different in between Esh-1 and Adokaye at $P<0.05$. Significant difference was also in between (Esh-1 & Adokaye) varieties and the rest of others sorghum varieties under study at $P<0.05$.

Table 2. Minerals content of different Sorghum varieties

Varieties	**Results in (mg/kg)**			
	Calcium	**Zinc**	**Iron (Fe)**	**Total Phosphorous**
JLM Control	900 ± 2.50^{a}	32.39 ± 0.98^{a}	67.9 ± 0.92^{a}	2600 ± 8.85^{a}
AdoKaye	1200 ± 3.65^{b}	34.83 ± 0.96^{b}	100.4 ± 0.98^{b}	3300 ± 8.95^{b}
Dekeka	900 ± 4.24^{a}	34.16 ± 0.86^{b}	127.4 ± 1.24^{c}	3600 ± 7.95^{c}
ESH-1	1401 ± 6.55^{d}	37.50 ± 0.94^{c}	160.7 ± 1.55^{d}	4100 ± 9.96^{e}
Asso-1	1300 ± 6.75^{c}	33.45 ± 0.92^{ab}	175.8 ± 2.08^{e}	3800 ± 9.02^{d}
Melkam	1400 ± 7.01^{d}	40.42 ± 0.97^{d}	180.1 ± 2.21^{f}	4200 ± 9.13^{f}

Same letter in the same column is not significantly different from each other at $p<0.05$
JLM: The control sorghum sample

Minerals are important in fighting against hidden hunger or micronutrient deficiency. The calcium content in the range of 900 mg/Kg to 1401 mg/kg for sorghum sample JLM control and Eshi-1 respectively. The calcium content is significantly different between Asso-1 and the rest of others sorghum varieties under study at $P<0.05$. When it comes zinc content different sorghum varieties, it is in the range of 32.39 mg/Kg to 40.42 mg/Kg for JLM control and Melkam sample respectively. No significant difference in zinc content were observed in between Adokaye, Dekeka and Asso-1 varieties at $P<0.05$. The iron content of different sorghum varieties is also indicated in table above. The iron content in the range of 67.9 mg/Kg to 180.1 mg/Kg for JLM control sample and Melkam sorghum sample respectively. Significant difference was observed in iron content in all sorghum varieties under study at P<0.05. The total phosphorous content is also indicated in table 2 above. In a similar fashion JLM control has the lowest (2600 mg/Kg) while Melkam sorghum sample has the highest in total phosphorous sample which is 4200mg/kg. Significant difference was observed in total phosphorous content of all sorghum varieties under study at P<0.05.

Table 3 Functional Properties of different Sorghum varieties

Varieties	Results	
	Water Absorbing Capacity	**Oil Absorbing Capacity**
JLM Control	1.640 ± 0.02^{b}	0.9150 ± 0.03^{a}
AdoKaye	0.875 ± 0.04^{a}	0.6050 ± 0.05^{a}
Dekeka	1.080 ± 0.03^{a}	0.6900 ± 0.04^{a}
ESH-1	1.075 ± 0.03^{a}	0.6250 ± 0.06^{a}
Asso-1	0.850 ± 0.02^{a}	1.0500 ± 0.09^{a}
Melkam	0.930 ± 0.04^{a}	1.1900 ± 1.01^{a}

Key: Same letter in the same column is not significantly different from each other at p<0.05
JLM: The control sorghum sample
WAC= Water Absorbing Capacity OAC= Oil Absorbing Capacity

The functional properties of different crops or food types are important in determining the integration of food with oil, water and other ingredients. Water absorbing capacity in the range of 1.075 to 1.640 for Esh-1 and JLM control samples respectively. No significant difference was observed in water absorbing capacity among all sorghum samples except JLM control samples which is significantly different at P<0.05 as indicated above. When it comes to oil absorbing capacity, it is in the range from 0.6050 to 1.1900 for Adokaye and Melkam sorghum samples respectively. The oil absorbing capacity is not significantly different among all sorghum samples as indicated above at P<0.05.

Table 4. Physical properties of different sorghum varieties

Varieties	Results in	
	100 seed weight	**Bulk density (g/ml)**
JLM Control	3.645 ± 0.23^{b}	0.760 ± 0.01^{b}
AdoKaye	3.045 ± 0.31^{a}	0.695 ± 0.02^{a}
Dekeka	2.800 ± 0.24^{a}	0.750 ± 0.02^{b}
ESH-1	2.975 ± 0.26^{a}	0.770 ± 0.03^{bc}
Asso-1	2.855 ± 0.30^{a}	0.685 ± 0.01^{a}
Melkam	3.005 ± 0.34^{a}	0.785 ± 0.03^{c}

Same letter in the same column is not significantly different from each other at p<0.05 JLM: The control sorghum sample

The different physical properties are also important as quality indicators for different crop types. The 100 seed weight is in the range of 2.800 g to 3.645 g for Dekeka and JLM control sorghum samples respectively. When it comes bulk density, it is in the range of 0.685 g/ml to 0.785 g/ml for Asso-1 and Melkam sorghum samples respectively. The bulk density of Melkam sample is significantly different as compared to other sorghum samples under study except Esh-1 sample at P<0.05.

Discussion

Proximate composition/Macronutrient/ of different sorghum varieties

The proximate composition different sorghum varieties indicated in table 1. The moisture content is significantly different among some sorghum samples. The difference in moisture content is might be due difference in variety, farm management, agro-ecology, soil fertility and some other reasons. The result obtained is in line with the research done by Mesresha *et.al*. [20] for the sorghum grown in Ethiopia. The result is in contradict with the research done in Sudan by Nefisa [18], and Mexico by Miria *et.al* [19]. The findings confirm that varieties of sorghum tested were not exposed to deterioration due to mold growth or any damage related to wetness. This could be attributed to a moisture level of less than 15% [17]. The ash content of different sorghum varieties in the range of 2.33 to 3.83%. Significant difference was observed among some sorghum varieties as indicated in table 1. The difference is due to the fact that being difference in variety, farm management, soil fertility and some other reasons. The result is in contradict with the research done in Sudan by Nefisa (18), in Mexico by Miria *et.al* in (19) and with the research done by Mesresha *et.al* [20]. for the sorghum grown in Ethiopia. This might be virginity and fertility of Somali region soil which expected to contributed to higher ash content of sorghum samples.

Significant difference in fiber content was observed among different sorghum varieties. The difference might be being different in varieties type and farm management during farming. The fiber content of the six varieties under this research were lower as compared to the other research done in Sudan by Nefisa [18], in Mexico by Miria *et.al* [19] and with the research done by Mesresha *et.al*. [20] for the sorghum grown in Ethiopia. This may be due to the high in ash, moisture and carbohydrate content of these varieties. The protein content in the range of 5.23 to

6.50% is significantly different among different sorghum sample in this research as indicated in table 4.1 above. The difference in protein content might be due being different in varieties, farm management and some other cases. The protein contents of these six varieties in this research is relatively lower as compared to the other research done in Sudan by Nefisa [18], in Mexico by Miria *et.al* [19] and with the research done by Mesresha *et.al*. [20] for the sorghum grown in Ethiopia. This indicates, these sorghum and the other sorghum varieties need some kind of interventions like bio-fortification.

The fat content in the range of 5.165 to 8.270% as indicated in table 1. The fat content is significantly different among all sorghum varieties under study at $P<0.05$. The difference is due to the fact that being different in variety types, origin of the seed, farm management and some other reasons. The result obtained for fat content is in line with the research done by Mesresha *et.al*. [20] for the sorghum grown in Ethiopia. The result is in contradict with the research done in Sudan by Nefisa [18] and Mexico by Miria *et.al* [19]. The carbohydrate content of different sorghum depicted in table 1 above. There is significant difference in carbohydrate content among some sorghum varieties under study. This is mainly contributed due to being difference in variety type and especially the difference in other macro components such as protein, fat, moisture, fiber and ash of sorghum under study. The result of carbohydrate is in line with or comparable with the research done by Mesresha *et.al*. [20] for the sorghum grown in Ethiopia and with the research done in Sudan by Nefisa [18] while it is in contradict with the research done in Mexico by Miria *et.al* [19].

Energy is calculated with standard factors designed for carbohydrate, fat and protein. The energy was calculated in calory unit and is in the range of 354.5 Kca; to 376.1 Kcal. Significance difference was observed in energy content among some of the sorghum varieties in this research at $P<0.05$. This difference come as result of being different in macro component (Protein, fat and CHO) which in turn due to being different in variety and some other reasons.

Mineral's content of different sorghum varieties

The calcium content is the range of 900 mg/Kg to 1401 mg/Kg. There is significant difference in calcium content among some sorghum varieties under this research at $P<0.05$. This might be due to being different in variety, soil fertility, farm management. The result obtained is comparable to the with the research done in Sudan by Nefisa [18]. The Zinc content of different sorghum varieties are in the range of 32.38 mg/kg to 40.42 mg/Kg as indicated in table 2. The zinc content is significantly different among some sorghum varieties at $P<0.05$. This might be due to being different in variety, soil fertility, farm management.

The iron content in the range of 67.9 mg/Kg to 180.1 mg/kg and it is significantly different among all sorghum varieties in this research. This might be due to being different in variety, soil fertility, farm management. The phosphorous content also indicated in table 2. It is in the range of 2600 mg/Kg to 4200mg/kg. The phosphorous content significantly different among all sorghum varieties in this research. This might be due to being different in variety, soil fertility, farm management. The result obtained is in contradict with the research done in Sudan by Nefisa [18]. This might be the fact that, the difference in ash content, agro-ecology difference, soil fertility and some other reasons.

Functional Properties

The water and oil absorbing capacity of the sorghum varieties shows no differences in their association with oil and water except the control sample. Water absorption capacity (WAC) is the capacity of the flour to absorb water and swell for enhanced consistency in food (21). The observed mini variation in water absorption capacities between different sorghum varieties maybe attributed to different protein concentrations, their degree of interaction with water and their conformational characteristics (22). Oil absorption capacity is an indication of the rates at which proteins bind to fat in food formulations (21). Oil absorption capacity is an important functional property that enhances the mouth feel while retaining the flavors of food products which intron important in food formulation (22). The oil absorption capacities of the flours were different among the different sorghum varieties as shown in table 3 above. From statistical analysis, there was no significant difference ($p< 0.05$) in the oil absorption capacity of the flour samples.

Physical properties

The physical properties among different sorghum varieties are depicted in table 4. There is more or less some significance difference between different sorghum varieties with respect bulk density. The difference in bulk density may be due to the intrinsic characteristics of each variety. Density values are useful in design of silos and storage bins. Hundred seed weight showed significant difference and varied from 2.855 to 3.645 g. Low hundred seed weight may due to the low moisture content which increases the probability of more damaged grains during milling.

Conclusion and recommends

The research was done on six sorghum varieties of which one is a control sample. From the data obtained we conclude that, the moisture content of all varieties below 15% which is an indication for their better shelf stability. The ash content of all sorghum varieties is high which an indication for their high mineral content. The fiber, carbohydrate and fat content of all sorghum varieties are also high enough. But the protein content of all sorghum varieties is very low. When it comes to minerals content, all varieties of sorghum have high amount calcium, iron, zinc and total phosphorous. Significant different were observed in all varieties for both macro and micro nutrients. Therefore, we recommend, Further research and biofortification or any other ways of fortification to all sorghum varieties.

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5.2. Macro and Micro-Nutrient Analysis of Different Sesame Varieties Produced/Adapted Under SoRPARI in Somali Regional State

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Abstract

The study was conducted in Somali Regional state with objective to analyze the macronutrient and micronutrient (minerals) content of different sesame varieties produced in Somali reginal state. Five different types of samples such as Idaan, Adi, Barsan Local and JLM control as control sample were collected. The collected sesame samples were individually grounded to a fine powder (30 mesh size), packed in air tight polyethylene plastic bags and were stored at 4°C until further analysis. Proximate composition such as crude Protein, crude Fat, crude fiber, moisture content, carbohydrate, total energy, different minerals like Calcium, Iron, Zinc and Total phosphorous were determined by AOAC. Based on the result all locally adapted those sesame varieties adapted by the Somali region research institute were better in both macro and micro nutrients especially when it comes fiber, protein, total ash, moisture content as compared to the control sample with brand name JLM control which is purchased from Jigjiga local market. Fat content is exceptional which means the control sample has high amount fat as compared to samples. There is significant different in different components of sesame between different varieties at $p<0.05$. Significance difference were also observed at $p<0.05$ in minerals content such as Calcium, zinc, iron and Total Phosphorous. Overall, from the finding we conclude that, almost all locally adapted and the control sesame varieties have better in nutritional content especially moisture, ash, protein fat, and fiber and very poor in carbohydrate content. Therefore, all actors should engage in mass production of sesame with improved varieties so as to get more income and currency from abroad.

Key words: *Sesame, macronutrient composition, micronutrient composition, oil content.*

Introduction

Sesame (*Sesamum indicum* L.) is one of the world's important and oldest oilseed crops [1,2] and has been used extensively for thousands of years as a seed of worldwide significance for edible oil, paste, cake, confectionary purposes and flour due to its highly stable oil contents, nutritious protein (rich in methionine, tryptophan and valine) and savory nutty roasted flavor [2,3]. The oil contains, in addition to phytosterol and tocopherol, two compounds which are not found in any other oil, namely sesamolin; this, upon hydrolysis, yielded sesamol, which is responsible for the antioxidant behavior of sesame seed crop oil [4].

Some of the variations in the seed are hundred seed weight that can range 0.11-0.46 g [9], protein 19%-30% [10,11], oil 34.4%-59.8% [10], carbohydrates 6.4%-21.0% [12]. In Ethiopia, improved sesame seed varieties were developed through researches that have good disease resistance, improved yields, different oil composition, size and color [6, 13, and 14]. Sesame contains important minerals and vitamins such as Ca, P, and Fe, niacin and thiamin [12, 15, 16].

Sesame is an oilseed herbaceous crop of the Pedaliaceae fam is produced by only a few developing countries in the world due to its high demand for labor farming and harvesting [22]. About 96% of the world sesame production is contributed from Asia and African countries. Considering a 10-year average report (from 2008 to 2018), the top ten sesame producers are Myanmar, India, Tanzania, Sudan, China, Nigeria, Sudan (Former), Ethiopia South Sudan, and Burkina Faso, in the same order (http://www.fao.org/faostat/en/#data/QC/ visualize, accessed on 12th August 2021).

Study reports indicate that Ethiopia is among the six producers of sesame seed, linseed and niger seed in the world [5]. In Ethiopia, the production of sesame is both by small- and large-scale farmers; and it is an important crop and export commodity [18]. The major sesame seed producing regions are situated in the North West and South West Ethiopian in Humera, North Gondar and Wollega [6-8]. The major sesame producing areas are situated in the low land of Tigray, Gambella, Benshangul Gumuz, Somalia, Amhara, Southern and Oromia regions of Ethiopia [5]. Sesame production is increasing in the country due to increase in demand and price. Thus, sesame cultivation is expanding to new potential growing areas [23]. Sesame is an important annual oilseed crop being cultivated as an ingredient for human food oil, meal, and animal feeds [19, 20].

These days, there are several varieties and genotypes of sesame adapted to different geographical conditions. However, the cultivation of modern varieties is limited due to insufficient genetic information [21]. According to some studies the seed is believed to exist in 16 genera and 60 species, most of which exist in Africa [21]. Due to the high market demand and adaptability to several environmental factors, sesame production is increasing year to year in different countries [22]. In Ethiopia, sesame seed production and export alone are twice larger than all other oil seeds together. In Ethiopia, both black and white sesame seed varieties are cultivated but the oil yield, the dominant fatty acid constitutes of the oils and phenolic compounds of these sesame seed varieties cultivated in these districts have not been reported so far, though the country is one of the major sesame seed producers and exporters from Africa.

As sesame seed is nutritionally important in some parts of the world, few reports were documented about color, size, oil and other nutritional content of Ethiopian sesame seeds in the literature [13-115] and oil characteristics [17]. So, limited scientific research has been done on the physico-chemical composition of sesame varieties. The scientific information generated from this research could serve as an important input for production, marketing, food industry, human nutrition and maximum utilization, particularly for the benefits of sesame growing areas. Therefore, the objective of this study was to investigate some, proximate, mineral compositions of different sesame varieties grown under SoRPARI potential areas and Somali Region in Ethiopia.

Materials and Method

Four different sesame varieties produced/adapted under SoRPARI were collected from Kelafo research sub center and one popular widely marketed variety as a control was purchased from the local market. The five varieties produced or adapted under SoRPARI that were used for this study includes *Adi*, Local, *Barsan* sesame, *Idaan* sesame whereas the control sesame sample was purchased from Jigjiga City local market. Only whole sesame grains without any physical damage or insect infestation were selected for analysis. All equipment used in sample preparation was expected to be obtained from SoRPARI laboratories and missed equipment can be used from local institutes further, after bringing to the laboratory, sesame samples were individually ground to a fine powder (30 mesh size), packed in air tight polyethylene plastic bags and were stored at 4°C until further analysis.

Proximate Composition

Moisture content

Moisture content (%) of the sesame seeds was determined according to the procedure described in the Association of Official Analytical Chemists (AOAC), No. 930.15. Five grams of each sample was accurately weighed into a moisture dish and transferred into a hot air-oven at 103°C and then dried until a constant weight was attained. The final weight of each sample was taken after cooling it in desiccator [27]. The analysis was carried out in triplicate and the average value was recorded as moisture content.

$$\text{Moisture (\%)} = \frac{\text{(Initial moisture of the sample-Weight of Oven Dried sample)} * 100}{\text{Initial weight of the samples}}$$

Protein content

The crude protein content of sesame seed was determined from the nitrogen content by Kjeldahl method AOAC [27]. The percentage of crude protein was calculated from the % nitrogen as:

$$\text{Nitrogen (\%)} = \frac{((Vs-Vb)*mMHCl*0.014008)) * 100}{\text{Weight of the sample}}$$

Where Vs= Volume (mL) of HCl required to titrate sample; Vb = Volume (mL) of acid required to titrate the blank; mM HCl = Molarity of acid; W = Weight of sample (g). Crude protein (%) = % nitrogen *F, where F (conversion factor), equivalent to 6.25 AOAC [27][81. A blank was run through along with the sample and triplicate analysis was conducted for samples.

Determination of crude fiber

The crude fiber in the sample was determined by following the method described in the Association of Official Analytical Chemists, No. 962.09 AOAC [27]. The percentage of fiber was calculated as:

$$\text{Crude fiber (\%)} = \frac{\text{(Weight of dried sample – Weight of Ash)} * 100}{\text{Initial weight of samples}}$$

Determination of crude fat

The crude fat in the powdered samples was determined by Soxhlet extraction method described in the Association of the Official Analytical Chemists, No. 2003.06 AOAC [27]. The % fat in the sample was calculated as:

$$\text{Fat (\%)} = \frac{\text{(Wt. of flask containing the crude fat in the filter paper – Wt. of flask plus paper)} * 100}{\text{Weight of sample}}$$

Determination of total ash content

The total ash content was determined by using direct method described in the Association of the Official Analytical Chemists, No. 923.03 AOAC [27]. The weight of ash was determined by subtracting the weight of dried empty crucible from the weight of crucible containing ash.

$$\text{Ash (\%)} = \frac{\text{Weight of Ash}}{\text{Weight of initial Sample}}$$

Determination of total carbohydrate and gross energy values

The carbohydrate content of the sample was obtained by subtracting the sum of percentages moisture, fat, fiber, protein and ash from 100 % following a standard procedure reported [28].

Carbohydrate (%) = 100 – (% moisture + % fat + % protein + % fiber + % ash).

Gross energy values (kcal/100 g) of the samples were determined by multiplying the protein content by 4, carbohydrate content by 4 and fat content by AOAC:

Energy value (kcal/100 g) = (crude protein *4) + (Total carbohydrate *4) + (Crude fat * 9).

Mineral analysis

Mineral contents (Fe, Zn and Ca) of sesame seed were determined by Atomic Absorption Spectrophotometer AOAC [27] the powdered sesame seed sample (1.0 g) was taken in a glass tube. Twelve milliliters of HNO3 were added to the powdered sample and the mixture was kept for overnight at room temperature. Then, 4 ml $HClO_4$ was added into the mixture and put in the fumes block for digestion. The temperature was gradually increased starting from 50°C until completion of digestion as indicated by the appearance of white fumes. The mixture was cooled down and the contents of the tubes were transferred into 100 ml volumetric flask and the volume was made to 100 ml with distilled water. The wet digested solution was transferred to the plastic bottle and the digest was used for mineral determination. Phosphorus is determined by AOAC method No. 964.06, which was demonstrated as adequate recovery, reproducibility and has no bias. It is an alkali metric ammonium molybdophosphate method appropriate for all concentrations of phosphate AOAC [29].

Statistical analysis

All the analysis was performed in duplicate (unless stated otherwise) and presented as mean ± standard deviation. Statistical significance of the data obtained was analyzed by One-way analysis of variance (ANOVA) followed by Duncan test by using GenStat version 18.0. The level of significance was considered at $P < 0.05$.

Results and Discussions

Results

Table 1: Proximate composition of different Sesame Varieties

Key: Same letter in the same column is not significantly different from each other at p<0.05

Varieties	Results in (%)/(100g)						
	Moisture	**Ash**	**C. Fiber**	**C. Protein**	**C. Fat**	**CHO**	**Energy**
JLM control	2.94± 0.2[a]	4.15±0.4[a]	7.78±0.3[a]	21.70±1.2[a]	55.60±2.6[c]	7.83±0.3[b]	618.5±2.9[d]
Idaan	3.98±0.32[b]	6.93±0.5[d]	8.94±0.4[c]	25.65±1.4[e]	52.98±2.5[b]	1.52±0.01[a]	585.5±2.2[c]
Adi	4.00±0.1[b]	5.95±0.6[b]	12.18±0.3[e]	22.68±1.3[b]	47.87±2.4[a]	7.32±0.2[b]	550.8±2.1[a]
Barsan	4.00±0.2[b]	6.43±0.4[c]	9.40±0.4[d]	24.92±1.5[d]	47.78±2.3[a]	7.47±0.2[b]	559.6±2.2[ab]
Local	4.02±0.4[b]	6.82±0.3[cd]	8.44±0.4[b]	24.55±1.3[c]	48.50±2.2[a]	7.67±0.3[b]	565.4±2.3[b]

CHO: Carbohydrate,
Energy: Energy in Calory unit obtained from consuming 100g of these sesame varieties

Table 1 above indicates the macronutrient contents of different sesame varieties under study. The JLM control variety has the lowest moisture content 2.94% while the "local" variety has the highest in moisture content 4.02%. Except the "JLM control" varieties which is significantly different as compared to the others four varieties under study, there is no significant difference in moisture content among the other four varieties at P<0.05. The ash content of the five sesame varieties under study is in the range of 4.15 up to 6.93%. The "JLM control" has the lowest while the "*Idaan*" has the highest in ash content. The ash content is significantly different among the five sesame varieties under study at P<0.05. But there is no significant difference in between "*Idaan*" and "Local" varieties and the same is true for "*Barsan*" and "Local" varieties at P<0.05.

The “JLM control” sample is lowest in Crude fiber content (7.78%) while the “Adi” variety has the highest (12.18%). The crude fiber content for all sesame varieties is significantly different at P<0.05. When it comes to crude protein content, it in the range of 21.70% (For “JLM Control” sample) and 25.65% (for “*Idaan*” sample) as shown in table 4.1. Above. The crude protein content is significantly different among all sesame varieties at P<0.05.

The fat content of “JLM control” sample is the highest (55.60%) while that of “*Barsan*” sample is the lowest which 47.78% as shown in table above is. There is no significant different in fat content among “*Adi*”, “*Barsan*” and “Local” varieties of sesame under study at P<0.05. But there is significant difference in fat content between “JLM control” variety and that of “*Idaan*” variety at P<0.05.

With respect to carbohydrate content, “*Idaan*” variety has the lowest (1.52%) and while “JLM control” has the highest which is 7.87%. Except the “*Idaan*” sesame variety which has the lowest in carbohydrate content, there is no significant different in carbohydrate content among the others sesame varieties at P<0.05. Finally, when it comes to energy obtained from 100g of sesame varieties, it is in the range of 550.8Kcal (for “Adi” sesame variety) to 618.5Kcal (for “JLM Control” sample) as indicated in table above. There is no significant difference in energy for “Local” and “*Barsan*” varieties and as well in between “*Barsan* and “Adi” at P<0.05. But there is significant difference in between “Adi” and “Local” and “JLM control” and “*Idaan*” sesame varieties and vice versa at P<0.05. As shown in table1. Above.

Table 2. Mineral’s content of different sesame varieties

Sesame varieties	**Result in (mg/100g)**			
	Calcium (Ca)	**Zink (Zn)**	**Iron (Fe)**	**Total phosphorous (TP)**
JLM control	55±2.5^{a}	4.087±1.8^{d}	10.25±1.5^{a}	620.0±6.4^{ab}
Idaan	133±4.5^{b}	3.992±1.6^{c}	20.62±2.4^{d}	600.0±6.2^{ab}
Adi	104±3.5^{b}	3.559±1.5^{a}	17.66±1.6^{c}	540.0±5.6^{a}
Barsan	140±4.9^{b}	5.208±1.9^{e}	22.86±2.5^{e}	590.0±5.7^{ab}
Local	135±5.7^{b}	3.690±1.7^{b}	17.54±1.8^{b}	640.0±6.8^{b}

Key: Same letter in the same column is not significantly different from each other at p<0.05

The mineral contents of different sesame varieties are indicated in table 2. Above. The "JLM control" sample is the lowest in calcium content (550mg/kg) while "Local" sesame variety has the highest which is 1350mg/kg. The "JLM Control" sample is significantly different in calcium content from other four varieties of sesame at P<0.05. But there is no significant difference in calcium content among "*Idaan*", "*Adi*", "Local" and "*Barsan*" sesame varieties at P<0.05. With respect to zinc content, the "*Adi*" variety has the lowest (35.59mg/Kg) while the "*Barsan*" variety has the highest which is 52.08mg/kg. There is significant difference in Zinc content among all sesame varieties at P<0.05.

When it comes to Iron content, the "*Barsan*" sesame verity has the highest (228.6mg/kg) while the "JLM control" sample has the lowest which is 102.5mg/Kg. There is significant difference among all sesame varieties in iron content at P<0.05. Lastly, The total phosphorous content in the range of 5400mg/Kg (For "Adi" sesame variety) to 6400mg/kg for "Local" sesame Varieties. There is significant difference in total phosphorous content among "Local" and "Adi" sesame varieties at P<0.05. But there is no significant difference in total phosphorous content in between "JLM control", "*Idaan*" and "*Barsan*" sesame varieties and the vice versa at P<0.05.

Discussion

The Macronutrients content of Different Sesame Varieties

Table 1 above indicates the macronutrient contents of different sesame varieties under study. Except the "JLM control" varieties which is significantly different as compared to the others four varieties under study, there is no significant difference in moisture content among the other four varieties at P<0.05. The difference in moisture content might be due to agro-ecology, farm management difference. The moisture content of the studied sesame seeds was low, which corresponds to the moisture content of different sesame varieties ranging from 4.16% to 7.80% [3-, 31]. [4] Reported the moisture content of sesame varieties from Werer Agricultural Research Center ranged from 4.4% to 4.8%. The relatively low moisture content of sesame seeds is helpful for the storage of sesame seeds. At low moisture, deterioration would occur relatively slowly [32].

The ash content of the five sesame varieties under study is in the range of 4.15 up to 6.93%. The ash content was significantly different among the five sesame varieties under study at P<0.05. The difference may as a result of being different varieties, soil condition in which they grown.

Ash content was observed significantly ($p \leq 0.05$) different between sesame varieties. T-85 had the highest (6.19 g/100g) ash content and least was for bawnji (4.46 g/100g) [9]. [33] reported ash values to be between 1.4 and 6.6 g/100g for Saudi Arabia and foreign varieties (Lebanese, Indian and World collection), which is similar with the results of this study. High level of ash makes the oilseed a good source of mineral nutrition to the consumer [34] [25].

The "JLM control" sample is lowest in Crude fiber content (7.78%) while the "Adi" variety has the highest (12.18%). The crude fiber content for all sesame varieties is significantly different at $P<0.05$. The difference may be as a result of being different in varieties, farm management and some other reasons. Fiber contents were higher than the fiber contents of previously reported values fiver contents (5.24-7.70%) from Ethiopia sesame varieties [23], indicating the studied sesame varieties from Somali region could be useful source of fiber.

When it comes to crude protein content, it in the range of 21.70% (For "JLM Control" sample) and 25.65% (for "*Idaan*" sample). The crude protein content is significantly different among all sesame varieties at $P<0.05$. The difference might be due to varietal difference among sesame, farm condition and another components difference. The crude protein content in the studied sesame seeds was high, which was in agreement with that of sesame protein contents reported by [31] and by [30] (17.02-21.00%), and [23] who reported the mean crude protein content (23.12%) of ten sesame seeds in Ethiopia. This result is consistent with range (18-25%) reported by [12] but are lower than those reported by [20] for Sudan varieties and USA genotypes (32.5-40.0%) and by [21] for 13 sesame accessions of Nigeria (27.50-45.68%). [35] Found protein content (19.81-24.45%) in Turkey's sesame genotype. The difference might be due to varietal difference among sesame, farm condition, agro-ecology difference, fertilizer management.

The fat content of "JLM control" sample is the highest (55.60%) while that of "*Barsan*" sample is the lowest which 47.78% is. There is no significant different in fat content among "Adi", "*Barsan*" and "Local" varieties of sesame under study at $P<0.05$. But there is significant difference in fat content between "JLM control" variety and that of "*Idaan*" variety at $P<0.05$. The crude fat contents of the studied sesame varieties were comparable to the mean crude fat content (47.33%) reported by [4]. Higher crude fat content (46.6-52.4%) in sesame seeds has also been reported in India [36]. [37] Reported the oil content can range from 43.4-58.8% for 42 strains of sesame with the highest oil content found in white-seeded strain. [24, 38] reported oil content in Saudi and Indian sesame seeds ranging from 43.2-54.0%. Both the above results are consistent with the result of current study. Variation in the oil yield of sesame may be due to variation in variety, soil type, climatic, maturity of plant, the harvesting time of the seeds and the extraction method used [24,38].

With respect to carbohydrate content, the "*Idaan*" sesame variety which has the lowest in carbohydrate content, there is no significant different in carbohydrate content among the others sesame varieties at P<0.05. Finally, when it comes to energy obtained from 100g of sesame varieties, it is in the range of 550.8Kcal (for "*Adi*" sesame variety) to 618.5Kcal (for "JLM Control" sample) as indicated in table above. There is no significant difference in energy for "Local" and "*Barsan*" varieties and as well in between "*Barsan* and "*Adi*" at P<0.05. But there is significant difference in between "Adi" and "Local" and "JLM control" and "*Idaan*" sesame varieties and vice versa at P<0.05. Carbohydrate content had ranged (7.32-7.83%) between varieties studied which is inconsistent with range (8.31-11.69%) reported by [5] but are higher than the range 1.05-2.88% reported by [31] for Sudan varieties and USA genotypes. The highest carbohydrate values (27.90-45.15%) were reported in 13 sesame accession of Nigeria by [30][84]. Compositional differences can exist among the different varieties of sesame seeds, and among the sesame variety grown in different countries. Further studies by [39] [40] on some legume crops reported that there might be differences between varieties of the same species. The mean energy value of the studied sesame varieties was lower than energy value of sesame seeds reported by [4].

The mineral contents of different Sesame varieties

The mineral contents of different sesame varieties are indicated in table 2. The "JLM control" sample is the lowest in the calcium content in the range of (55-140mg/100g. The "JLM Control" sample is significantly different in calcium content from other four varieties of sesame at P<0.05. But there is no significant difference in calcium content among "*Idaan*", "*Adi*", "Local" and "*Barsan*" sesame varieties at P<0.05. This might be the fact that, being different varieties, different agro-ecolology, soil type, fertilizer and other farm management. The calcium content of this study is lower than 1450 mg/100g reported by [40] and [41] in some Indian sesame varieties. However, some Lebanese sesame varieties exhibited the lowest (228.3 mg/100 g) calcium content [42]. The current study results which are in the range 55-140 mg/100g is also lower than the research done on different sesame varieties which are in the range of 600-2000 mg/100g.

With respect to zinc content, the "*Adi*" variety has the lowest (3.559mg/100g) while the "*Barsan*" variety has the highest which is 5.208mg/100g. There is significant difference in Zinc content among all sesame varieties at $P<0.05$. This zinc content found is higher than the range (0 - 3.8 mg/100g) reported by [33] for Saudi Arabia and varieties (Lebanese, Indian, Nigerian and World collection). This might be the due to difference in variety, soil condition, farm management and agro-ecology.

When it comes to Iron content, the "*Barsan*" sesame verity has the highest (22.86mg/100g) while the "JLM control" sample has the lowest which is 10.25mg/100g. There is significant difference among all sesame varieties in iron content at $P<0.05$. The values were comparable with the Fe content of sesame varieties reported from Saudi Arabia (10.4 mg/100g Fe) [43]. This indicated that the studied sesame varieties could be considered to have normal amount of iron that can help consumers identify products with higher iron content [44]. Iron is an essential element for human being by contributing to a wide variety of metabolic processes including oxygen transport, DNA synthesis and electron transport, transportation of oxygen around in the body [45]

Lastly, The total phosphorous content in the range of 540mg/100g (For "*Adi*" sesame variety) to 640mg/100g for "Local" sesame Varieties. There is significant difference in total phosphorous content among "Local" and "*Adi*" sesame varieties at $P<0.05$ as shown in table 4.2 above. But there is no significant difference in total phosphorous content in between "JLM control", "*Idaan*" and "*Barsan*" sesame varieties and the vice versa at $P<0.05$. The P content was comparable with that reported elsewhere (501.99-762.79 mg/100 g) [46].

Conclusion and Recommendations

The study was conducted with aim of analyzing the macro and micronutrient content of the different sesame varieties. The protein, fat, fiber and moisture content are up to the standard while the carbohydrate content is very low. The lower moisture content is the indication for shelf stability of the different sesame varieties. The higher fat content is the indication for the studied sesame varieties are good for oil production. In addition to this, with being higher in protein content, all sesame varieties are nutrient rich which is indicated in their calory content that are higher than 550kcal/100g of sesame. The higher ash content of all sesame varieties indicates, all varieties have good source of minerals. Except the calcium content, all sesame varieties have high amount of zinc, iron and total phosphorous.

Based on the finding and identified gaps, the following points are recommended;

- Further research should be done by expanding the area coverage and adding more samples from different areas of the region including the control samples.
- More parameters should be added in the future research that going to be done on different sesame varieties.
- Sesame is one of the nutrient dense crops. Community should use it by mixing with the different stables crop they use as regular food.
- Especial research should be done on the oil characterization of the different sesame varieties.
- More to be done on the different products that can be produce from sesame and as well the different use of sesame such as culinary, medicinal, industrial

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6. Socio-Economic and Gender Research Directorate




6.1. Factors Affecting Adoption of Improved Wheat Varieties in Awbarre Worda, Fafan Zone of SRS, Ethiopia

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Abstract

The main objectives of the study were to measure and analyze the main factors affecting the adoption of wheat (Triticum aestivum) varieties in Awbare woreda employing simple descriptive statistics and logistic regression (binary logit) model. Household adoption, were analyzed to measure the state of household adoption of improved wheat (Triticum aestivum) varieties, 95 farm households were selected from two kebeles. The logistic model was initially fitted with 13 variables of which nine were found to be significant. Oxen ownership is the main factor that determine to adopt new technology at household level. Off-farm and non-farm incomes also influence adoption of farm households in the study area. Their importance is significant in supplementing total farm income and enhancing the state of household adoption of wheat varieties. the differences in the use of chemical fertilizer have also significant impact on the improvement adoption of new technology. That increase the productivity of off-farm/non-farm income and livestock should be given prior attention. It is also appropriate to the area to promote intensive agriculture thereby attain adoption of new technology

Key Words: *Wheat, Varieties, Adoption, Non-adoption,*

Introduction

Agricultural sector in Ethiopia is dominated by subsistence low input, low output and rain fed farming system. The use of improved seeds is quite limited despite government efforts to encourage the adoption of modern agricultural system and intensive agricultural practices Therefore, improving the productivity profitability, and sustainability of smallholder farming is the main pathway out of poverty in using agriculture for technology (Leake, 2015).

Wheat (Triticum aestivum) is one of the important grain crops produced worldwide, Ethiopia is the second largest wheat producer in sub Saharan Africa, next to South Africa, area under wheat cultivation expanded from 1.4 million-hectare 2004/05 to 1.6 million hectares by 2010/11 and from these the production yield was 2.9 million tons (Aklilu *et al.,* 2015).

Wheat producers have been identified in the Ethiopia: small-scale farmers, state farms, and producer cooperatives. The small-scale farmers (i.e., private Wheat is one of the major cereal crops grown in Ethiopia. In sub-Saharan Africa, Ethiopia ranks second to South Africa in terms of total wheat area and production. In Ethiopia, wheat ranks fourth in total crop area and production. It is grown in the highlands at altitudes ranging from 1500 to 3000 m.a.s.l., situated between 6-16^0N and 35 42^0E; however, the most suitable agro ecological zones for wheat production fall between 1900 and 2700 m.a.s.l. (Bekele, 2000). Wheat is among the most important staple food crops grown in Ethiopia it also Given the low productivity of traditional varieties, Ethiopia imports significant quantities, especially in drought years when deficits are large (Bekele *et al.*, 2014).

Out of the total area under cereals, about 11.89% (1,437,484.73 ha) of land is covered by wheat; and it shares about 13.34% (29.16 million tons) of the total production and it grows in the Ethiopian highlands, at altitudes ranging from 1500 to 3000m and is produced exclusively under rain-fed conditions (Alem *et al.,* 2015).

The rate of adoption of improved varieties, and therefore the time lag from varieties release to wide spread use, varies across regions the remarkable success of wheat improvement lines on the decisions of millions of farmers to adopt, or replace older wheat varieties with superior material, the more important modern wheat (*Triticum aestivum*) which is adapted to all divers climatic conditions, except for the very warm tropics prevailing in agricultural land (Dixon *et al.*, 2006).
The demand for wheat has been increased due to growing population, urbanization and the expansion of food processing industries in the country. If the country is to feed the rapidly growing population and meet the high demand, it needs to increase the production and yield of wheat varieties However; increasing yield requires successful adoption of improved agricultural technologies (Dorosh and Rashid, 2013 as cited by Tolesa, 2013).

The challenge faced in wheat production in the country is low productivity per unit area of land Low productivity of the crop is attributed to the use of old and low-yielding varieties, and depletion of soil nutrients, poor weed management practices, low levels of fertilizer application Water logging in vertisol areas prevalence of aggressive and harmful crop pathogens, and unavailability of modern crop management inputs (Haile *et al.,* 2013).

The constraints limiting wheat productivity which include production and market problems, low level of crop management practices, Rain failure: Labor shortage, higher fertilizer price, low soil fertility, erosion, Low output price, poor infrastructure, and post-harvest crop losses (Muhammed, 2011).

The study area adoption of improved wheat significantly affected by age, education level, farm size, farmers participation in on farm demonstrations, and contacts made with extension service, and total livestock units owned are significant influence on the adoption of wheat, adoption of improved wheat verities increased from time to time (Tesfaye, 2001).

Generally, Awbare woreda wheat is practicing for a long period of time, and this wheat is used for a means of income, and food resource. But its production is declined from time to time, because pest, disease, low fertility rate, lack of technology, the society is a victim of starvation and poverty, In the study area the main reasons why non adopters did not grow improved wheat varieties were due to financial constraints and lack of awareness, high cost of fertilizers. lack of income, low education level, lack of credit service etc. the General Objective of this study is To assess factors that affects adoption of improved wheat (*Triticum aestivum*) varieties in Awbarre district while the Specific Objectives of assessing production and marketing of wheat (*Triticum aestivum*) varieties, and identifying factors affecting the adoption of wheat (*Triticum aestivum*) varieties.

Research Methodology

The study is conducted in Awbarre District of Fafan Zone, Eastern Ethiopia. Awbarre is one of 11 districts in Fafan Zone known for its predominant cultivation. Awbarre is located on 694 km away from the capital Addis Ababa and 70 km from Jigjiga. This woreda is boarded on southwest by Jigjiga on west by Sitti Zone, on east by Somaliland and southwest by Kabribayah Woreda. The altitude of this woreda ranges from 1,200 to 1,660 meters above sea levels.

In the first stage Awbare woreda was selected based on potentiality of wheat production. Two Kebeles were selected among those three kebeles of highly producing wheat using a random sampling technique. Individual households were randomly selected in the target wheat producing kebeles. Finally, as the household was considered as basic sampling unit 95 households were selected using probability proportional to sample size-sampling techniques.

Data was gathered by using primary data through structured questionnaires that were fitted out through face to face and direct interview of respondents about 95 household This questionnaire was translated into local language to make questions clear for the respondent and to facilitate data collection during household survey. Thus, primary data was obtained from sample respondents using household interview survey method to get firsthand information about purpose of adoption of wheat technology, primary data was used to helped researcher in providing information for specific purpose of addressing the problem at hand so that questionnaires were prepared and distributed to sample respondents to gather necessary information for the study and interview were also be conducted with participants.

Primary data was also collected information on several factors including land and non-land farm assets, livestock ownership, household membership in different rural institutions, varieties and area planted, costs of production, yield data for different crop types, indicators of access to infrastructure, household market participation, household income sources and major consumption expenses. preference for different improved wheat producers and reasons for adoption and dis-adoptions of new varieties were also included in the data collection.

The data analysis process was carried out after collection of the required information from primary and secondary sources. The data were analyzed by Statistical Package for Social Sciences (SPSS) version 20.0. SPSS were used to analyze different variables through descriptive statistics which were used to provide a summary statistic related to variables of interest. Descriptive statistic such as, mean, standard deviation, frequency, and percentage were used to describe the demographic and socio-economic characteristics of the respondents.

Chi-square test was also used to identify categorical variables that vary significantly between adopters and non-adopter. the t-test was used to see if there is any statistically significant difference between the mean of the respective adopters and non-adopters with respect to continuous variables, Binary logistic regression analysis was also applied for identifying significant factors affecting adoption of wheat varieties.

Results and Discussion

Description of the Socio-economic Characteristics of Sample Households

The basic summary statistics of the sample farm households are discussed under this section. The dataset contains 95 farm households and of these, about 60% households are adopters were as

40% are non-adopters. Characteristics like age, family size and distance to nearest market of the household heads etc. are very important alternative indicators for individual behaviors and are commonly used as explanatory variables for adoption decisions. This section deals with these variables

Descriptive Statistics of Continuous Variables

Age of household heads: from this table show that the mean age of adopters and non-adopters are 31.39 and 49.32 respectively with min/max 20(76) respectively So that most of the adopters are young farmers show it has positive and significant effect 5% at probability level on the adoption so that young farmers are physically matured, active learner and more productive also young farmers can gain access to information about new technologies through various means, such as attending field days, visiting demonstration fields, participating in formal training, and through communicating with neighbors, relatives, and community leaders farmer's age can generate confidence in new technology. In other words, with more experience, a farmer can become more or less risk-averse when judging new technology. This variable could thus have a positive effect on a farmer's decision to adopt improved wheat technology (as indicated in table 2)

Family size of household: the table below shows that the mean age households of family size of adopters and non-adopters are 4.09 and 5.03 respectively with min/max 0(9) respectively the data indicates that most of adopters are large family size so large family available for active labor force in the household, which significance affects (1% at probability level) farmer's adoption. Since production is the function of labor, availability of labor assumed to have positive relation farmers adoption, however, family size is expected to have Positive impact on adoption of improved wheat varieties.

The number of oxen owned: as shown in the table the mean age of household on adopters and non-adopters are 2.86 and 2.53 respectively, with standard deviation of 1517.62 and 2025.831 respectively, with min/max 1(5) respectively, oxen ownership positively influenced the probability of adoption of improved wheat technology at less than 5% significance level. This result suggests that, those farmers who owned more oxen have better chance to use improved wheat technology than those who have owned small number of oxen .and household assures timely plowing and adopted better production (As indicated in table 2).

Off-farm income was one of the socioeconomic characteristics hypothesized positively and significant at 5% probability level to influence the decision to adopt improved wheat technologies, in that households involved in off farm jobs may be able to afford to invest in improved technologies. However, off-farm activities daily labor in agriculture is the major off-farm job for adopters of improved wheat varieties and the mean age of adopters and non-adopters are, 1012.20, 1890.03 respectively with min/max 0(6000) respectively, off-farm income provides financial problems in relation to farm inputs that they can buy fertilizer, purchase livestock etc. (as indicated in table 2).

Non-farm income : the other variable that influence adoption of improved wheat varieties negative and insignificance is non-farm activity as shown in the table2 the mean age household adopters and non-adopters are 3207.05 and 2626.32 respectively, with min/max 0(8000) respectively the possible explanation for this is if the household held to participate non-farm activity like trade activity like (poultry, milk product, hides and skins) , handicrafts, construction work, sale of charcoal and fire wood collection other source of money to make investment this source of investment used to buy for agricultural inputs including improved wheat varieties (as indicated in table 2)

Total income obtained from wheat in a year: income is expected to have positive effect on adoption at significant probability level of 5% from this data indicates that when annual income of improved wheat varieties increases the rate of adoption also increases in frequency whereas when the level of income decreases number of non-adopter's increases. The mean age of adopters and non-adopters are 3816.00 and 2792.86, with min/max 1000(15000) respectively, this shows that they have most likely have enough income to adopt the technology since it requires much amount of expenses for fertilizer, herbicide, labor wage, and purchase of seed. By this we mean farmers that gain high amount of income per year are adopters. (as indicated in table 2)

Land size owned by households: as indicates in the table above the mean age adopters and non-adopters are, 2.08 and 2.04 with min/max of 1(3) respectively this indicates that land size is expected to be negatively associated with the decision to adopt improved wheat varieties this means that farmers who have relatively small landholding would be less initiated to adopt the improved wheat varieties (as indicated in table 2).

Number of Livestock ownership: this variable was hypothesized to have negative relation with adoption house hold with small numbers of livestock may not able to adopt new technology in the table below that the mean age household adopters and non-adopters are10.42 and 11.00 respectively, with min/max 0(11) respectively**,** Household with no Livestock may not serves source of cash., (as indicated in table 2)

Use of fertilizer: Use of chemical fertilizer was hypothesized to be positively and significant at less than 5% probability level. as shown in the (table 2) the mean age of adopters and non-adopters are 1.63 and 1.97 respectively with standard deviation of .816 and 0.636 respectively this indicates that availability of fertilizer household increase adoption of an improved wheat variety

Distance to markets: it is institutional variable measured as the walking distance in kms that the household travel to reach the nearby market. The mean age adopters and non-adopters of distance to market is 6.37 and 9.38 hours respectively. So that this data a farmer having access to agricultural market have better market information. It was hypothesized to have a positive significant at probability level of (P=0.00) contribution to the adoption of improved wheat varieties these results were unexpected, farmers living nearby market gets Low transaction and easy information costs and this may likely to adopt a new technology (as indicated in table 2).

Table 2. Descriptive Statistics of Continuous Variables

	Total HHS (95)		Adopters HHS (57)	Non-adopter's HHS (38)	
Variables	mi(max)	mean (SD)	Mean (SD)	Mean (SD)	t.value
Age	20(76)	38.56(13.669)	31.39(7.740)	49.32(12.688)	8.16**
Family size	0(9)	4.46(1.668)	4.09(1.340)	5.03(1.993)	2.74***
Number of oxen	1(5)	2.73(0.85)	2.86(0.833)	2.53(0.725)	2.009**
Off-farm income	0(6000)	1690.6(1934)	1012.20(1517.62)	1890.03(2025.8)	1.975**
Non-farm income	0(8000)	2974.76(2390)	3207(2508.6)	2626.32(2186.5)	1.162
Total income from wheat	1000(15000)	3062.11(2253.46)	3816.00(2242.149)	2792.86(2211.3)	1.979**
Number of livestock ownership	0(11)	10.65(1.934)	10.42(2.478)	11.0 (0.00)	1.438
Land size owned	1(3)	2.05(0.674)	2.08(0.759)	2.04(0.647)	0.235
Distance	3(14)	7.57(2.67)	6.37(2.241)	9.37(2.174)	6.46***
Use of fertilizer	1(4)	1.77(0.764)	1.63(0.816)	1.97(.637)	2.18**

** and*** significant at less than 5% and less than 1%, respectively.

Source: on survey 2022.

Descriptive statistics of categorical variables

Sex of household head: sex one of the categorical variables which positively and significant effect at less than 5% probability level as shown in the table3 sex of household head percent of adopters and non-adopters of improved wheat varieties (67.6%) and (47.8%) Are adopters of male and female respectively and (32.5%) and (52.5%) are non-adopters of male and female respectively From these data show that most of the adopters are males due to many socio-cultural values and norms, male have freedom of mobility and participation in different extension programs and consequently have greater access to information (as indicated in table 3) most of participant in farm activities are, male and more of are adopters than females.

Marital status of sample household heads: in the below table show that the sample respondents the percentage of adopters that married, single were 72.1%, 43.9% and respectively. were as in the sample respondents the percentage of non- adopters that married, single, were 27.9%, and 56.1% respectively, this data indicates that married households can handle and manage their overall livelihood (social duties and farm activities) better than households who are not that enabled them to produce more and generate more income. Therefore, married households are more probability to adopt than the non-married (single) Thus, this variable was hypothesized to have positive relationship at significant level of $P< 0.01$with adoption of the improved wheat varieties (as indicated in table 3）.

Educational level of household head: education was therefore, expected to increase the probability of the farmers to adopt new technologies at insignificant, as it indicated in the table 3. The percent illiterate of adopters and non-adopters are 57.5% and 42.5% respectively and the percent literate adopters and non-adopters are 61.3% and 38.7% respectively the data indicate that, majority of non-adopters is low education level than adopters; these leads to the low will be the knowledge, information and resist to adopt new technologies. More educated farmers are able to access information on a given technology and understand and asses the attributes of that technology compared to less educated farmers (as indicated in table 3)

Access to agricultural credit service: access to credit service was hypothesized positively and significantly at less than 1% level is one of the major institutional factors influencing the decision of the farmers to adopt new technologies. The farmers who access to credit have higher probability to adopt improved wheat varieties than those who had no access to credit service the as shown in table5 mean age of household adopters and non-adopters are 1.45 and 1.87 respectively this indicates most of adopters obtain credit service in order to buy farm inputs to increase new technology.

Access to agricultural extension service: Access to extension service was one of the institution characteristics hypothesized at significant 5% level to influence farmer's decision to adopt new technologies. One can gain an extension service through various means, such as attending filed days, visiting demonstration fields, participating in formal training, listening agricultural programs on the radio and through communicating with neighbors, relatives and community leaders. Of these, the main sources of information for the adoption of improved wheat varieties were extension service through development agents and district of agricultural office. Development agent were the main sources of information for the household farmers in table above show that the number of percent of adopters and non-adopters are, 47.4% , 68.4% and 52.6%, 31.6% respectively this data indicates Extension service and adoption have positive relation because in extension service farmers get advice, training, information, demonstration and distribution of agricultural input.

Table 3. Descriptive statistics of categorical variables

Variables	**Categories**	**Adopters%**	**Non-adopters%**	**Chi-square**
Sex of HHS	Male	67.6	32.5	3.94**
	Female	47.82	52.8	
Marital statue	Married	72.1	27.9	4.74**
	Single	43..9	56.1	
Access to credit	Yes	83.7	16.3	10.9***
	No	48.4	51.5	
Education	Illiterate	57.5	42.5	0.14
	Literate	61.3	38.7	
Access to extension	Yes	47.4	52.6	4.21**
	No	68.4	31.6	

** and*** significant at less than 5% and less than 1%, respectively.

Source on survey (2022).

Factors affecting the adoption of wheat varieties

Regression analysis of shows that, variables like age of house hold distance to local market, extension service, sex of household heads, family size, access to credit, number of oxen owned by household have positive effects on the adoption of improved wheat varieties, whereas variables like land holding, size of household, education has a negative effect on the adoption of improved wheat varieties as indicated the table below, selected explanatory variables were used to estimate the logistic regression model to analyze the determinants of households' adoption behavior on wheat technology. A logit model was also used to estimate the effects of the hypothesized explanatory variables on the probabilities of adoption.

Table 4: Results for logit model

Explanatory var	B	S.E.	WALD	Df	Sig	Odd ratio
Age of household heads	.150	0.031	23.435	1	.001***	1.162
Sex of household heads	1.732	.924	3.512	1	.001***	5.651
Marital status	-.930	.431	4.649	1	.031**	.395
Education level	.154	.438	.124	1	.725	1.167
Distance to local market	..576	.125	21.401	1	.001***	1.779
Number of oxen	-564	.290	3.781	1	.05**	.567
Land holding size	.285	.316	.871	1	0.351	1.343
Access to credit	1.711	.549	9.727	1	.001***	5.535
Off-farm in come	.00	.00	3.596	1	.05**	1.00
Family size	.360	.141	6.567	1	.01***	1.434
Livestock ownership	20.851	23205.422	.000	1	0.999	.000
Non-farm income	.00	.000	1.346	1	2.46	1.00
Availability of fertilizer	.603	.288	4.394	1	.036**	1.827

** and*** significant at less than 5% and less than 1%, respectively.

(Source: model output)

Logistic model was used to identify determinant of improved wheat technology in study area Specially, variables assumed to have influence on household adoption of improved wheat technology and were also tested in the model and out of 13 variables nine of them were found to be significant. Among variables fitted in to the model age of household head, educational level of household head, off-farm, non-farm income, use of chemical fertilizer, oxen ownership, family size distance to local market found to be significant

Age is a continuous variable particular to the household head and that matter the result of this survey revealed that age of the household head has positive and significant (at 1 % level of probability) technology relationship with household adoption of improved wheat (as indicated in the Table 4). The logit increases by old ratio of 1.162 as the age of head of that household increases by one year. The possible explanation of for such positive association might be due to household head not apply for his time on farming activities and as age increases, in such cases one can acquire less knowledge and less experience assumes vulnerability adoption of new technology

Family size was hypothesized to have positive on influence on household adoption of improved wheat varieties and It is significant (at 1 % probability level) and has a positive association with household adoption of I improved wheat varieties as number of family increases labor force also increases and household is likely to adopt new technology, The odds ratio in favor of adoption technology increases with increasing family size and was found to be 1.434 .This implies Households with large family size, increases their production.(as indicated in table 4)

Off–farm income was hypothesized to have positive association with household adoption of new technology the logit model output illustrates that it is significant (at 5 % probability level) and has positive relationship with probability to adopt new technology (as indicated in Table 4) This shows that off-farm and /or non-farm job opportunities play prominent role in managing household adoption in Awabarre district The odds ratio in favor of adoption increases by factor of 1.00 off-farm of labor force increases in birr In order to purchase farm inputs and fulfill family needs and thus, they are fully adopted on new technology

Non-farm income : the other variable that influence adoption of improved wheat varieties negative and insignificance at probability level is non-farm activities the possible explanation for this is if the household held to participate non-farm activity like poultry trade , handcrafts, construction work and other source of money to make investment this source of investment used to buy for agricultural inputs including improved wheat varieties the odds ratio in favor of adoption decreases by factors of 1.00 non-farm income decreases by the factors of 1.00 adoption of new technology has probability to decrease (as indicated in the table 4)

Oxen ownership was significant at 5% level of probability and positive association with household adoption of improved wheat varieties (as indicated in Table 6). Oxen are main traction power in rural households of the Awabare district. Most of time oxen plowing allows effective utilization of land and labor resources, and this in turn enables households to have better chance to increase food production. Oxen ownership allows the saving of labor and spreads employment of the family labor of difficult period for the farm and non-farm activities, contributing towards ensuring adoption of technology. The odds ratio of household adoption increases by factor 0.137 for each additional ox owned by household.

Availability of fertilizer on time had positively and significantly influenced the probability of adoption of improved wheat technology at less than 5% level. The model result implies that those farmers who get chemical fertilizer on time are more likely to adopt improved wheat variety than those who do not have access to fertilizer on time. The odds ratio of 1.827 in this respect shows that, other explanatory variables kept the same, the odds in favor of adopting improved wheat technology increases by a factor of 1.827 as the fertilizer is made available on time (as indicated in table 4)

Sex of household head: the variables was significant at 5% significant level and positively related adoption of new technology the relationship indicating the probability of man to adopt new technology is higher than that of woman the odd ratio to adopt new technology increase by the factors of 5.651 for man as compare to woman the possible explanation is that due to many socio-cultural values and norms, male have freedom of mobility and participation in different extension programs and consequently have greater access to information and higher dominance of male in agricultural fields and most of participant in farm activities are male.

Conclusion and Recommendations

The study revealed that the rate of adoption of improved wheat varieties has increased from time to time the major actors in the dissemination of information about wheat technology are extension agents and neighbors, other sources of information included relatives, researchers, traders, producers, and service cooperatives.

Access to extension service was found to be positive and significantly affect the adoption new technology in the study, the reason behand is extension service farmers get advice, training, information, demonstration and distribution of agricultural input. therefore, agricultural extension service office should be strengthened to promote the adoption of improved wheat technology through field days, formal training and demonstration fields. The extension service should give attention in accessing information; Knowledge and skill to household farmers through including poor household farmers and women groups in its program in order to participate in income generating activities. Therefore, those who have relatively high income could increase the capacity to purchase improved seed other agricultural inputs.

Accessibility of credit was found to be serious problems in the study area. The main reason behand is that Farmers who have access to credit can minimize their financial constraints therefore it is better to improve the efficiency of credit system, efficient and effective delivering credit service to the farmers has to be considered as a central and core components of any development intervention, the formal credit system needs to address the credit constraints faced by farmers and increase awareness about the type of credit available for agricultural production. In addition, the government should encourage farmers to form their own saving and credit cooperatives at the village level.

Age of household head was found to positive and significant relation to adoption. The main case behind is that household head having a young ages' due to life experience have much better association with adoption of new technology and provide better information about the institutions that facilitate access to use new technology. as result, facilitation on experience sharing and selective training to older households is essential.

Oxen ownership was found is the main source of traditional means to cultivate land in the study area. It allows effective utilization of land and labor resources, and evenly spread labor over peak and difficult periods. Thus, consideration in this regard should be made to undertake development activities and proper interventions towards improving oxen ownership and animal health services through provision of farm credits and appropriate extension services.

The most important credit problems cited in the study area were the unavailability of loans from informal sources, high interest rates, and it has been noted that with rising input prices, improved access to credit for peasant farmers has become indispensable. The informal credit system needs to address the credit constraints faced by farmers and increase awareness about the types of credit available for agricultural production. In addition, the government should encourage farmers to form service cooperatives or farmers' groups to reduce transaction costs and improve their constraints.

Adoption of the improved wheat varieties was observed to improve the productivity of the adopting farmers, which provides them with marketed wheat surplus. This marketed wheat surplus also facilitated these farmers to participate in output markets. Therefore, government organization and non-government organization should facilitate the non-adopters to adopt the new varieties through creating market opportunities while supporting the adopters to continue adopting. Hence, farmers can produce more and by connecting to markets and selling their products, they can improve their livelihood. Exploiting the full benefits of the technology in improving food and nutritional security will require increased investments and policy support for improving wheat productivity through greater access to variety information, improved seeds, complementary inputs, such as fertilizer and herbicides, better producer prices and value chain development for reducing transaction costs related to input and output markets.

Income was found to have positive and significant effect on the adoption of new technology therefore government (local or/and country) and other Non-Governmental Organization (NGOs) should do their part in creating awareness, facilitating the access and mobilizing farmers to adopt the improved varieties so that farmers can improve their agricultural productivity and then change their livelihood.

Distance to market was found to be positive influence the adoption of new technology in the study area, since households near market centers tend to have easier market access to dispose of their production, easy information lower transaction cost, better market information therefore, measures including construction of new market, creating market opportunities and improving infrastructure lower cost of agricultural inputs, creating awareness, facilitating the access and mobilizing farmers to adopt new technology and strengthening timely response mechanisms to adopt new technology should be given emphasis.

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6.2. Analysis of Production and Marketing of Gum and Resin to Integrate Pastoralist Sustainable Economic Benefits

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Abstract

The main objectives of the study were to analyze production and marketing of gum and resin to integrate Pastoralists' sustainable economic benefits in Adadle Woreda of Shebele Zone. The major data sources of this study were both primary and secondary data sources. The initial survey was conducted to collect village-level information such as Challenges facing by gum and resin production in pastoral community's, Market opportunities for gum and Resin and Socio-economic benefits of gum and resin and others livelihood activities major gum and resin collectors and traders. For the quantitative analyses, a total of 67 households from study area were randomly selected. The study was mainly used descriptive method of data analysis. Data collected from the sources were cleaned, coded and entered in to Excel and made ready for analysis. Qualitative data obtained through focused group and key informants discussion were summarized, interpreted and narrated. The finding of this study shows that majority of the interviewed respondents were cooperatives. Finally, the study showed that their positive expectation of the respondents towards gum and resin collection if practiced community awareness creation, mobilization and establish strong linkage from collectors, retailers/whole sellers, cooperatives and national actors of gum and resin product.

Key Words: *Production, Gum and Resin, Marketing*

Introduction

In Ethiopia dryland covers about 65 ppercent of the country's landmass (Mulugeta and Demel, 2004). Ethiopia Somali region constitute estimated dry land coverage of 40 percent, the largest dry land of the country (EPA, 1998). The dryland of Ethiopia constitutes several economic and ecological important plant species, uniquely adapted to the variable and extreme conditions of these areas. The natural gum and resin bearing dry woodland tree species are one valuable plant predominantly grown in the dry land of the country. Ethiopia is one of the African countries endowed with natural gum and resin bearing plants, namely *Acacia*, *Boswellia*, and *Commiphora* species. This makes the country is one of the world's leading producers of incense, notably frankincense (product of Boswellia spp.) and myrrh and myrrh-like resins (products of

Commiphora spp.) (Lemenih and Teketay, 2004). Ethiopia also has a large resource base for the production of gum arabic (product of *Acacia senegal* or *A. seyal*), although current production levels fall far short of the potential. There are no up-to-date data on the area of land covered by oleo-gum resin bearing tree species and the potential production capacity. However, previous studies indicate that the country land covered by gum- and resin producing species such as *Commiphora, Boswellia, Sterculia,* and *Acacia* ranged from 2.86-4.36 million ha. In Ethiopian Somali regional state, the land covered by these species ranged from 150, 000–1.5 million ha (Fitwi, 2000; Lemenih and Kassa, 2011) Table 1. As indicated in Table 1 Ethiopian Somali regional state has the largest land coverage of *Commiphora, Boswellia, Sterculia,* and *Acacia* in the country.

It has been estimated that Ethiopian Somali regional state has a potential of producing 11,250 qt of gum arabic and a total of 46,000 qt gum *olibanum*, myrrh and oppoponex annually (Ayele and Tadesse, 1990).

Gum and resin-producing species cover substantial areas of Ethiopia recognition of the contribution that gums and resins make to local livelihoods and the national economy is growing. These natural plant products play significant role as income source of local community as well as in foreign currency generating. In subsistence and rural economies, the role and contributions of gum and resin collection is crucial because of their variety of application as food, herbal potions, hygiene, cosmetic and cultural values (Adefires, 2006). It is one of important income generating source for dry land reside community in Ethiopian Somali region. Study conducted in Liban revealed that a total of 903 tons of oleo-gum resins is estimated to be collected from the vegetation of the area. Out of this, 209 tons is gum arabica, 266 tons is frankincense, 187 tons is myrrh, 33 tons is gum talha and 208 tons is hagar (Lemenih *et al*., 2004). About 96.4% of all the interviewed households in the area collect oleo-gum resins mainly for earning cash income with average annual cash income of US$80.0727.6 per household. The total annual economic contribution of oleo-gum resin collection was estimated to be 32.6% per household ((Lemenih *et al*., 2004). These indicate the contribution of oleo-gum resins for livelihood improvement of pastoral community. In dry land where rain fed agriculture and livestock rearing is constrained with shortage rainfall, the use of Non-timber forest products in general and gum and resin, in particular become a necessity than an option for income diversification and ensure food security of the community. Among the several advantages gum and resin had, their ability to be accessed by the household during the dry seasons where other options were either declined or not available at all. In this regard, the majority of the respondents (87.3%) in Borana believed that gum and resins may be the first most quick and even more sustainable means of getting income for the local society (Adefires, 2006).

Gum and incense is one of exported commodities of Ethiopia and generate hard currency. Ethiopia harvested about 38 million USD worth foreign currency, from 29, 340 tonnes exported natural gums and resins in the 10 years period 1997/98 to 2007/08. This is equivalent to average annual earnings of about 3.5 million USD (32.8 million Eth Birr) Lemenih and Kassa, 2011). It contributes a lot for national economy of the country (Adefires, 2006). The increased demand for natural products in the global market offers a good opportunity to plan for development strategies that improve the livelihood of people by making use of natural resources such as gum and resins (Kindeya, 2003).

The production of various gums and resins varies according to the type and place of production. Common to all, however, is the fact that production and harvesting are seasonal and performed solely during dry seasons. Ethiopia's current gum and resin production system can broadly be subdivided into two activities: production by tapping and collection of naturally oozing gums and resins (Lemenih and Kassa, 2011). In Ethiopian Somali regional state, collection of naturally oozing gums and resins is the most single production practice. Quality of natural exudates is compromised by such factors as overexposure to radiation, which bakes the resins and discolours them, and premature collection, which means the gum has high moisture content, making iclumpy and with loose granulation. Furthermore, poor and excessive tapping of individual trees and poor harvesting technique, threaten stands of Boswelliaand Commiphora species**,** and possibilities of sustainable production of frankincense and resin, while there hasn't been significant effort made to fill the knowledge gaps on how to improve yield and quality of this product.

Ethiopian Somali regional state has hug gums and resins production potential nearly account of 34% of the country. However, the sector is one of untapped and /or underutilized natural resource and contribution for the dry land community minimal compared to existing resource. Gum and resin products in the ESRS are collected mainly from natural ooze except the case of frankincense from *B. papyrifera*. However, quality of natural exudates is compromised by such factors as overexposure to radiation, which bakes the resins and discolors. On other hand, though tapping is a very important operation for effective harvesting, but is rarely practiced by pastoral and agro-pastoral communities and if done it is made using traditional/ aged methods, which not only yield lower product but also significant impacts on the mother trees. Moreover, the methods of collection, post-harvest handling/cleaning and storage are also not well developed in Ethiopia in general and in ESRS in particular. This has its adverse effect on the quality and quantity of gum produced and thus on the role that they could play both at local and national level. Moreover, the mixing up of gum and resins of different species for the sake of increasing trade volume which leads to adulteration, and hence poor quality, is one of the big problems affecting the market condition for gums and incenses produced (Adefires, 2006).

In the views of aforementioned facts on the limitation of natural gum and resin productions in Ethiopian Somali regional state, this study is intended to analysis production and marketing of gums and resins producing area of study in Somali regional state. This study was conducted with the objectives of analysing the market opportunities for gum and resin in the pastoral communities of project area; analysing the challenges faced by gum and resin production in pastoral communities' project target area and investigating socio-economic benefits of gum and resin and its sustainability of pastoralist

Methodology of the study

The study site was selected objectively by their potential of having sufficient gum- and resin-bearing tree resources and mostly characterized as dry forest and woodland ecosystems with low rainfall and high temperature (Eshete *et al.* 2011, Worku *et al.* 2012). The study was conducted in Somali regional state, Shebelle Zone, Adadle Woreda. The district is among the potential areas in Ethiopian Somali regional state where diversity of gum and incense bearing plant species exists. It is borderd by west in Afder Zone, on the north by the Shebelle River which separates it from Gode, east by Kelafo Woreda and on the south by Somalia.

The climate of the district is characterized as arid to semi-arid agro-ecology, where livestock is the main occupation and cultivation is undertaken along Shabelle river bank. About 10% of the district population depends on riverine cultivation, 28% are agro-pastoralists, 60% are pastoralists and 2% are urban dwellers (SCF-UK 2001a). According to CSA, 2007, population projection, Adadle has total population of 83,260, of whom 48,166 are men and 35,094 women.

The major data sources of this study were both primary and secondary data sources. The initial survey was conducted to collect village-level information such as Challenges facing by gum and resin production in pastoral community's, Market opportunities for gum and Resin and Socio-economic benefits of gum and Resin and others livelihood activities major gum and resin collectors and traders. At this phase, questionnaire pre-testing was carried out after a verbal agreement was made with respondents on the purpose of the research and how the findings would be reported and benefit to the local communities. Based on the information from such a rapid appraisal, sample respondent households, key informants, and collectors and cooperatives practicing in gum and resin activities were selected for the detailed study. In general, data collection was involved a sequential exploratory strategy (Creswell 2009) where quantitative data collection and analyses will be supplemented with qualitative information obtain through group and key informant discussions and field observations (Yin 2009). For the quantitative analyses, a total of 67 households from study area were randomly selected.

In this study both quantitative and qualitative analyses were undertaken. The study was mainly used descriptive method of data analysis. data collected from the sources were cleaned, coded and entered in to Excel and made ready for analysis. Qualitative data obtained through focused group and key informants discussion were summarized, interpreted and narrated.

Results and Discussion

According to the gender segregation of the respondents, the result shows as depicted below figure 1. i.e. 90% were age group between 25-64, while 9% of the respondents were fall between the age 18-25, and the remaining 1% was above 65 years old. Nevertheless, the findings indicate most of the respondents were under age of productive which between 25-64 (90%).

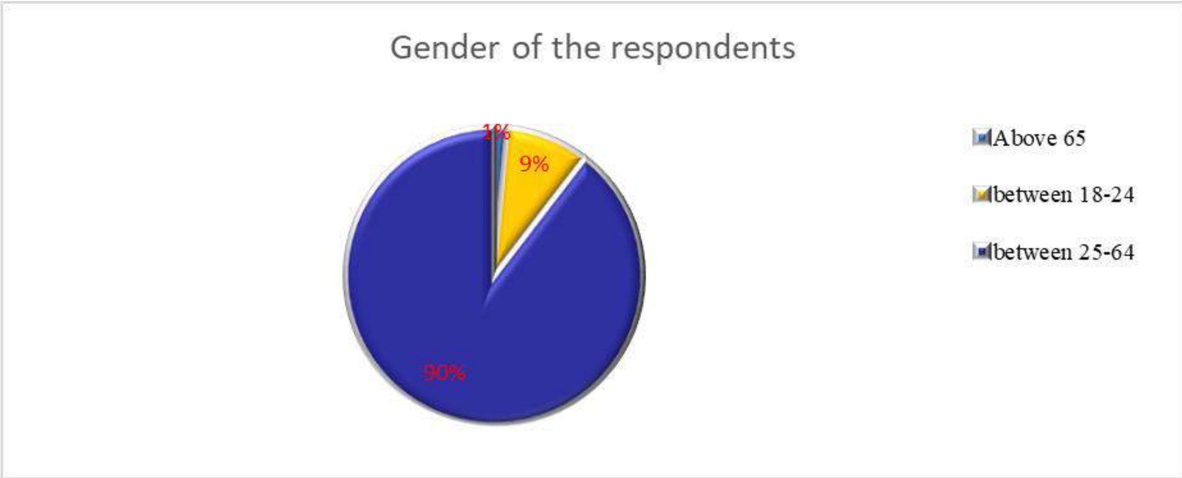


Figure 2. Gender of the respondents

Regarding to the respondent's social status majority of them 61% reported that they are cooperative members who practicing gum and resin business, 25% confirmed they are gum and resin collectors while the other 14% are wholesalers or retailers of gum and resin. As the study mainly focused on gum and resin cooperatives existed in the study area. See below figure2 for further explanations.

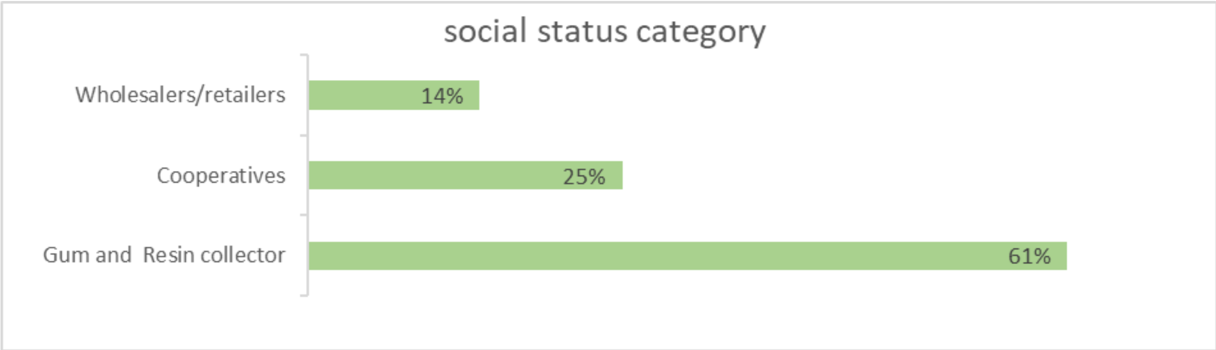


Figure 3. Share of respondents regarding their social status categories.

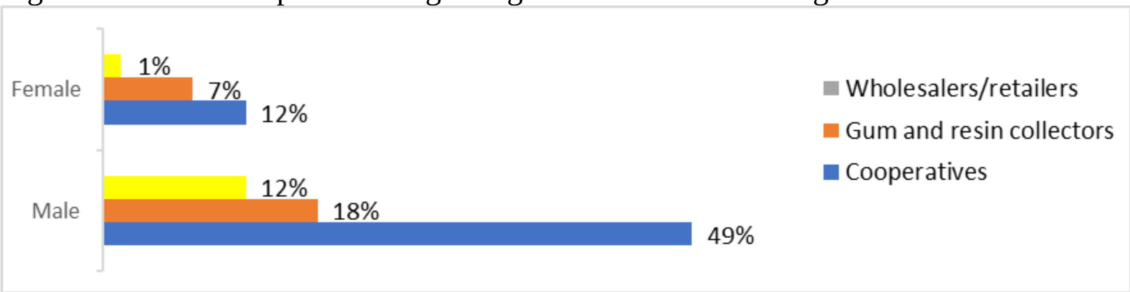


Figure 4. Gender of the respondents with the respect of their social status.

Regarding to the above figure3 with respect of the how gender of the respondents influences the respondent's category. However, findings show that 49% and 12% of the respondents stands cooperatives, which are composed of male and female respectively. This gives us 61% of the interviewees are cooperatives regardless of their gender. In addition to that, 18% and 7% of the respondents stands for Gum and resin collectors which of their gender segregation are aforementioned above male and female respectively. Similarly, this shows 25% of the respondents are gum and resin collectors. Finally, 12% and 2% of the total respondents represents for wholesalers/retailers of gum and resin, which also consists as previous once male and female respectively, which depicts the general interviewees 14% of respondents represent wholesalers and/or retailers of gum and resin.

Generally looking for gender inclusivity of the three types categories of the respondents (cooperatives, collector and whole/retailers) there is less in number of female participants which indicates male are dominating such business activities. In addition to these some other studies (Babulo *et al.*, 2008, Shiba and Michael 2012), stated their findings demographic factors such as age, gender, level of education of the head, whether children go to school or not, and family size affect a household's choice of livelihood strategy and, hence, decision to engage in the gum and resin business. This follows as most of the socio-economic activities dominated by male, gum and resin business is similar to that which needs more socially awareness for all gender participation of all activities.

Table 1: Level of education

Level of education	Above 65	between 18-24	between 25-64	Grand Total
Diploma	0%	0%	3%	3%
Illiterate	0%	1%	27%	28%
Primary	0%	7%	48%	55%
Secondary	1%	0%	12%	13%
Grand Total	**1%**	**9%**	**90%**	**100%**

According to the above table1 result shows, level of education for the respondents, 55% of the respondents are primary school holders which means they can read and write, 13 % reported they are secondary school holders which also indicates this portion of respondents they are literate, while only 3% of the total respondents confirmed they have diploma level education and finally

28% of the total respondents are illiterate this part of people they cannot read and write. However, as result shows 90% of the total respondents are under age of productive age between 25-64 years which shows the gum and resin activity are type of business that needs the actors themselves to be under productive age and also 9% reported that they are under between the age of 18-24 years which still shows that they are approximately near to the productive age, while the remaining the 1% falls under the age category of above 65 years. Overall, the result reveals that 99% of the respondents are convenient the type of work they have in terms of age category.

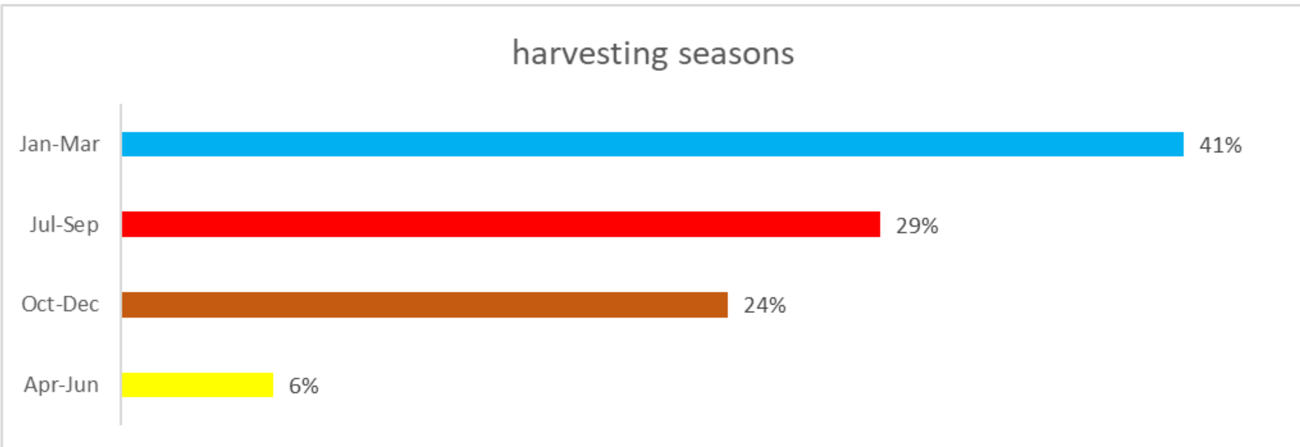


Figure 5. Harvesting Seasons

However, gum and resin collection with the respect of seasonality as shown above figure3, result indicates 41% of the respondents confirmed they harvest gum and resin between January- March which shows harvesting is good for dry and climatically warm months, while the second largest response are 29% which reveals, they collect gum and resin between July- to September whereas also 24% reported collecting gum and resin in between October to December which also dry season in Somali region and 6% represents collecting the product between months of April-June. Generally, this means gums and resin collects mostly during the first three months of the year which are driest period in the region, since these months are in a dry season and temperature is high in the eastern region, makes a sense of gum and resin availability is high and convenient for collection. Furthermore, a study conducted in Borana zone of Oromia region revealed that harvesting of gum and resin is usually performed at dry seasons, I.e. good quality product are available at dry season (Worku, 2006). Overall, this shows its general to collect gum and resin at desiccated period, which is common as revealed the studies.

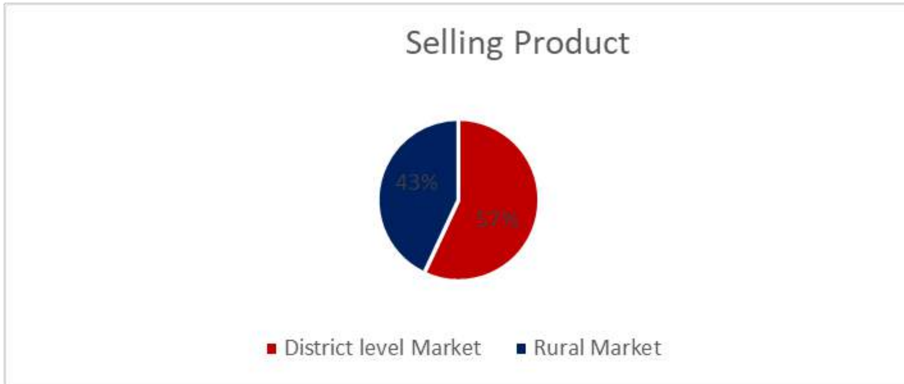


Figure 6. Selling Product

Based on the above figure4 total of 17 respondents from gum and resin collectors, 57% of them reported they sale their products at district level while remaining 43% of respondent's sale their gum and resin collected at rural (villages). Furthermore, during focus group discussion gum and resin business practicing cooperatives stated that they sell their product at Gode Town as it is a main hub connecting other parts of the region. Nevertheless, this depicts the gum and resin harvesters have market for their products even though the price is different, regarding whether the actors (gum and resin collectors) get fair price for their products, result shows that 47% of them sale their product at fair price (a price that they are agree with buyers), however this does not mean its highest price or equivalent its measures only the satisfactory of the respondents. While 41% of the respondents described that they sale their gum and resin collected at flexible price. i.e. there is no fixed selling price they sell what amount they receive however in terms of their satisfactory shows this their convenient at this price. But, 12% of the product collectors sell at low price which are not convenient for their satisfaction. Hence, though the result shows majority of the respondent satisfied the price of their product but to ensure potential harvesting of gum and resin as the region is woodland in nature so investing this sector results good resource consumption and many unemployed individuals will involve looking their daily live and livelihood for this sector. For more detail about pricing of gum and resin please see figure6 below.

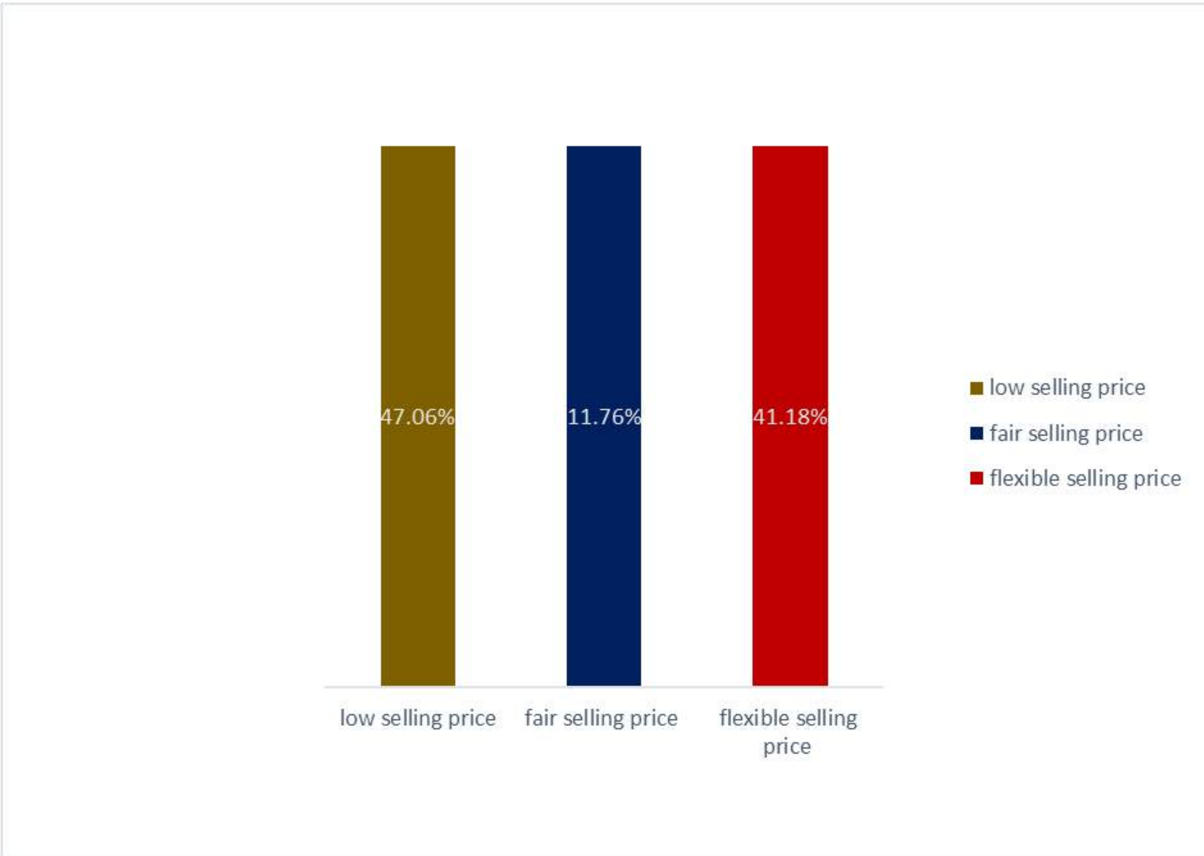


Figure 7. Gum and Resin Selling Price

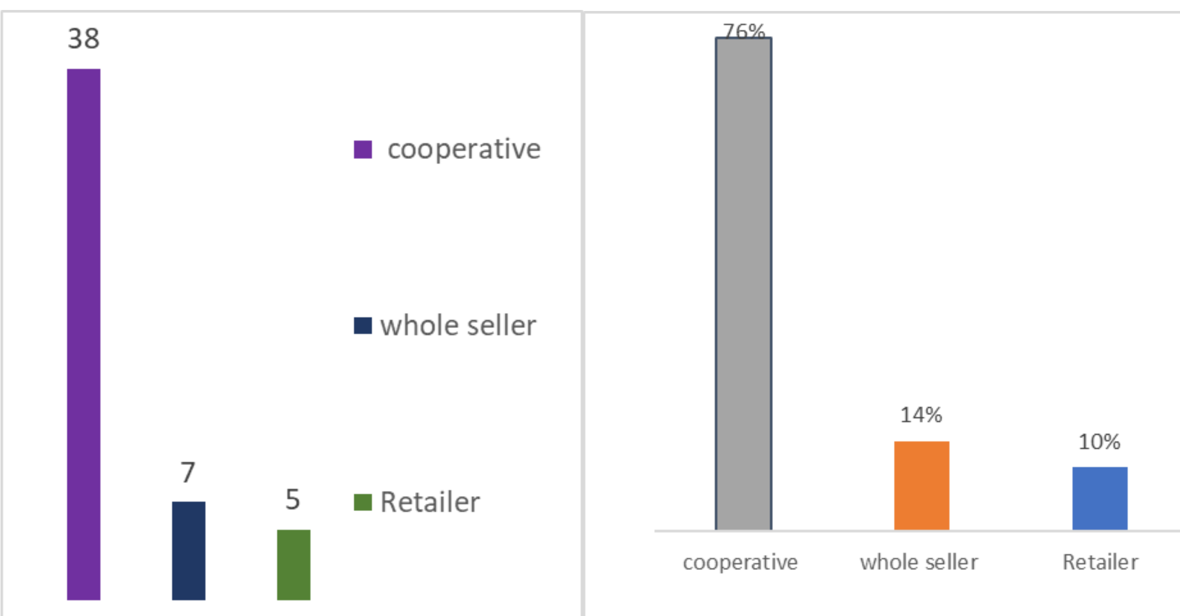


Figure 8.Gum and resin traders categories

Regarding type of gum and resin actors they are the respondents 50 of them confirmed that they are traders out of these 50 participants 76%(n=38) reported they are cooperatives they work us a group who share profits and risks they face, while 14%(n=7) depicted that they are whole sellers and the remaining 10%(n=5) revealed that they are retailers. This shows that majority of the respondents are cooperatives who are group people who as common business objectives. This helps government and NGOs when they want to capacitate this people it's easy and convenient to train a group of people while its somewhat challenged when training individuals. In terms of source of gum and resin, the respondents confirmed as shows below figure 62% of the respondents reported they gain from rural pastoralist collectors and 34% of the respondents confirmed they gain from individual collectors those collect from rural areas, while the remaining 4% collect themselves in the rural areas.

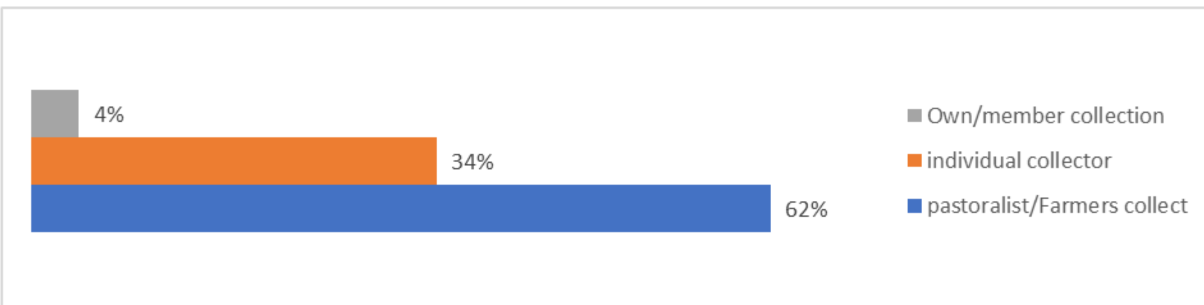


Figure 9. How do you get gum and resin for your market

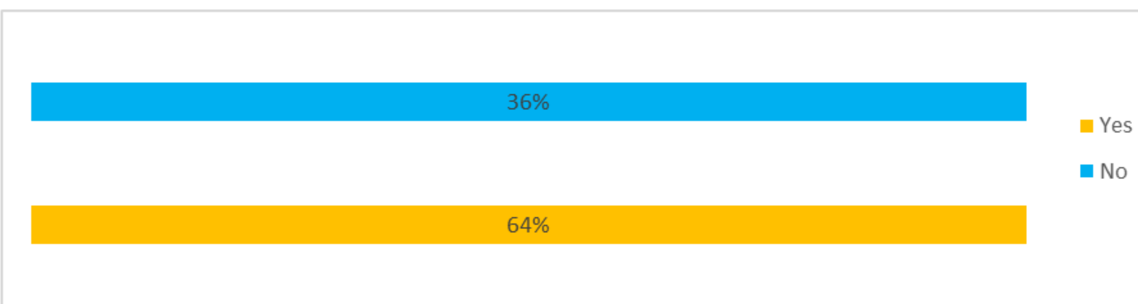


Figure 10. Cooperative members

Regarding to their business legality 64% of the respondents were found that they are cooperative and registered for the collection of gun and resins and 36% confirmed that they are gum and resin retailers/ whole sellers who is not registered their business. This shows that 36% of them do not have registered license, while the majority of them have license and registered they business had the legal allowance for their business.

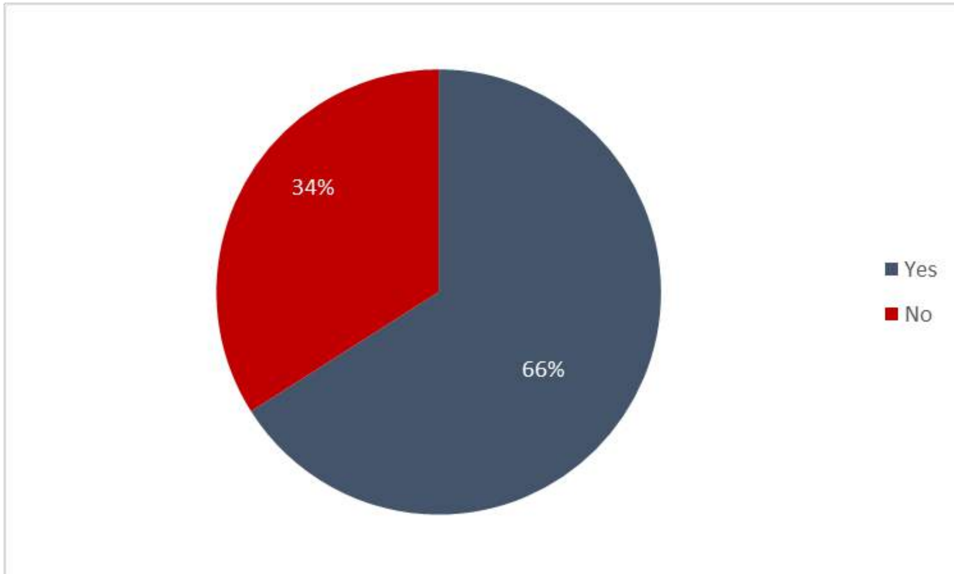


Figure 11. Respondents received training

In terms of the training about collection and marketing 66% are receiving training and capacity building about gum and resin collection from local government and NGO. While the remaining 34% do not receive any training this also relates the above discussion means as some of the gum and resin operates not found legal registration for their business and not in the list of local government office, they do not have chance to get training while the majority of them receiving training means those are registered in the government are receiving training and incentives.

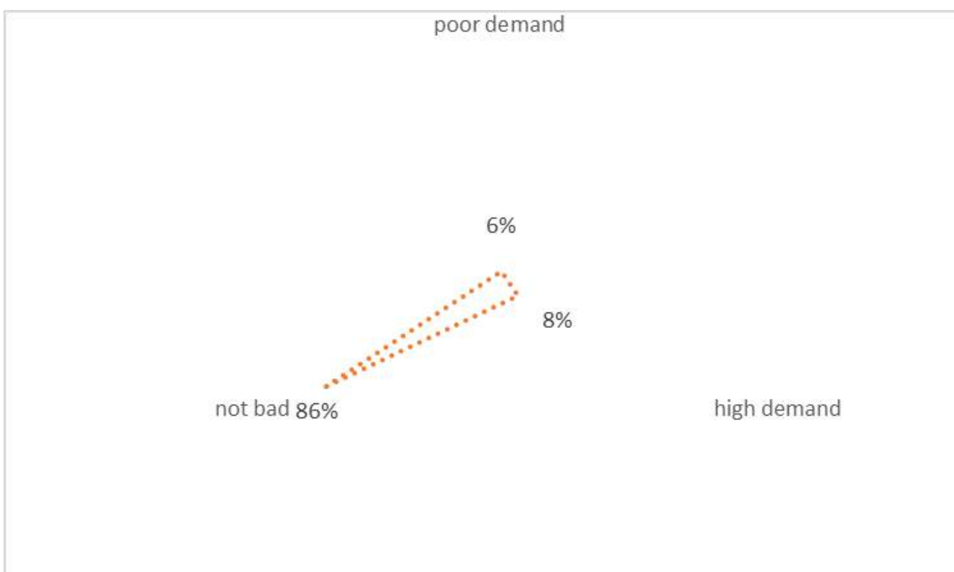


Figure 12. Demand for the product

About the market demand of gum and resins the respondents stated during the survey 86% of them reported there is demand for their product while they mentioned normal demand/not bad this indicates there at least demand of their gum and resins collected regardless of their price and profitability. While 8% confirmed there is high demand of their product. However, 6% revealed there is poor demand of their product.

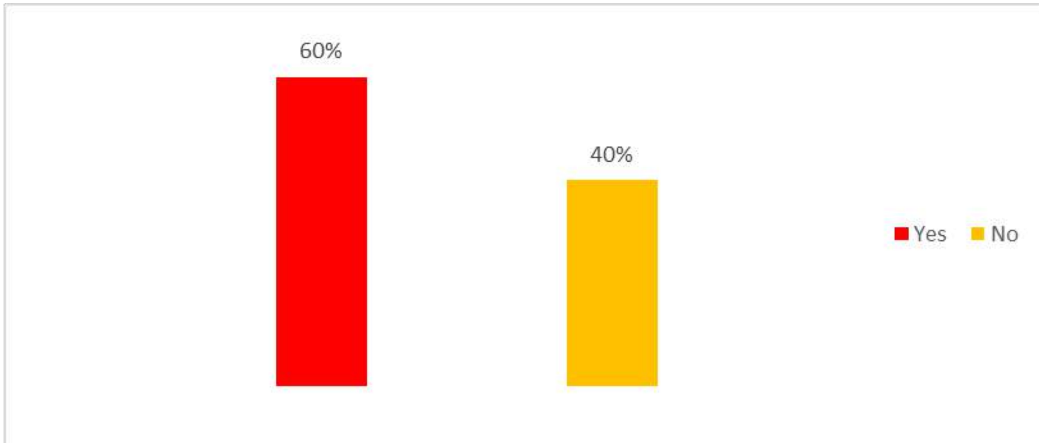


Figure 13. Respondents received support from organizations

More than half of the respondents 60% clearly stated that they are receiving support or motivational incentives for the collection of gum and resin from local government and NGO, whereas the remaining 40% stated they are not getting any support. similarly, this finding supports and agrees the business legality as those who registered from government receives capacity building training while those not registered were not found gaining capacity building training. Generally, this shows the licenses helps the business to gain support and incentives from the government and NGOs.

Table 2. Expenditure of income from gum and resin

Response	Count of spending money
spent back to the business	64%
partially home consumption	28%
invest some other activity	8%
Grand Total	**100.00%**

According to the above table, the interviewees have responded as coming points. The responders said that after dealing trade of gum and resin the transactions obtained are spent back to the business (64%), partially home consumption (28%) and invest some other activity (8%) respectively.

Therefore, the most respondents claim that money from trade should invest back to the business to keep nurturing and operation of the business plus to this investing back to the business maintains being competence and strong firm. So this shows as a specialization of one business activity and experience of gaining and losing seasons of that particular business.

Challenges for gum and resin production

Its usual that any type of business that are operating faces challenges. Regarding to this study as the target community were pastoralist those in Adadle woreda of Shabelle zone they revealed that 46% of them faces hardship challenges as the environment is hard to work and operate such environment as it needs to travel far areas of rural land and collect the gum and resin were woodland founds and 43% frequency of drought which makes them not regularly collect gum and resins in the woodland and 11% food insecurity are the third challenges faced the gum and resins harvesters in pastoralist.

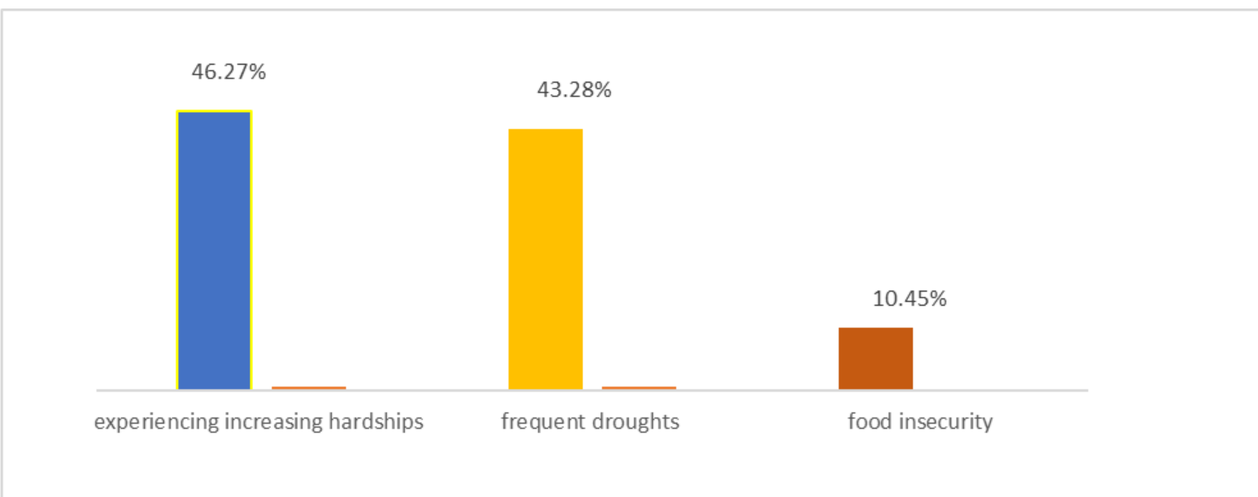


Figure 14. Challenges faced by respondents

About the challenges facing the pastoralist communities as discussed in the below table 44% of the them reported they face challenges relating to the road access, while 38% of them reported poor food availability as they cannot stay in the bush area without enough food this caused people will not travel and stay long time due to food accessibility. Following this also lack of water and rainfall causes people are at risk not to have are another challenge that counts 7% while lack of knowledge and storage included the challenges 6 and 3 % respectively. However, 2% of them confirmed that poor and remoteness of health facilities adds fuel the challenges facing the pastoralist. This limits the accessibility of pastoralists to engage such activity of gum and resin collection for more details see below figure.

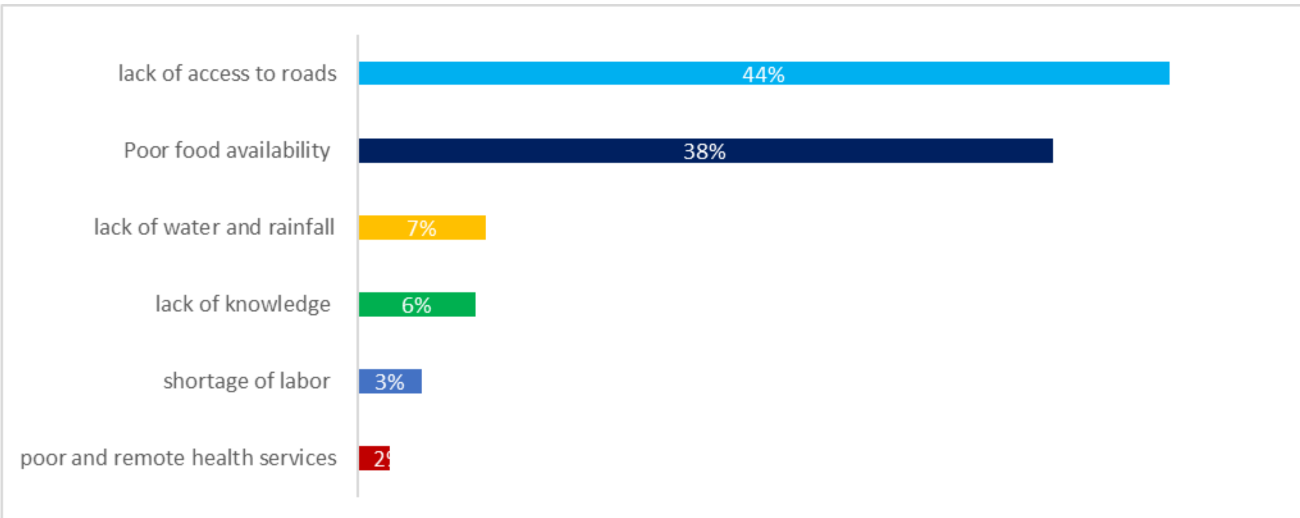
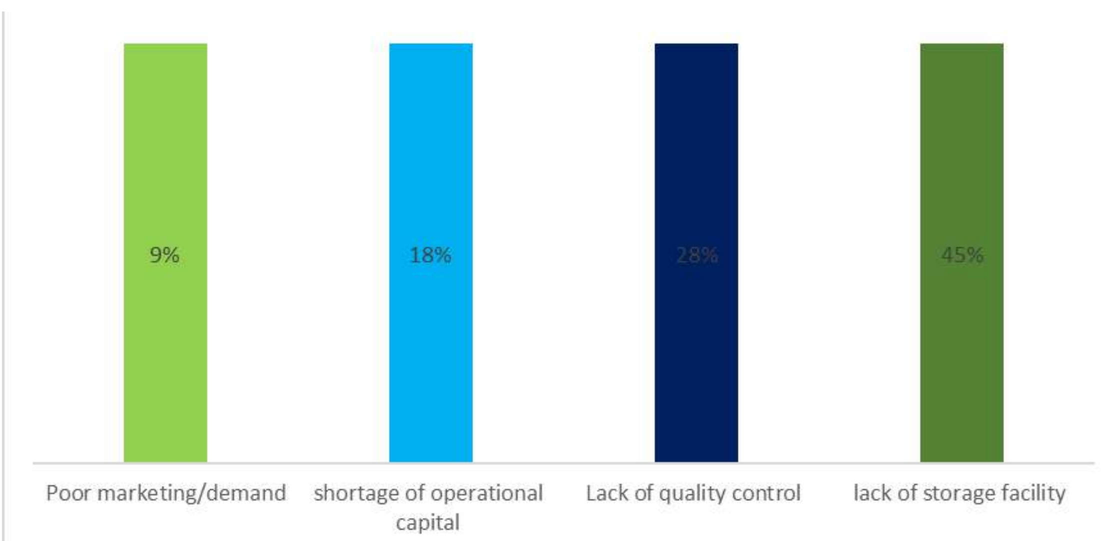


Figure 15. Challenges to production of gum and resin



Fugure 16. Challenges to market

Based on above graph traders of gum and resin challenges are interpreted as follows according to the responders perspectives. The participants have responded that lack of storage facility (44.78%) were the top obstacles they face since professions of dealing gum and resins. Secondly the interviewees have responded that the lack of quality control (28.36%) were the next major contests they have been encountered. While the shortage of operationla capital (17.91%) placed the third difficulty one and lastly responders said that the poor marketing/demand (8.96%) was the least hinderence encountered.

According to this data, the availability of storage facility contributes energy to the fortering of gum and resing trade enhancement therefore, the feeling this gap pays to immidiate attention so as to remore buisness tention and to stabilize availabity of gum and resing through the year.

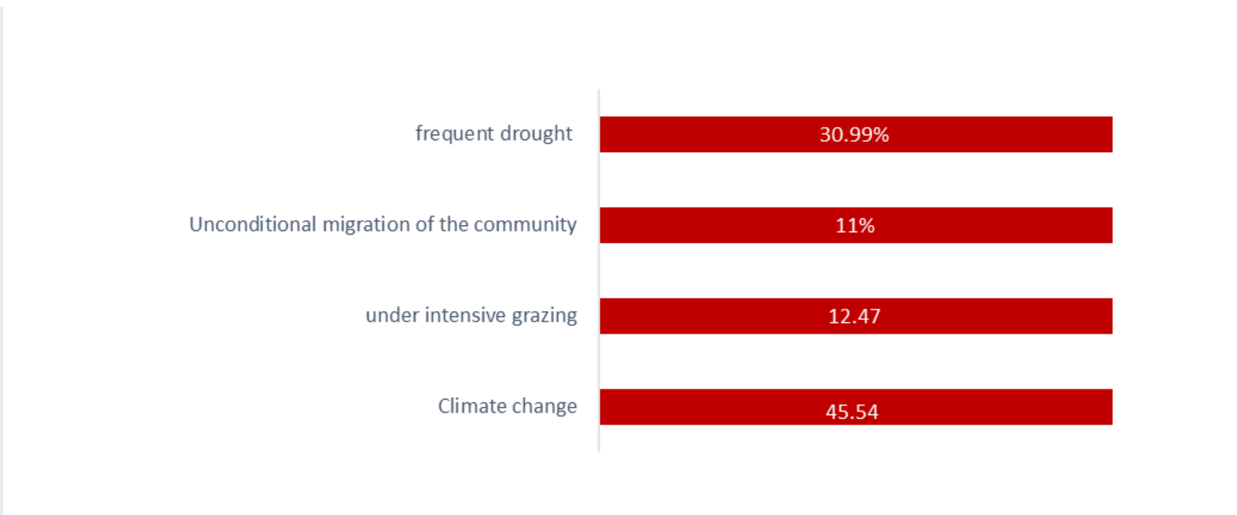


Figure 17. Challenges to hurvest good product

During harvesting product collectors faces challenge other challenges including climate change which holds share of 45.54% an the remaining shares are intensive grazing, unconditional migration of the community and frequency of drought 12.47%, 11% and 30.99% respectively. Generally this shows climate change affects collection of good quality gum and resin.

On other hand during qualitative survey the

Socio-economic Benefits of Gum and Resins

To assess socio economic benefit of gum and resin harvesters in Adadle woreda of Shabele zone somali region. 63% out of the interviewed respondents reported that they believe gum and resin harvesting have an opportunuty of improved marketing and demand of good production, while 34% mentioned awareness creation of the people involving gum and resin collection is the opportunity that can improved the of gum and resin and only 3% stated value added processing is the opportunity that can be improved the demad and marketing of the woodlad product. Nevertheles this shows majority of the respondents confirmed improving the gum and resid product will pave the way good marking of the gum and resin product.

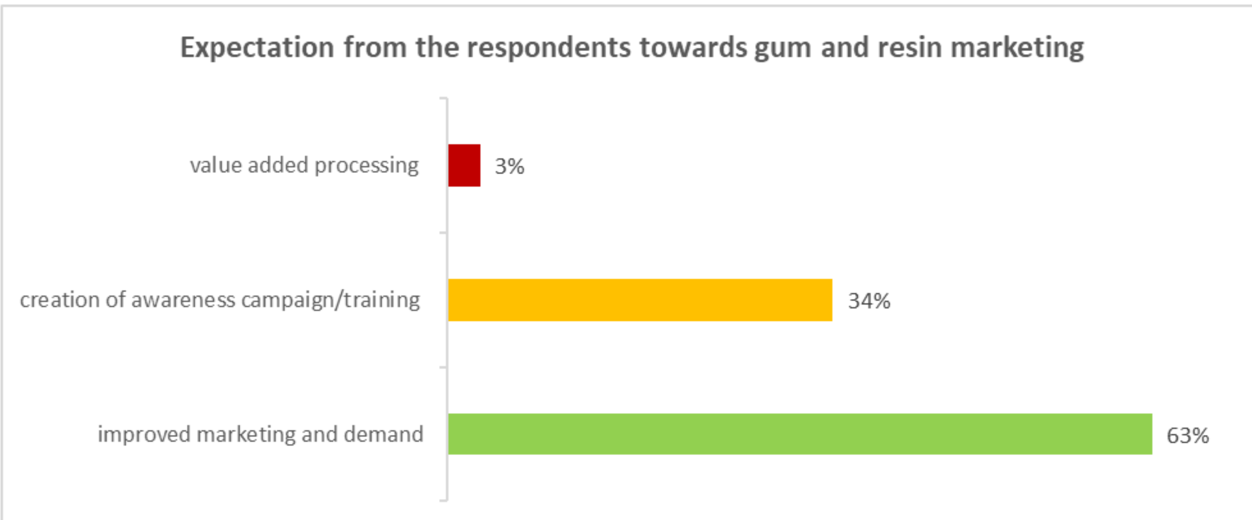


Figure 18. Expectations from respondents

Table 3. Expectation regarding gum and resin production

Response options	Frequency	Percentage %
increased government attention	17	25%
improved recognition of gum and resin resources	22	33%
linkage of market networking	21	31%
strong market demand at national and international level	7	11%
Total	67	100%

As shown above table the respondents were asked as a trader what are their expectation regarding gum and resin production. But the result shows that 33% of the respondents confirmed that they expect improved recognition of gum and resin resources, 31% of them reported they expect linkage of market network, whereas 25% of the respondent confirmed their expectation of gum and resin collection is to increase government attention toward their businness and the remaining 11% revealed that strong market demand at national and internatiobal level of gum and resin production.

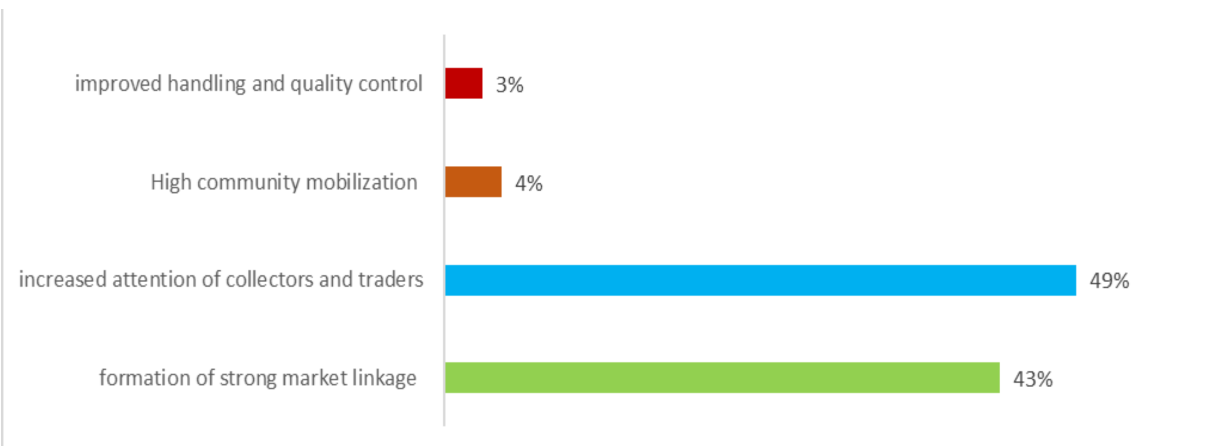


Figure 19. Market opportunity

In terms of community and trader's perception regarding gum and resin collection 49% of the respondents reported that increased attention of collectors and traders, 43% of them confirmed formation of strong market linkage, while the remaining of small portion of the respondents 4% and 3% stated high community mobilization and improved handling and quality control of gum and resin collection respectively. In generally this shows good perception and understanding of the community and traders about gum and resin collection and the gap that needs to filled is awareness creation and community mobilization while also mention that have an expectation of improving marketing and demand of gum and resin product regarding harvesting of the woodland product.

Gum and resin production and marketing system

In the study area, gum and resins are gathered through the collection of natural exudates. When myrrh is harvested naturally, it is extracted from the tree's bark in the form of an amber or reddish-brown liquid that is thick, extremely scented, and yellow in colour. The average size of the tears, which come in a variety of sizes, is that of a walnut. During the two dry seasons, gum and resins are harvested twice a year. Herdsmen, women, and kids are the primary collectors.

There isn't a very explicit program for collectors to follow in order to gather gum and resins like the resin from B. papyrifera. The collection is typically done concurrently with herding, unless households are in need of cash income.

Processing and grading

Before being packaged for sale, collected gums and resins passes the cleaning and grading process. Gum and resins must be prepared by drying in the shade, sorting into piles of whole tears and smaller pieces, removing any gloomy gum or resin, and separating any bark or other unwanted objects. This Processing is typically carried out by manually.

Before being packed for transport, the raw frankincense is kept in small, specially made hats or dry caves to allow the resin to dry out. Women in the main stores further process the dried resins by hand-picking the items to sort them according to size, color, and the presence of any external objects. The grading method entails removing impurities the resin using various mesh sizes. Smaller, darker, and powdery pieces and siftings are less valuable than the larger, white pieces, which are typically bagged for export. A tear size of 6 mm and above and white in colour is first grade. The only primary processing that is done is the grading and sorting of the resin that was discussed earlier.

Myrrh is typically divided into two categories: cleaned and unclean. Because of the frequent occurrence of a mix of species in export shipments, it is more prone to quality variation than resin from B. papyrifera. Breaking pieces of high oil content, good quality, selected myrrh should be slightly sticky rather than crystalline. For the production of essential oils, it is crucial to use high quality materials like this. The size and colour of myrrh are also graded. First grade is regarded as being red and large, while second grade is large but brown in colour.

Conclusion and Recommendations

It’s obvious that most of communities in Somali region are pastoralist dominating their livelihood for livestock and their product, however due to frequent of recurrent drought which resulted to loss this people their livestock that led them to look their livelihood by harvesting woodland product specifically gum and resin as well as charcoal production. In this were focused on only gum and resin harvesting to assess the product`s marketing opportunity, challenges faced by the collectors of pastoralist and socio-economic benefit of the production.

The finding of this study shows that majority of the interviewed respondents were cooperatives. 57% of the respondents were mentioned that they sell the harvested gum and resins in district level while the other counterpart sells at rural areas i.e. where they collected from the product. While majority of the participants reported that they sell the collected gum and resin in price that is fair or either flexible this does not mean that it in lines with the price equivalents comparing with the national, regional and international price of the product however only this shows in terms of their satisfaction towards what they had collected from the bush land. Regarding to business legality majority of the respondents revealed that they had business license while some them do not have business license, for the consequence of above point also those who do not have business license do not obtain incentives from the government and other supporters. More than half of the respondents unveiled that the income they attain from the gum and resin spent back to their business and other confirmed they spent home consumption as well as other activities. Environmental hardship and movement of communities because by recurrent drought that makes them to shift their residential to new place where their livestock can find pasture are main obstacles that the gum and resin collectors/traders face. Finally, the study showed that their positive expectation of the respondents towards gum and resin collection if practiced community awareness creation, mobilization and establish strong linkage from collectors, retailers/whole sellers, cooperatives and national actors of gum and resin product.

Based on the result discussed aforementioned findings, the researcher proposed below recommendations.

- To ensure good gum and resin harvesting it is highly recommending the concerning government offices to encourage the gum and resin collectors to register their business or register them, this will help to provide them capacity building trainers and obtain incentives.
- Land buffering for the gum and resin production; this will make to increase the production of the gum and resins to protect production from the land degradation of others. Like cutting or burning the trees to make them money.
- Regular awareness creation, mobilization and capacity building for the gum and resin collectors/traders to booster the production and encourage
- To mitigate climate change that effected woodland forest production Government and stakeholders are required clear climate mitigation action plan
- To conduct further studies to investigate the nature of the gum and resins and their selling price in relation to the national and global prices of the products.
- To maximize benefits for the sustained production and development of the resources, multi-institutional coordination and action integration are necessary to carry out the aforementioned interventions. At the federal, regional, and municipal levels, including the business sector, activities may be shared across multiple entities and stakeholders.
- Institutions that offer credit or enable loans to cooperatives, build and maintain market ties and networks, and promptly disseminate market information are all crucial.

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6.3. Value Chain Analysis of Sesame in Kelafo District, Somali Region, Ethiopia

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Abstract

Globally, the top largest producers of sesame are Myanmar, India, China, Sudan, Uganda and Ethiopia. In terms of export potential, Ethiopia is the third world exporter of sesame seeds after India and Sudan. Sesame is the second major export cash crop in Ethiopia, next to coffee. Therefore, the objective of this study was to analyze the value chain analysis of sesame in Kelafo District, Somali Region, Ethiopia. The study was employed two-stage sampling techniques to draw 123 sesame producers and other chain actors. Descriptive statistics and econometric models were used to analyze the data. The results of this study show that there are different actors across the sesame value chain in Kellafo District. The major once is input suppliers, producers, traders, oil miller's processors and exporters. The results of profit and marketing margins of actors in sesame value chain showed that producers and collectors receive the highest profit share as well as marketing margin in the sesame value chain in Kellafo District. Moreover, the linear regression model result showed that family member aged in 15-70, land cultivated to sesame, yield per hectare, Seasons harvested sesame, farmer experience of sesame production, Access to loan, Usage of improved sesame seed have statistically significantly affected the amount of sesame supply to the market.

Keywords: *Kelafo, value chain, marketing margin, Sesame*

Introduction

Globally, the top largest producers of sesame are Myanmar, India, China, Sudan, Uganda and Ethiopia (Girmay, 2018). Evidence also indicated that Ethiopia ranked the second in Africa in terms of sesame production (Hagose, 2017). In terms of export potential, Ethiopia is the third world exporter of sesame seeds after India and Sudan (Alemu and Meijerink, 2010). Sesame is the second major export cash crop in Ethiopia, next to coffee (Abebe, 2016). According to FAO

(2015), sesame marketing has significantly increased in Ethiopia. Between 2002 and 2012, the earning from the sesame export increased from 66 to 427 million US dollars and its contributions to the national earnings has increased from 6.7% to 12.8% in the same period. From 2000 to 2016, the total amount of sesame export increased from 21 thousand tones to about 217 thousand tones, an increase of more than tenfold (Kedir, 2017).

Regardless of its increased export marketing and economic earnings, the Ethiopian Central Statistical Authority (CSA) and FAOSTAT figures indicate that the sesame area coverage, production and productivity are not in a constant increment in recent years. For instance, the average sesame area coverage, production, and yield at the national level over the period of 2010 to 2018 were 222,952 ha, 2,486,469 quintals and 7.47 quintals per hectare, respectively (CSA, 2019; FAOSTAT, 2019)

However, the sesame production has registered significant growth over the period from 2000 to 2009. In 2000, the total area cultivated for sesame was 28,190 ha, which produced 156,240 quintals with a yield of 4.09 quintals per hectare. On the other hand, different studies claimed that Ethiopia has ample potential for sesame production (FAO, 2015; Gelalcha, 2009; Girmay, 2018; Kostka and Scharrer, 2011; Wijnands *et al.,* 2007). This is mainly linked to sesame natural flexibility to adopt different soil types and harsh environments as well as Ethiopian diversified agroecology and potential of arable land, water, labor force, and market opportunities. However, this potential has not been adequately tapped yet due to different production-related problems. For example, studies by Gelalcha (2009); Kostka and Scharrer (2011); FAO, (2015); Girmay (2018); Hagose (2017), and Kedir (2017) indicated that shortage of improved varieties, poor seed supply systems, producers dependence on traditional seeds for many years, poor agronomic practices, pests and disease, drought, poor postharvest management, weak farmers organization, poor market information system; and little research support to increase yields and erratic rainfalls are among major constraints hindering sesame production in Ethiopia. Similarly, the sesame value chain in Ethiopia, which links producers to market, is hampered by a variety of constraints; primarily sever coordination challenges (FAO, 2015; Galalcha, 2009).

Sesame is one of the longest-established crops of the Somali people. The Somali regional state is ideal for cultivating sesame scientifically and fertilely, especially the Shebelle river. Sesame oil is widely used in the Somali region. Kelafo district is a well-known in producing quality sesame in Somali region. Kelafo farmers sell their products in Shabelle zone and some neighboring towns in Somalia. Therefore, the objective is study to identify the actors and their functions across the sesame value chain; to identify actors those have the highest profit share in the value chain and to show which factors that can be the main causes of the sesame production.

Materials and Methods

This study was conducted in Kelafo District. It is a woreda in the Somali Region of Ethiopia. Part of the Shabelle Zone, Kelafo is bordered on the south by the Somalia, on the west by Adadle, on the northwest by Gode, on the northeast by the Korahey Zone, and on the east by Mustahil. The total population (in 2007) of the woreda is estimated about 77,471 The Shebelle River is flowing through this woreda.

The study was employed two-stage sampling techniques to collect data from actors involved in the sesame value chain. In the first stage, from a total of 15 kebelles in the Kellafo District, four kebelles , namely Dariiqo, Boholaws, Afdub and Bargun were selected purposively based on their production potential and experience in sesame production. In the second stage, sesame farming households, traders, oil millers and processors/exporters were randomly selected using probability proportional to the size. Accordingly, a total sample of 123 (90 producers, 13 collectors, eight wholesalers, four oil mailers, three processors/exporters and five local consumers) were used in the study.

In this study both primary and secondary source of data were employed. The required primary data were collected through questionnaires. Alongside the survey, from each selected kebele, one focus group discussion (5-10 participants) which contain men and women, actors in the sesame value chain and researchers' direct observations were conducted to generate general information across the sesame chain. Moreover, the secondary data were collected from kellafo district government offices, Bureau of Agriculture and Rural Development (BoARD), Kelafo Agricultural Research Sub-Center (KARSC) and non-governmental institutions including both published and unpublished documents.

The study was used both descriptive and inferential statistics to analyze the data. Under the descriptive methods such as chain map was used, Analysis specifying functions of each actor across sesame chain, described under the map. Economic models were used to analyze profit and gross margins across the chain. Moreover, multiple linear regressions were used to analyze the determinants of sesame quantity supplied to the market.

Marketing margin of the given agricultural commodity is referred as the difference between purchase and sale prices of that commodity through its marketing channel. Gross margin is calculated by dividing the gross income or gross profit to the revenue earned from sales. Then, multiply by 100 to give a percentage. For this study, the gross marketing margin (GMM) of sesame is given as:

$$\text{GMM} = \frac{\text{Endbuyerprice} - \text{Sellerprice}}{\text{End buyer price}} \text{ x } 100 \ldots\ldots\ldots\ldots(1)$$

The net marketing margin (NMM), which is the percentage of the final price earned by the Intermediaries as their net income after their marketing costs are deducted, and calculated as:

$$\text{NMM} = \frac{\text{Gross margin} - \text{Marketing cost}}{\text{End buyer price}} \text{ x } 100 \ldots\ldots\ldots\ldots \text{(2)}$$

Moreover, multiple linear regression model (OLS) will fitted to analyze factors affecting amount of sesame supply to the market. The dependent variable is the amount of sesame supplied to the market which is a continuous variable. Hence, OLS model is right fit to the farm household data analysis. The multiple linear regression models are specified as:

$$Yi = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \cdots + \beta iXi + \varepsilon i \ldots\ldots\ldots\ldots(3)$$

Results and Discussion

Sesame Value Chain Map of Kelafo District

The value chain map helps us to understand how different businesses interconnect to form one system. It is a potential starting point for the inclusion of producers, traders, consumers, and other stakeholders in the chain (Lundy *et al.*, 2014). Hence, presenting our results by mapping of the sesame value chain in the study area (Figure 1). The map involves functions, actors and other service providers in the whole value chain.

The main actors in the sesame value chain are an individual or institution directly involved in sesame value chain activities from the points of production to consumption. The main actors of the sesame value chain in Kellafo District are described in bellows figure.

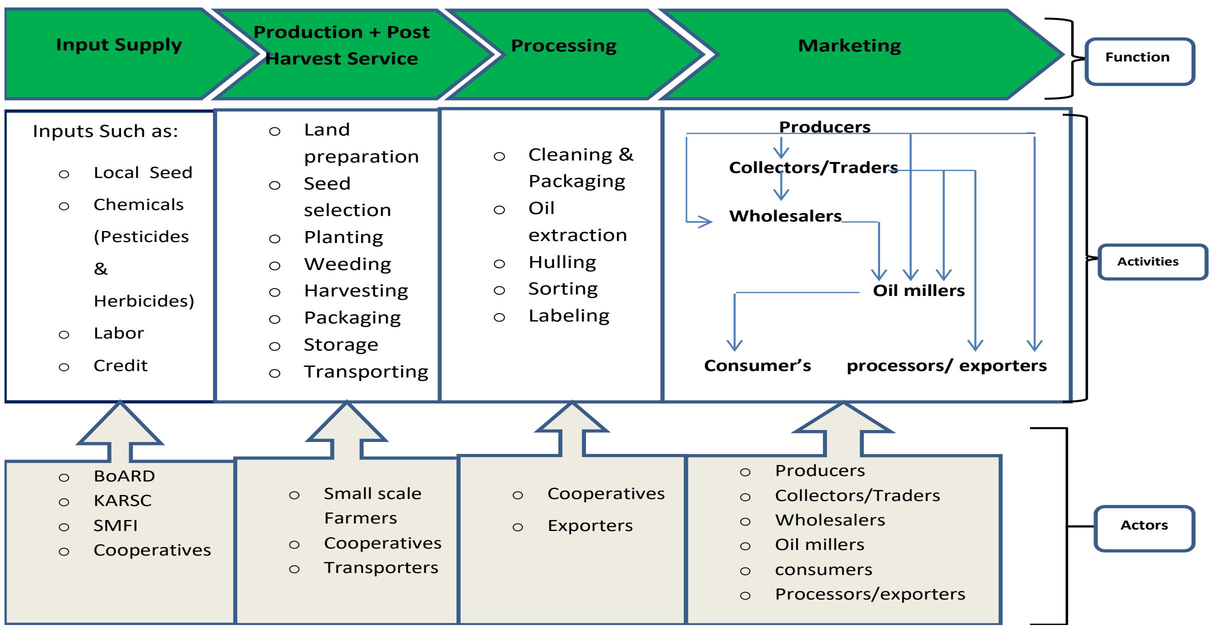

Figure 1. Sesame value Chain map in Kellafo District

The main input suppliers in the sesame value chain in Kellafo District are Bureau of Agriculture and Rural Development (BoARD), Somali Microfinance Institute (SMFI), Kellafo Agricultural Research Sub-Center (KARSC), and Cooperatives.

The major inputs supplied to the farmers in the district include local seed, chemicals such as pesticides, and credit. Although Bureau of Agriculture and Rural Development (BoARD), kellafo Agricultural Research Sub-Center (KARSC) are serving as sources for improved sesame seeds. All the farmers use recycled or local seed that they have saved from their previous production. The main reason is that farmers believe that local sesame varieties are better adaptable to their local conditions. As a result, their sesame yields are continuously decreasing in year to year. Some farmers told us that they did not get any improved seeds. However, Kellafo Research Sub-center have shown that planting the different sesame seed varieties can achieve good yields. After that, farmers should plant/test a new variety.

On the other hand, farmers in the study area stated that they do not use fertilizer for sesame production due to the availability of fertilizer and also the price is non-refundable. All sources of chemical fertilizers supplied to farmers were from the government through cooperatives.

Other important inputs for sesame farmers are pesticides, which are often supplied by the traders/cooperatives in the district. However, the pesticides are too expensive in market prices offered by traders or private dealers, and often arrive too late.

Credit, which is one of the essential inputs for sesame producers, is provided by Somali Microfinance Institute. Yet, according to interviewed farmers, loans are too small, ranging from 5,000 to 10,000 Birr depending on the collateral and repayment history of farmers. To pay for all the required inputs, as well as land preparation and harvesting, loan-size needs to be increase in order to be effective.

Another alternative source of loan is Commercial bank. Commercial banks also offer loans but needs collateral which farmers usually do not have since there land do not qualify for collateral in Ethiopia. For this reason, Commercial Bank of Ethiopia does not provide loans to individual farmers, but to cooperatives.

Producers are the first link in the value chain and directly involved in the production activities beginning from land preparation up to delivering product to the different actors. The roles of farmers in sesame production include land preparation, cultivation, planting, weeding harvesting by using different farm tool or machines.

Sesame producers, in the study area, are predominantly small-scale farmers. All of farmers apply traditional way of farming including mono-cropping. They use broadcasting for planting and manual weeding, harvesting, drying, and threshing. Farmers in the study are do not practice a modern agro-mechanization technology that would reduce extensive use of labor force except land preparation during land preparation trackers even are rent there are a need of sesame harvesting technologies like per-harvesting technology, cleaning technology and so on. They produce sesame only for commercial purpose. They supply their product to cooperatives or local traders. In some times, they sell directly oil millers and exporters

Collectors are seasonal and operate for a short period after sesame is harvested. The primary target of those sesame collectors was getting a profit margin that would be obtained from producers share and wholesalers share. Some collectors do not have sufficient capital to purchase sesame.

Village collectors are also involved in sesame, by collecting through the product directly from producers and resell to wholesalers, oil millers and exporters, oil miller and exporters are becoming important stakeholders in sesame sectors in the study area.

Wholesalers are also the main actors and connect between producers and other actors in sesame value chain. Wholesalers are larger suppliers who have better capacities in terms of finance and other facilities. They buy the seeds from producers; collectors and they resell the seeds to oil millers and exporters. They act as an important role in the supply chain of sesame trading in the study area.

There are around five private owned oil milers especially in the Kelafo Town, which produce edible oil exclusively for local market. They buy the seeds from the producers, collectors and wholesalers. Some interviewed oil millers told us that they travel sometimes in the farmers in the time of harvesting by buying from the product. Improvement in the production quality could enable the larger oil refining plants to produce for export market.

Local consumers are the end users of both sesame seed and edible sesame oil. Sesame oil consumption is steadily rising around the Kelafo District owing to shifting consumer habits and rising health consciousness. Sesame oil is often used to sauté meats, vegetables and foods. the interviewed people believed the sesame oil to have some important health benefits, some of them told us that they use as purpose of as a medicine.

Processors and Exporters are individuals, who buy the seed from village collectors/traders and wholesalers to sell in the export market after processing and packing. Processors and exporters that are found in Kelafo Town are small. Exporters screen, clean and bag sesame into 50 kg of bags. Sesame processors are facing problems such as dirt, branches, and stones. This poor quality of sesame supply with high impurity level needs more cleaning costs to get it ready for export this lowers the sesame export.

Sesame Market Channel

A marketing channel is the people, organizations and activities that make goods and services available for use by consumers. It transfers the ownership of goods from the point of production to the point of consumption. It is the way products get to the end-user, the consumer; and is also known as a distribution channel. There are four main marketing channels and they are:

Channel 1. Producer's →Collectors/traders→ Wholesalers →Oil miller's → Consumers

Channel 2. Producer's → Wholesalers →Oil miller's → Consumers

Channel 3. Producer's →Collectors/traders→ Oil miller's → Local consumers

Channel 4. Producer's →Collectors/traders →Processors/Exporters

Channel 5. Producer's → Oil miller's → Local consumers

Channel 6. Producer's → Processors/Exporters

Marketing costs and margins

The results of profit and marketing margins of actors in sesame value chain in the study area showed that producers and collectors received the highest profit margin (see table 1). This indicates that producers and collectors involved in the sesame value chain can make reasonable profit on their sales as long as they can to reduce overhead cost such as labor costs.

Moreover, the gross marketing margin of farmers is the highest in the chain followed by producers and collectors.

Table 1. Costs, marketing profit and margins of actors in sesame value chain

Item (measured by Birr/Quintal)	**Producer**	**Collectors**	**Wholesalers**	**Oil Millers**	**Exporters**
Purchase price	_	8,000	8,500	8,500	9,000
Production cost	5,840	_	_	_	_
Marketing cost	240	35	25	15	55
Total cost	6,080	8,035	8,525	8,515	9,055
Unit sell price	8,300	8,500	8,700	8,900	9,300
Gross profit margin	2,220	465	175	385	245
% share of profit margin	36.50%	5.79%	2.05%	4.52%	2.71
Gross margin %	26.75%	5.47%	2%	4.33%	2.63%

Source: Own survey data. Currency listed is in ETB (Ethiopian Birr),

Factors affecting sesame supply to the market

The results of multiple linear regressions in (Table 2) indicate that the 13 hypothesized independent variables seven of them were found to have statistically significantly influenced market supply of sesame in the district. The significant variables were family member aged in 15-70, land cultivated to sesame, yield per hectare, Seasons harvested sesame, farmer experience of sesame production, Access to loan, Usage of improved sesame seed and membership in co-operative.

Table 2. OLS Results of Factors affecting Quantity of Sesame Supplies to the Market

Variable description	**Coefficients**	**Std. Error**	**t-value**	**Sign**
Constant	-16.320	7.590	-2.150	0.04
Family member aged in 15-70	-0.633	0.292	-2.163	0.033
Land cultivated to sesame in (hector)	10.483	0.488	21.467	0.000
yield per hector	1.495	0.120	12.442	0.000
Seasons harvested sesame in year	-2.447	0.802	-3.050	0.003
farmer experience of sesame production(year)	0.147	0.049	2.984	0.004
Access to loan	-2.902	1.281	-2.265	0.026
Access to extension service	-0,817	0.812	-1.006	0.317
Usage of improved sesame seed	2.327	1.160	2.006	0.047
Usage of fertilizer for sesame	-1.932	1.039	-1.860	0.066
Membership in co-operative	5.595	2.320	2.411	0.018
Current Selling Price 100kg of Sesame	0.001	0.001	0.701	0.485
Distance to the market (km)	-0.106	0.067	-1.570	0.119
Access to the market information	0.207	0.472	0.438	0.662

Source: Own survey result. Dependent variable: Quantity of sesame supplied to market in the 2022 production year. The level of significance is 5%.

R-squared is a goodness-of-fit measure for linear regression models. This statistic indicates the percentage of the variance in the dependent variable that the independent variables explain collectively. In the result the overall goodness of fit represented by model summary R-square is very good and the value of adjusted R2 is 0.909. Which means that 90.9% of the variation in quantity of sesame supplies to the market was explained collectively. Family member aged in 15-70 was statistically significance and have a negative relationship to the quantity of sesame seed supplies the market. The result implies that as family member aged in 15-70 decreases by one person, quantity of sesame supplied to market decreases by -0.633 quintals keeping other variables constant.

Land cultivated to sesame was statistically significant and have positively related to the quantity of sesame supplied to the market. The result tells us when the size of land cultivated to sesame production increases by one hector, quantity of sesame supplied to market also increases by 10.483 quintals keeping other variables constant. Yield per hector was statistically significant and have positively related to the quantity of sesame supplied to the market. The result tells us when the yield of sesame increases by one quintal per hector, the quantity of sesame supplied to market also increases by 1.495 quintals keeping other variables constant. It also indicates that households/farmers with high level of yield had also supplied more to the market than those who had a less yield of sesame.

Season's harvested sesame was statistically significance and has a negative relationship to the quantity of sesame seed supplied to the market. The result implies that as Season's harvested sesame decreases by one other season in a year, quantity of sesame supplied to market decreases by -2.447 quintals keeping other variables constant. Farmer experience of sesame production was statistically significant and have positively related to the quantity of sesame supplied to the market. The result implies as when Farmer experience increases by one year, quantity of sesame supplied to market also increases by 0.147 quintals keeping other variables constant.

Access to loan is statistically significance and has a negative relationship to the quantity of sesame seed supplies the market. The result implies that when access to loan decreases the amount of sesame supplied to the market also decreases by -2.902 keeping other variables constant. Usage of improved sesame seed is statistically significant and has positively related to the quantity of sesame supplied to the market. It shows that usage of improved sesame seed increases the amount of sesame supplied to the market increases by 2.327 keeping other variables constant. Membership in co-operative was statistically significant and have positively related to the quantity of sesame supplied to the market. The result implies that when membership in co-operative increases by one unit the amount of sesame supplied to the market also increases by 5.595 keeping other variables constant.

Conclusion and Recommendations

The results of this study show that there are different actors across the sesame value chain in Kelafo District. The major once is input suppliers, producers, traders, oil miller's processors and exporters. Producers are facing a lower yield as compared to the production potentials of the Kelafo District. Indeed, there is a need for increased production and productivity of sesame in the study area. This could be enhanced through the use of modern agricultural practices and technologies such as improved sesame seed, pesticides and improved post-harvest management practices and so on. Developing these practices can enhance quality as well as the increased supply of the sesame product to the market. The result of profit share and marketing margin, the producers and collectors tend to gain the highest amount of profit share and marketing margin across the sesame chain. This indicates that the sesame market is not well developed, and with small improvement in agricultural practices and use of modern technologies both the producers and collectors can add value and make more profit than they receive now.

Moreover, the linear regression model result showed that family member aged in 15-70, land cultivated to sesame, yield per hectare, Seasons harvested sesame, farmer experience of sesame production, Access to loan, Usage of improved sesame seed have statistically significantly affected the amount of sesame supply to the market. In light with results the following recommendation are forwarded. The government and other concern bodies like District, and Zone agriculture office, institutions, and NGO those who aim to improve the production and marketing of sesame need to address these factors: They should give more emphasis to the availability and use of improved seeds and other yield enhancing technologies, improving post-harvest practice technologies, improving financial & loan access, improving farmer's knowledge through capacity building & experience sharing with other sesame producing farmers in the country, also establishing with cooperatives and support them with finance.

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6.4. Value Chain Analysis of Wheat in Tuli Guled Woreda of Fafen Zone, Somali Region, Ethiopia.

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ABSTRACT

This study focused on the analysis of the wheat value chain in the Tuli Guled District of Fafen Zone with specific objectives of analyzing the market structure-conduct-performance of wheat markets; identifying the value chain of wheat supply to the market and market outlet choice of wheat producers, and wheat value addition at different stages of the marketing chain. Primary data were collected from 90 farmers and 30 wheat traders using structured questionnaires. Descriptive statistics were used to analyze the collected data. Results show that the study area's main wheat value chain actors are input suppliers, farmers/producers, assemblers, wholesalers, processors, retailers, and cooperatives. Results from the functional and institutional approach of value chain analysis showed that input providers, producers, cooperatives, collectors, wholesalers, retailers, and processors were found to be important wheat value chain actors. According to the survey results, only 15.8% only from the total sample households had access to credit and the remaining 84.2% had no access to credit. Cooperatives, Somali microfinance credit, and saving institutions, traders, and families/relatives are the sources of credit in the study area. The results of the study Woreda, indicate that the major wheat production constraint includes lack of stability, high input costs, shortage of rainfall, shortage of seeds of improved varieties, less awareness of farmers about improved crop management practices, the spread of weeds, and difficulty of saving pure seeds from farmers' harvest in combine harvested areas, and high cost of combine harvesting are among constraints reducing the productivity, production and return from the crop. Therefore, policies aiming to increase farmers' awareness of producing value-added wheat produce to enhance value creation are recommended to strengthen chain development.

Keywords: wheat, value chain Analysis, value chain actors, margin, market channel.

INTRODUCTION

Wheat is an important industrial and food grain, which ranks second among the most important cereal crops in the world after rice and is traded internationally. The area coverage, production, and productivity of wheat are steadily increasing from time to time, and fluctuating because of population growth, changing food preferences, and a strong urbanization trend. In Ethiopia, wheat production and consumption have increased over the past twenty years despite strong markets for potential substitute grains. The Ethiopian government has played an active role in wheat markets by making large investments in extension programs and adopting protectionist policies to ensure government control of all commercial grain imports. Despite these efforts, Ethiopia is expected to face a growing supply deficit in the absence of increased domestic production and/or changes to government policy.

Wheat is a source of food and income for Ethiopian farmers in general, and the Somali region in particular. Despite the region's high wheat production potential, several constraints impeded the wheat sector's and value chain's development. This study, thus, analyzed the wheat value chain in the Somali region in general, and the Tuli Guled District in particular, the most wheat production area in the region. According to the findings, results from the different studies showed that the actors in the wheat value chain have a shaky relationship. The domestic wheat consumption demand of the country for the last five years has revealed high growth over years. According to USDA (2014), the domestic consumption of wheat demonstrated the fastest-growing trend from 3.72 million tons in 2010 to 5.25 million tons in 2014, which is a growth of 41%. Despite the county's attempt to increase wheat production through various strategies, such as enhancing productivity and area expansion, domestic self-sufficiency of wheat in the form of wheat grain and flour is still far from the plan for the country. This might be because of high population growth, change in food habits resulting from the fast growth of urban, action, and the expansion of service sectors, such as universities, hospitals, commercial com, panties, and others which largely require at least one meal of wheat products per day. Therefore, filling the huge gap of supply and analysis of the wheat value chain are demand in the wheat sector needs and strategic approach. One of these strategies is employing a value chain approach in the wheat sector. The value chain approach involves identifying and assessing the whole range of actors involved and activities ranging from input supply to final utilization. It could include operations such as improved wheat variety generation, seed and supply of other inputs, production, marketing, and processing and consumption segments. It also investigates supporting and enabling environments at each segment of the chain to understand the interwoven problems in the sub-sector actor. Wheat consumption has increased faster than any other major food grain in the country, particularly for pasta and bread, and is expected to continue to do so in the future (Minot et al., 2019). It is a staple food in the diets of many Ethiopians, accounting for roughly 15 percent of the country's caloric intake for the country's over 90 million people (FAO, 2014). According to Mamo *et al.* (2018), domestic wheat consumption increased by 41 percent from 3.72 million tons in 2010 to 5.25 million tons in 2014. Even though wheat production has increased significantly over the last two decades as a result of various government programs and efforts aimed at improving agricultural growth and food security in the country, domestic wheat grain and flour self-sufficiency remain a long way off (Gebreselassie *et al.*, 2017). For example, the Ethiopian Grain Trade Enterprise imported 1.05 million tons of wheat in 2016 (Brasesco *et al.*, 2019).

However, the country has a large potential for wheat production, which has yet to be fully realized due to various production-related issues. For example, Hei *et al.* (2017), Abate (2018), Tesfaye *et al.* (2018), and Ayele *et al.* (2019) found that a lack of improved varieties, poor seed supply systems, producers' reliance on local seeds, high fertilizer and seed costs, poor agronomic practices, weeds, pests, and diseases, weak farmers organizations, poor market information systems, and little research support to increase yields and climate change are major constraints to Ethiopian wheat production. On the other hand, Ethiopian wheat output markets are characterized by an insufficient transportation network, a small number of traders, insufficient capital facilities, high handling costs, an insufficient market information system, farmers' poor bargaining power, and underdeveloped industrial sectors (Mohammed and Addisu, 2016; Mamo *et al.*, 2018).

According to Mahamud (2016) and Shikur *et al.* (2020), price cheating by traders, farmers' lack of bargaining power in the market, and unfair competition from illegal traders are the major marketing challenges faced by Ethiopian wheat farmers. To reduce the influence of local collectors, traders, and transporters on the pricing process, it is critical to establish marketing centers and cooperatives based on value chain studies (Tarekegn *et al.*, 2020). The theory was one of the proposed solutions to popularize the value chain concept as a collection of generic activities that operate within a company and collaborate to provide value to customers. Value chains include all production factors as well as all economic activities such as input supply, production, transformation, handling, transportation, marketing, and distribution that are required to create, sell, and deliver a product to a specific location (Mango *et al.*, 2015). Corrective measures can be identified by revealing strengths and weaknesses along the value chain, which improves overall value-chain performance and benefits all stakeholders (UNIDO, 2009).

Even though cereals, particularly wheat, are the most common crop in the Tuli Guled District where this study was conducted, the overall potential for wheat production and marketing, as well as comparative advantages and existing bottlenecks across the value chain, have not been well documented in order to assess possible value chain development strategies for upgrading wheat value chain. Moreover, there is an imbalance between the supply and demand of wheat products. In order to close the supply and demand gap in the sector, a strategic approach will be required. One of these strategies is value chain analysis. Therefore, this study aimed to analyze the value chain of wheat in Tuli Guled District, Fafen Zone, Somali Region of Ethiopia. More specifically, to assess the wheat value chain structure and performance of wheat markets in the study area; to identify marketing channels of wheat and to identify major opportunities and constraints of wheat value chains in the study area.

MATERIAL AND METHODS

The study was conducted at Tuli Guled Woreda in the Somali regional state of Ethiopia in 2021/22. The district has an altitude of 500-1600 m above sea level. The mean annual rainfall of the areas is 500-600mm with erratic distribution having a bimodal pattern increasing from April to August with peak rain section in April to July and the average mean Maximum and Minimum temperature of the area are 16 – 31 °C and 15 – 32 °C respectively. The location is characterized by arid to semi-arid agroecology, where crop cultivation is undertaken especially sorghum, wheat, maize, and groundnuts. The soil is sandy loams that can be grown for cereal and other crops (Badel, 2012).

A multistage purposive random sampling procedure was used to select representative households in the study area. In the first stage, the Tuli Guled District was purposively selected for this study because of its highest wheat production potential in Fafen Zone. Systematic sampling methods have been used to select farmers that are participating in the study. Participant farmers were selected by discussing with DAs the woreda agricultural office. In the first stage, from a total of 17 rural kebeles in the Tuli Guled district, three kebeles were selected randomly. In the second stage, wheat producers, traders, and processors were randomly selected in order to gather the necessary information from samples (90 respondents from farmer cooperatives, 25 from wheat traders, and eight from processors) were interviewed. A total of 123 sample wheat chain actors for the study were determined based on the following formula. Finally, appropriate numbers of sample farmers from three kebeles were selected in proportion to population size using Yamane's formula. Accordingly, the required sample size at a 95% confidence level with a degree of variability of 5% and a level of precision equal to 9% is recommended to obtain a sample size required which represents a true population

$$n = \frac{N}{1+N(e^2)} = 123 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$n = \frac{92065}{1+92065(0.09^2)} = 123 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where, n = sample size, N= Population size, and e = level of precision assumed 9%. Based on the above formula a total of 123 farm household heads and wheat traders were selected from the district. In addition to the survey, the qualitative data on current production and marketing constraints wheat chain in the study area was collected through group discussion. Two focus group discussions were conducted with a group of eight farmers from each *kebele* by using the checklist. The selection of farmers for group discussion was done based on their experience in wheat production and marketing and their involvement in the community. The discussion was assisted by the researcher and enumerators by using a discussion guide to encourage group members to speak freely on a particular topic.

The data for this study were collected from primary and secondary sources. Formal and informal sample survey methods were used to collect primary and secondary data. Primary data were collected from producers, wholesalers, assemblers, retailers, processors, cooperatives, and, agricultural input suppliers. The main data types collected include production, buying and, selling, pricing, input delivery, and distribution, the market supply of wheat, market outlets, constraints, and, opportunities characteristics of the actors involved in wheat crop production and marketing in the study area. Secondary information was gathered from published and unpublished materials, district agriculture and rural development offices, farmers' organizations, input suppliers, marketing agencies, and, different development organizations of the study area. For this study, a pre-tested interview schedule consisting of different types of questions related to the topic of the research and relevant variables was used for collecting the essential data through interviews. Group discussion has been used to crosscheck the data collected through formal surveys and also to generate additional contextual data.

To meet the study's objectives, descriptive statistics were used to analyze data collected from households and wheat value chain actors. The analysis defines each actor's role in the wheat chain depicted on the map.

RESULTS AND DISCUSSION

Demographic and Socioeconomic characteristics of the respondents:

The results of the study revealed that of the sample households 58.3% were male-headed and 41.7% were female-headed. The marital status indicates 72.5 % of the sample households were married, 15% were widowed, 7% were Divorced and 12.5% were single. The educational background of the sample household heads is believed to be an important feature that determines the readiness of household heads to accept new ideas. It is clear that education can influence the productivity of producers and the adoption of newly introduced technologies and innovations. Hence, literate producers are expected to be in a better position to get and use information that improves their wheat production. The educational level of the households also indicates that 45.0% were illiterate, while 12.5% of them were primary, 10.8% of them were secondary, 4.2% of them were religious and 27.5% of them were College (Table 1). Farming was the main occupation and source of livelihood for all sample producers, where the major ones are crop production and animal husbandry. Moreover, in addition to farming activities, 88.3% of respondents have also reported that they have been engaged in farm activities, while 11.7% were Agro-pastoralists. According to the survey results, 88.3% of respondents earn their source of income from crops, while 11.7% were they earn their income from livestock production.

Age is one of the important characteristics of the community. Age plays a significant role in any kind of business, particularly in agriculture, Accordingly, the maximum and minimum age of the respondent was 15 and 60 years respectively with a mean age of 38.8 years. The family size with age composition is important to carry out different agricultural activities. The average family size in the study area was 6.3 with a standard deviation of 2.60. The respondents indicated their sources of income as follows: 88.3% crop; 11.7% livestock; (see table 1). Therefore, the main occupation of the respondents were farmers for financial support.

Table 1. Demographic and Socio-economic Characteristics

Description		Number (n=120)	Percentage
Kebele	Kebele-1	34	28.3
	Kebele-2	23	19.2
	Kebele-3	61	50.8
Sex of the farmer	male	70	58.3
	Farmer's	50	41.7
Marital status	single	15	12.5
	married	87	72.5
	divorced	18	15
Education level	illiterate	54	45
	primary	15	12.5
	secondary	13	10.8
	religious	5	4.2
	College	33	27.5
Occupation	farmer	106	88.3
	Agro-pastoralists	14	11.7
Source of income	crop	106	88.3
	livestock	14	11.7
	Total	120	100

Inputs used by farmers in the study area are fertilizer, seed, herbicides and pesticides. Inputs are supplied to farmers either by cooperative or private traders. Cooperatives are major suppliers of fertilizer for producers in the study area. Government supplies to the cooperatives with DAP and Urea fertilizers and then the cooperatives can either sell to farmers in the study area. Fertilizer application is one of the most important agricultural practices that are used by wheat producers in the study area. Moreover, proper application of the recommended fertilizer rate is important to obtain the required production and marketable supply. The survey result indicated that the Input Suppliers is the first stage of wheat value chain, many participants involved in this activity. Primary multipurpose farmers' cooperatives, seed suppliers, wheat traders and private agricultural chemicals suppliers are the main actors in supplying inputs to farmers. Wheat farmers also participated in this stage in preparing their own inputs and they also supply input to fellow farmers. In combination, these actors supplied seeds, fertilizers (both DAP and Urea), chemicals and farm implements,

Table 2. Input Source and Input Suppliers

Description		Number (n=120)	Percentage
Type of seed uses	certified seed	55	45.8
	commercial seed	7	5.8
	local seed	57	47.5
Type of fertilizer uses	DAP	34	28.3
	UREA	35	29.2
	both of them	12	10
	Others	39	32.5
Kinds of input lacking	improved seed	23	19.2
	Fertilizers	55	45.8
	Ag. machineries	40	33.3
	lack of facilities	1	.8
	Others	1	.8
Source of input uses	Government	55	45.8
	Private organizations	24	20
	Farmer unions	19	15.8
	Total	120	100

Access to credit

According to the survey results, only 15.8% only from the total sample households had access to credit and the remaining 84.2% had no access to credit. Cooperatives, Somali microfinance credit, saving institutions, traders, and families/relatives are the sources of credit in the study area. Particularly at harvesting time traders and wheat processors also lend loans to the producers and then, secure their supply. Although taking interest is not their priority, they tend to secure their supply by giving loans and increasing their bargaining power. Their intention is by lending money, they can afford to pay less than the market price for the wheat they purchase from the producers and secure the supply of wheat. And The result of this research reveals that the reason for the lack of credit is the Awareness problem and shortage of credit Services in the study area.

Source of Credit service, and suppliers (table 3)

Description	Number (N=120)	Percentage

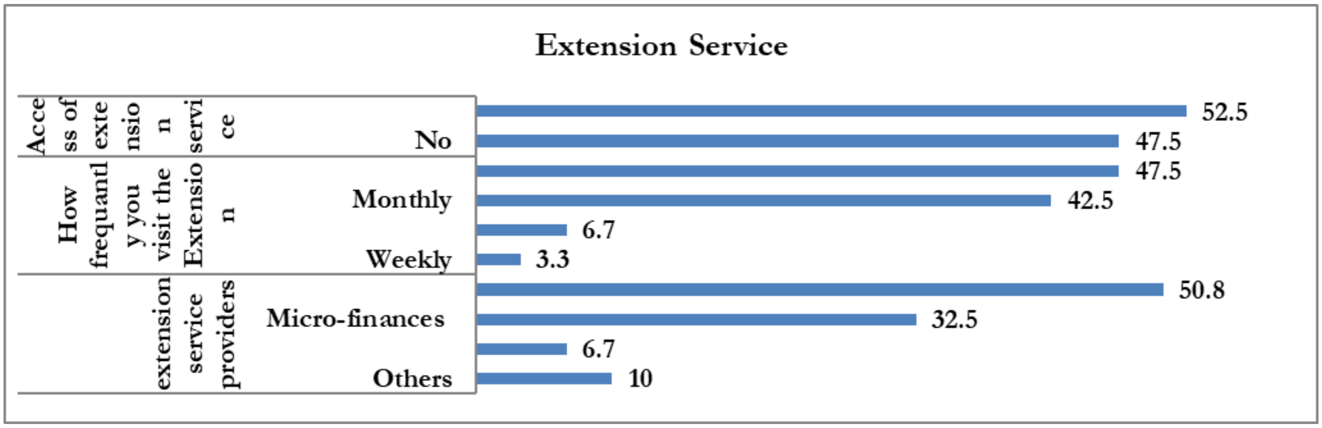
access to credits	Yes	19	15.8
	No	101	84.2
purpose of credit received	Not received	101	90.8
	Farm input	4	3.3
	Livestock purpose	3	2.5
	Family consumption	4	3.3
from where is the credit received	Not received	101	90.8
	NGOs	8	6.6.
	local money lenders	3	3.3
reasons for lack of credit Service	Awareness problem	11	9.2
	No service	107	89.2
	Total	120	100

The survey result shows that among the total sample of wheat producers 52.5% have better access to extension services in 2020/2021 production year. Wheat farmers In the area, through its DA is the major actor who provides information and advisory service on wheat production and management practices. Besides, model farmers, neighbour farmers/friends and other commercial wheat producers were also mentioned as source of information, advice and experience.

Furthermore, producers indicated that they are getting information particularly input application and farming method, however, there is the a shortage of trained man power (DA) where the maximum number is only 1 Agronomist per Block to disseminate the required extension service is not acquired on time by sample respondents.

The Access to extension services result indicated that 52.5% of respondents have access to extension services. 42.5% had Access to extension services monthly once per moth. 50.8% of they have got extension services from the district Agriculture bureau. The survey result shows that Access to extension services has positively and significantly affected the decision to value addition of wheat produce. The marginal effect indicated that access to market services increase the probability of adding values to wheat produce.

Access to extension services



Wheat is one of the major crops that national food security depends on in Ethiopia. Tuli Guled District is particularly known for its extensive wheat production. Wheat is a dominant cereal crop that grows in the study area, so all of the respondents (100%) in Tuli district were wheat growers and allocates a large proportion of the average land holding for the crop compared to other crops. The result of the study indicates that on average respondents allocated 2.92ha for wheat, which is 74.70% of their total average landholding. On average, a farmer's household produced 67.5qt and 7.8qt of wheat in the study area, and season respectively. The average productivities of the crop were 27.4qt/ha and 24.8qt/ha in Tuli district seasons respectively

Table 4. Production and Post-harvest

	Number (n=120)		**Percentage**
Type of wheat	bread	118	98.3
	durum	2	1.7
Method of wheat ploughing	Oxen	20	16.7
	other	100	83.3
Method of harvesting	labor	19	15.8
	combine harvester	98	81.7
	others	3	2.5
Means of wheat transportation	using tracks	45	37.5
	using animals	25	20.8
	Total	120	100

The wheat market value chain highlighted the involvement of diverse actors who participated directly or indirectly in the value chain. Access to agricultural markets and marketing information are essential factors in promoting competitive markets and improving agricultural sector development. A well-organized market intelligence information system helps all the producers and traders freely interact with one another in arriving at prices. Access to reliable market information help farmers sell their surpluses of wheat and choose modes of transaction, each of which yields a different benefit. It has been postulated that farmers will choose a profitable mode of the transaction if they can receive reliable market information on the prevailing market conditions.

Access to price information and source information of respondents in Table 6 showed that the major source of information was friends/neighbor farmers, which is 35%. About 34.2% and 25% of the respondents can get market information through public media and traders respectively. Additionally, development agents and television helped as sources of information by serving the large wheat producers in the study area, respectively.

Table 5. Market Chain of wheat in the study area

		Number (n=120)	Percentage
Who to sell wheat production	flour factories	70	58.3
	individual agents	27	22.5
	private traders	17	14.2
	farmer cooperatives	1	.8
	government	4	3.3
	Enterprises	1	.8
Where they sell products	right at the farm gate	61	50.8
	deliver to nearby markets	47	39.2
	taking it to buyers' warehouses	9	7.5
Major buyers of wheat production	private small buyers	76	63.3
	big wholesalers	28	23.3
	flour factories	15	12.5
	government organizations	1	.8
Access to buyers	through agents	42	27.5
	through friends	33	35.0
	direct contacts	41	34.2
	through public media	32	25
	Total	120	100

Marketing Channel and Value Chain actors of Wheat

Wheat market channels were constructed based on the data collected from the whole wheat chain actors. The result revealed that there are seven major marketing channels of the wheat value chain in the study area. It is from producer to consumer through different intermediaries are:

Channel 1; producers - consumers

Channel 2; producers - retailers - processors - consumers

Channel 3; producers - collectors - retailers - processors - consumers

Channel 4; producers - retailers - wholesalers - processors -retailers - consumers

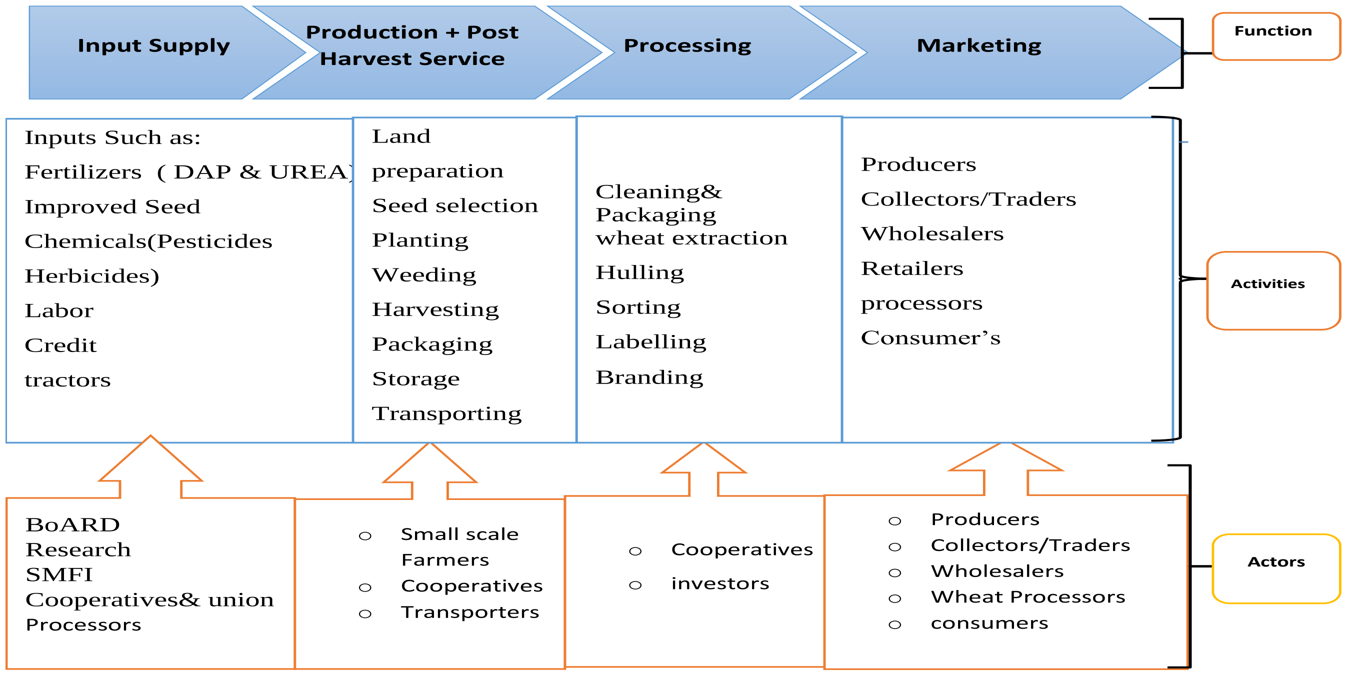
Channel 5; producers - cooperatives - unions - processors - consumers

Channel 6; producers - cooperatives - unions - processors - cooperatives - consumers

Channel 7; producers - collectors - retailers - wholesalers - processors - retailers - café/hotels – consumers

The value chain map highlighted the involvement of diverse actors who participated directly or indirectly in the value chain. The direct actors are those involved in commercial activities in the chain (input suppliers, producers, traders, consumers) and indirect actors are those that provide financial or non-financial support services, such as credit agencies, business service providers, and government, NGOs, cooperatives, researchers and extension agents. Defining each actor’s role in the value chain is one part of value chain analysis so in this section wheat value chain actors, their role, and linkages are discussed as role sows.

Figure 1. Value chain actors



Constraints and Opportunities in the wheat Value Chain

Various factors constrained the production of wheat in the study area. The major production constraint obtained include shortage of land, use of traditional production methods dilatory production, and limited access to and input supply, which is caused mainly due to shortage of supply, high input price, inappropriate delivery system, and delayed input supply. Especially inorganic fertilizer was also another production constraints farmers reported, limited knowledge of seed quality features, limited knowledge of technical advice for production, shortage of improved seed, high cost of inorganic fertilizer, absence of modern production technology, lack of technical training, shortage of rainfall, lack of input credit access, and lack of adequate pesticide/herbicides were major constraints on wheat production. Diseases, pests, and natural factors are other constraints to production.

The district is naturally endowed with wheat production. The district's geographical location, environmental condition, and fertile arable land are very suitable for wheat production. Increasing price periodically and its continuous demand in the market can store for a long time until price increases, high productivity potential related to other cereal crops are the opportunities for wheat production as most sample farmers reported. The survey result shows that 97.5% of the farmers are interested to expand wheat production due to those listed opportunities. In addition, the progress provision of infrastructure facilities like roads, telecommunication, and credit and saving institutions are the service that facilitates the production and marketing of wheat in the district.

CONCLUSION AND RECOMMENDATION

CONCLUSION

This study was conducted in Tuli district of Fafen zone in the Somali region. The main focus Was to analysis the wheat value-chain and Identify marketing channels of wheat and assess the outlet choice decisions of wheat producers. The study used both Primary and secondary data. Primary data were collected from 90 sample wheat farmers from three kebeles in Tuli district, 25 traders, and 8 processors from (flour factory), who were interviewed using a structured questionnaire. Additionally, input suppliers at Tuli Guled district and cooperatives at each kebele were interviewed. Focus group discussion using Rapid Market Appraisal and key informant interviews was also conducted. In addition to this, secondary data from the woreda agriculture office, bureau of agriculture, Somali region, and from published and unpublished documents were used. The result shows that 84.2% of the respondents have no access to credit. As well as 47.5% of the interviewed farmers have no access to extension services. Out of the respondents, 52.5% have access to extension services delivered in the study area. the extension services in agriculture are indispensable and it provides assistance for farmers in the improvement of production and productivity. Inputs used by farmers in the study area are fertilizer, seed, herbicides, and pesticides. These inputs are supplied to farmers either by cooperatives or private traders. The main wheat value chain actors in the area are input suppliers, farmers/producers, collectors, wholesalers, millers/processors, retailers, and cooperatives. primary cooperatives and private input suppliers are the main sources of input supply in the study area.

In the study Woreda, major wheat production constraint include lack of stability, high input costs, shortage of rainfall, shortage of seeds of improved varieties, less awareness of farmers about improved crop management practices, the spread of weeds, and difficulty of saving pure seeds from farmers’ harvest in combine harvested areas, and high cost of combine harvesting are among constraints reducing the productivity, production and return from the crop. Major marketing constraints include unfair pricing and cheating of traders on balance; lack of timely and sufficient market information; low price of commodities at harvest time; the high price of seeds, chemical fertilizers, and pesticides; weak market linkages among value chain actors, and less bargaining power of farmers in the market.

RECOMMENDATION

Recommendations that are relevant to improve the wheat marketing system in the study area which will indicate production and market orientation were set based on the significant variables and raised problems by the value chain actors. The research team that was assigned to study the project, related to the wheat value chain in Tuli Guled District of Fafan Zone, suggests that the following issues should be done so that the production and trade of wheat in the district can be improved the production and the productivity of wheat in the study area and resolving the prevailing production problems deems a necessary condition.

Improving the Input and supply: Increasing surplus production through the promotion of appropriate input technologies such as seed of improved varieties, recommended fertilizer rates, pesticides, and other appropriate agronomic recommendations can improve the production and productivity of wheat in the study area

- **Production and post-harvest technology:** The government and other key stakeholders should place a greater priority on the availability and utilization of better seeds and other yield-enhancing technology, as well as improving post-harvest techniques and creating steady demand for surplus production
- **Improvement of access to credit:** credit services affects positively and significantly farmers' decision to participate in value addition. Smallholder farmers are not a homogenous group; they differ in their resources and capabilities. The household economic portfolio provides a link between smallholders' resource levels and their abilities to respond to value additional opportunities. they may be unable to invest in agricultural upgrading due to shortages of working capital and lack of liquidity for longer-term upgrading investments. Therefore, it is important to create credit access and simplify the provision for farmers because it will help farmers participate in value-added activities that will increase their income.
- **Improving access to wheat market information:** market information affects the decision to participate in the value addition of wheat positively and significantly. This shows that farmers are willing to participate in value addition if higher-value markets for value-added agricultural produce information are readily available. Therefore, facilitating and improving the quality and types of market information delivery used by farmers shall take policy attention.

- **Improving access to extension:** extension services affect positively and significantly the probability of participating in value addition. Extension services in agriculture are indispensable and offer more than just expert assistance in improving production and processing; it also enables the flow of information and transfer of knowledge and scientific findings to practice that will help farmers in the production of value-added products. Therefore, strengthening agricultural extension services should be considered an important input for producing value-added products.
- **Improving linkage between actors:** There should be a strong linkage between the Bureau of agriculture, wheat producers, and processing companies to better understand the interrelationship between wheat production, marketing, and processing. For instance, there is no forum that forum connects real agriculture, producers of wheat, and processing factories.

  As a result, each of them is trying to solve the problem in the wheat sector. Hence, there should be a common forum for these institutions so that they seek a common solution for the problems that occurred along the wheat value chain in the study area.

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