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Journal of Science and Sustainable Development (JSSD)

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Following the abstract, about 3 to 5 **key words** that will provide indexing references should be listed.

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Pitout JDD, Church DL, Gregson DB, Chow BL, McCracken M, Mulvey M, Laupland KB (2007). Molecular epidemiology of CTXM-producing *Escherichia coli* in the Calgary Health Region: emergence of CTX-M-15-producing isolates. Antimicrob.Agents Chemother. 51: 1281-1286.

Pelczar JR, Harley JP, Klein DA (1993). Microbiology: Concepts and Applications. McGraw-Hill Inc., New York, pp.591-603.

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RESEARCH PAPER

Analysis of Factors Affecting Adoption of Vermicomposting Organic Fertilizer and Its Impact on Household's Income in Holeta District, Oromia National Regional State, Ethiopia

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Abstract

Agriculture remains the backbone of Ethiopia's economy, providing livelihoods for the majority of its population. However, despite its critical importance, the sector is characterized by persistently low productivity. To address this challenge and spur economic growth, the Ethiopian government has prioritized the promotion of value-added compost (VC) organic fertilizer. Nevertheless, the adoption of VC organic fertilizer remains low in many areas, including the Holeta district. This study was conducted to identify the factors influencing the adoption of VC organic fertilizer among farmers in this region. The study utilized both primary and secondary data collected from 174 household head farmers and published and unpublished sources. The analytical framework included descriptive statistics, logistic regression models, and propensity score matching to evaluate the factors influencing adoption and its economic impact. The results revealed that several factors significantly affected farmers' decisions to adopt VC organic fertilizer, including farming experience, farm size, family size, livestock ownership, access to extension services, access to information media, and participation in training programs. Moreover, propensity score matching analysis demonstrated that the adoption of VC organic fertilizer led to an increase in farm income per hectare, ranging from 45,571 ETB to 48,537 ETB. These findings underscore the economic benefits of adopting VC organic fertilizer and highlight the need for targeted interventions. To encourage adoption, the government and other stakeholders need to enhance farmers' access to training, provide robust extension services, and ensure the availability of VC organic fertilizer. Improved access to information about its benefits and usage is also crucial for fostering wider adoption and, ultimately, boosting agricultural productivity and rural incomes.

Keywords: Adoption, Vermicompost, Earthworm, Logit model, and Propensity score matching

Introduction

Agriculture plays a pivotal role in Ethiopia's economy, serving as the backbone of the country's development. It contributes 41.4% of the national GDP, accounts for 83.9% of total exports, and provides employment for 80% of the population (Gebeyanesh *et al*., 2021). Over the past decade, Ethiopia's agricultural sector has grown at an impressive annual rate of about 10%, outpacing population growth. Despite this progress, significant challenges persist, particularly with soil fertility management and sustainable production practices.

The adoption of value-added compost (VC) organic fertilizer offers a promising solution for improving soil fertility, enhancing crop yields, and reducing input costs. VC organic fertilizer contributes to soil health by maintaining fertility, improving soil structure, and reducing reliance on chemical fertilizers, which can harm the environment (Chen *et al*., 2018). Its adoption is seen as critical to addressing food insecurity and poverty while fostering a more sustainable agricultural sector (Kibere and Mwaura, 2022).

VC organic fertilizer also represents a profitable business opportunity. The increasing

consumer preference for organic produce, including vegetables and fruits grown without harmful chemicals, has spurred demand (Reddy, 2019). Additionally, the production of VC through the use of earthworms offers a cost-effective and environmentally friendly approach to managing biodegradable solid waste. The end product serves as a high-quality organic fertilizer suitable for agricultural use (Huang *et al*., 2014; Dar and Bhat, 2020).

Despite its potential benefits, challenges such as soil compaction, overuse of chemical fertilizers, and inefficient application techniques have hindered agricultural productivity. Excessive chemical fertilizer use often leads to nitrate accumulation in soil, groundwater contamination, and atmospheric pollution (Nikita and Puneet, 2020). Furthermore, traditional broadcasting methods result in significant nutrient loss due to rain, irrigation, or sublimation by sunlight, exacerbating food insecurity and poverty. Other barriers to sustained agricultural productivity include land degradation, recurrent drought, poor infrastructure, and inadequate nutrient supply (Scotti *et al*., 2015; Tura *et al*., 2017).

Organic fertilizers, including VC, address many of these challenges. They not only enhance soil health but also reduce food production costs by 60-70% while retaining soil moisture, thereby lowering irrigation needs (Adiloglu *et al*., 2018; Yousefi and Sadeghi, 2014). Despite these advantages, the adoption rate of VC organic fertilizer in areas like Wolmera Woreda (Holeta) remains low, with only 48.15% of households using it (WDAO, 2015). This low adoption rate persists despite efforts by the government and development partners to promote the technology.

To address these gaps, this study aimed to evaluate the factors influencing the low adoption of VC organic fertilizer in the Welmera Woreda, Holeta area, and assess its impact on household incomes. By understanding the challenges and opportunities associated with VC adoption, the study provides insights to inform strategies for enhancing agricultural productivity and improving the livelihoods of farming households in the region.

Materials and methods

Description of Study Areas

The study was carried out in Welmera district, West Shewa zone Oromia regional national state Ethiopia. This area is one of the towns of Oromia Regional State which is located 35 km away to the west of Finfinnee. In the north, south, and east the town is bordered by Welmera woreda and in the west by Ejere woreda. Astronomically the city is situated between the latitude of 90 01′ 08″N - 90 06′ 15″N and longitude of 380 26′ 40″E -380 32′46″E. The altitude ranges between 2250-2500m above sea level. The district has eight kebeles with total area coverage of 5550 ha (55.5km^2) of which five kebeles are from rural. The district was founded for the purpose of military services in the 1900s and it had the status of a Municipality since 1948 (Welmera Woreda Agricultural Office, 2015). This shows that the district has ample resources for preparing VC organic fertilizer, especially from animal dung which could enable the districts' smallholder and horticulture producers' productivity. Generally, Holeta district is shown below on the map depicted in Figure 1.

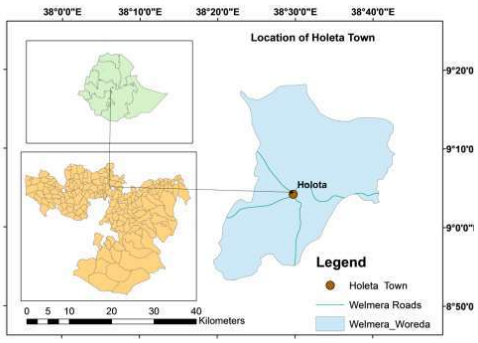

Fig 1. Map of the study area

Types and sources of data

Primary and secondary data sources were used to collect data from primary and secondary sources to describe the characteristics of

targeted individuals or groups of horticultural producers.

Sampling procedures and sample size

To achieve the objectives of the study, a multistage sampling technique was employed, combining simple random sampling and stratified sampling methods to identify respondents. In the first stage, a stratified sampling technique was used to select kebeles with relatively higher adoption rates of VC organic fertilizer and those with little to no experience in using it. In the second stage, two kebeles, Birbirsa Siba and Mada Gudina, were randomly selected from the group of kebeles with higher VC adoption rates. In the third stage, respondents from the selected kebeles were further stratified into two groups: adopters and non-adopters of VC organic fertilizer. This stratification ensured balanced selection. Finally, respondents were chosen using simple random sampling, proportional to the population size of each stratified group.

Sample size determination

The study targeted small-scale farmers of horticulture producer heads in the Holeta area of Ethiopia. A total of 174 household head samples were estimated based on the sample size determination formula of Yamane (1967). According to the 2019 Holeta town administration annual bulletin, there are a total of 57,828 populations in this town. The researcher randomly selects two kebeles from eight kebeles in the town. In those two kebeles, there are 1214 Household heads. To determine the sample size, for the study, Yamane's statistical formula was used at a 93% confidence level.

$$n = \frac{N}{1+N(e)2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where n= is sample size
N= is the total target population
e=is error margin $(0.07)^2$
1 = is constant

Thus, $n = \frac{1214}{1+1214(0.07)2} = 174$

Therefore, from the total household head population in the two kebeles, 174; were 85; adopters and 89; non-adopters of VC individuals were randomly selected after data was collected. In addition to 174 samples, 16 individuals were selected for Focus Group Discussion (with an arrangement of 1 group containing 8 individuals from each kebeles) and 4 people were used for key informant interview from concerned bodies.

Methods of data collection

A structured and semi-structured questionnaire was used as the data collection instrument, with pre-test interview and final data collection done by trained development agents. Focus group discussion was used to gather large information, with eight employees' heads and 16 household heads participating.

Method of Data Analysis

Descriptive and inferential statistics analysis

The study used descriptive statistics like %age, frequency, mean, standard deviation and economics model by the use of STATA software. The result of the study was presented by table and pi-chart.

Econometrics model analysis

For determining the impact of VC organic fertilizer adoption on farmers' income, the study used propensity score matching (PSM) as the best procedure to determine the impact of VC organic fertilizer usage on farmers' income. This was on the farmers choosing either to adopt or not to adopt a given technology based on expectations, objectives, and observable and unobservable characteristics. This is referred to as self-selection (Chala and Tilahun, 2014). PSM is the best procedure for assessing the effect of agricultural technologies on household income, especially when the dimensions of the covariates are large (Acheampong and Owusu, 2014; Chala and Tilahun, 2014; Awotide *et al*., 2012; Nguezet *et al*., 2011). PSM has the advantage of reducing the dimensionality of matching to a single dimension (Chala and Tilahun, 2014). It is the best possible procedure

to evaluate the individual probability of receiving the treatment given the observed covariates (Rubin and Rosenbaum, 1983). It determines the average treatment effect on the VC organic fertilizer adopters and non-adopter farms. The effectiveness of PSM depends on the two below assumptions.

Assumption of Conditional Independence (ACI): This assumption states that the selection into the adoption group is solely based on the observable characteristics. Given the values of some observable covariates, the assumption implies that the value of the outcome variable is independent of the treatment farm income state should be independent. Therefore, the VC organic fertilizer adopter's outcome is independent of the treatment status.

$Y_0, Y_1 \perp A|Z$……. (2)

$E\ (Y_1|\ P, Ai=1) = E(Y_0|P, Ai=0)$ ….(3)

Where, P is i^{th} farmer propensity of VC organic fertilizer adoption, Y_1 is outcome (farmers income) of i^{th} farmers when VC organic fertilizer is adopted, Y_0 is outcome of i^{th} farmers when VC organic fertilizer is not adopted, E is expectation operator, and A is the state where i^{th} farmers adopt or not adopt VC organic fertilizer; 1 for a farmer who has adopted VC organic fertilizer and 0 otherwise. Thus, this study used PSM methods to match and compare the impact per hectare farm income between samples of adopters and non-adopters of VC organic fertilizer.

Common Support Assumption (CSA): This assumption states that the average treatment effect for the treated (ATT) is only defined within the region of common support. It also assumes that no explanatory variable predicts the treatment perfectly.

$0 < p\ (A = 1\ |Z) < 1$…….. (4)

If the above two assumptions are satisfied, then conditional to estimates of propensity scores (p), the observed outcome (average farm income) of VC organic fertilizer adopters can be substituted for the missing average farm income of non-adopters.

Given that the propensity scores are balanced and the above assumptions are satisfied, according to Rosenbaum and Rubin (1983) the parameter of interest which is ATT can be estimated as:

ATT $\square E(y_1 \square y_0 / A \square 1)$

$\square E(y_1 / A \square 1) \square E(y_0 / A \square 1)$ …… (5)

Where, y_1 is outcome (farmers income) of i^{th} farmers when VC organic fertilizer is adopted, y_0 is the outcome of i^{th} farmers when VC organic fertilizer is not adopted, E is the expectation operator, and A is the state where ith farmer adopts or not adopt VC organic fertilizer; 1 for a farmer who has adopted VC organic fertilizer and 0 otherwise. In impact evaluation, the interest is not on $E\square y_0 / A \square 0\square$, but on $E\square y_0 / A \square 1\square$. Therefore, PSM uses estimated propensity scores to match the observed mean farm income of the non-adopters who are most similar in observed characteristics with adopters. That is, it uses

$E\square y_0 / A \square 0\square$to estimate the counterfactual $E\square y_0 / A \square 1\square$. Therefore:

ATT $\square E(y_1 \square y_0 / A \square 1)$

$\square E\square E\square y_1 \square y_0 / A \square 1, p(z)\square\square\square$

$\square E\square E\square y\_1 / A \square 1, p(z) \square E(y_0 / A \square 1, p(z) / A \square 1\square\square\square$

$\square E\square E\square y_1 / A \square 1, p(z) \square E(y_0 / A \square 0, p(z) / A \square 0\square\square$…….……..…..……...(6)

Where; ATT, E, y_1, y_0 , p and A are defined as earlier.

Advantages and limitations of PSM

The Propensity Score Matching (PSM) method offers several advantages in evaluating treatment effects. Firstly, it reduces dimensionality by condensing multiple covariates into a single scalar, the propensity score, simplifying the analysis significantly. Secondly, PSM effectively balances observed characteristics between treated and control groups, thereby minimizing selection bias and

ensuring comparability. Additionally, it provides a robust evaluation framework, particularly when treatment effects are influenced by observable covariates. However, PSM also has its limitations. It relies heavily on the assumption that there are no unobservable confounders influencing the treatment or outcome, which may not always hold true. Furthermore, the method requires a sufficient overlap in propensity scores between groups to ensure reliable results and poor overlap can restrict the generalizability of the findings.

This specification of PSM is well-suited for evaluating the impact of VC organic fertilizer adoption on farmers' income in the Holeta area. By addressing selection bias and ensuring robust matching, the model enables a reliable comparison of income outcomes between adopters and non-adopters. However, the study's validity heavily relies on satisfying the CIA and CSA assumptions, as well as the quality of the data used for propensity score estimation.

Results and discussions

Results of descriptive statistics for continuous variables by adoption category

The description was made using mean, minimum, and maximum values as well as, range and standard deviations. In addition, the mean difference for continuous variables and frequencies of discrete variables were tested using T-test and chi-square test respectively.

Results show that the average mean age for the sampled household farmers was 42.5 years Table 1. The mean age of VC organic fertilizer adopters and non-adopters was found to be 38.2 and 46.5 years respectively. These results show that the majority of the households were at productive stages of their lives in terms of the capacity to work. Although the difference was quite low, on average, VC adopters were younger than non-adopters. The result is in line with the study by (Ajewole 2010; Mwangi and Kariuki, 2015; Enete and Igbokwe, 2009).

Education level was measured as the number of years of schooling starting from zero or having no education to university graduate. The average mean years of formal schooling for the sampled farmers were 2.3 years Table 1. Among the VC organic fertilizer adopters, the average mean years of formal schooling was 2.6 while among the non-adopters, it was about 2.1. This shows that more educated farmers were adopters in the study area which might be the result of better education. Education could likely allow farmers to make efficient decisions and be the early adopters who can take advantage of the new technology (Orinda, 2013).

In relation to family size, the overall average mean family size among the respondents was found to be 5.44 Table 1. Among the adopters of VC organic fertilizer, the average family size was about 5.8 whereas it was about 5.04 amongst the non-adopters. On average, the family size was higher among the adopters compared to non-adopters. The fact that VC organic fertilizer is labor intensive compared to the other types of fertilizer supports the results. The t-test result shows that there is a mean difference between adopters and non-adopters of VC organic fertilizers in terms of family size at a 5% statistical significance level. A larger family size may enable one to provide additional labor needed in the use of the VC organic fertilizer (Ajewole, 2010).

The findings suggest that livestock ownership plays a critical role in the adoption of VC organic fertilizer, as livestock provides the raw material (animal manure) necessary for its preparation. The larger average livestock holdings observed among adopters likely facilitated their adoption of organic fertilizer compared to farmers with smaller livestock holdings. Additionally, the t-test results indicate a statistically significant difference in farm size between adopters and non-adopters at the 5% significance level. This highlights that both livestock availability and farm size are influential factors in the adoption of VC organic fertilizers, with larger farm sizes and greater livestock holdings potentially enabling easier integration of this technology into farming practices (Table 1).

The average farm size among the sampled household heads was 2.24 hectares Table 1. On average, the VC organic fertilizer adopters own about 2.6 hectares of the farm size while the non-adopters own about 1.9 hectares of the farm size. The current study predicted that farmers with relatively larger farm sizes are likely to adopt VC organic fertilizer. This could be primarily due to lower marginal costs associated with the adoption of labor-intensive technology on the larger area of the farm size. The results indicated that the households with larger farm sizes were adopters of VC organic fertilizer possibly due to lower marginal costs. Martey *et al*., (2013) argued that an increase in cultivation plots is associated with financial constraints for smallholder farmers in Ghana thus reducing the adoption of chemical fertilizer. Lower use of chemical fertilizer could result in more use of VC organic fertilizer in Ethiopia. The t-test results reveal a statistically significant difference in farm size between adopters and non-adopters of VC organic fertilizers at the 5% level of significance. This suggests that farm size is a distinguishing factor between the two groups, indicating that adopters tend to have either larger or smaller farms compared to non-adopters.

The average total household head agricultural income among the respondents was found to be 94,431.03 ETB per annum Table 1. Amongst the respondents who have adopted VC organic fertilizer, the average agricultural income was about 117,294.1 ETB while the non-adopters of VC organic fertilizer had an average farm income of 72,595.57 ETB. The higher average agricultural income among the adopters may justify that adopters of VC organic fertilizer are more dependent on agricultural activities. The dependency of farmers on agricultural activities makes them more concerned about yield-increasing technologies such as VC organic fertilizer. On the other hand, according to Makokha *et al*., (2001), a household whose income depends on agricultural activities does not have enough capital to use chemical fertilizer in Kenya thus they have the option to use manure to compensate outflow of nutrients. The probability of using household head outcome agricultural income has no significant relationship with VC organic fertilizer adoption decisions.

Table 1. Results of Descriptive statistics for Continuous Variables

	Adopters		Non-adopters			
Characteristics	Mean	SD	Mean	SD	Mean	*t* –value
Age of HH	38.235	9.764	46.561	12.882	42.494	3.0005
Education	2.552	1.096	2.067	1.146	2.304	-3.1862
Family size	5.828	1.400	5.038	1.421	5.442	3.3550**
Livestock	9.105	4.437	7.325	3.560	8.195	-0.9062**
Farm size	2.641	0.811	1.038	0.882	2.237	-3.3630
Outcome effect	117294.1	77485.46	72595.57	79358.47	94431.03	-3.7569

Descriptive results of dummy variables

The results presented in Table 2 show that about 132, or 75.86%, of the households were male-headed, while about 42, or 24.14%, were female-headed. Among the adopters of VC organic fertilizer, about 69, or 81.18%, of the households were male-headed, compared to 16 or 18.82% of the female-headed households. On the other hand, amongst the non-adopters of VC organic fertilizer, about 63, or 70.79%, of the households were male-headed, while the remaining 26, or 29.21%, were female-headed. The results showed that the proportion of male-headed households was higher both among the adopters and non-adopters of VC organic fertilizer compared to that for female-headed households. Among the adopters of VC organic fertilizer, the higher proportion of households headed by a male could be due to the better exposure that the male-headed households have to different technologies and training delivered by extension agents. According to Maria *et al*. (2023), male heads are more likely to attend community meetings and visit demonstration plots or research centers compared to female

heads. This could make male-headed households more adopters of VC organic fertilizer.

Extension services refer to demonstrations, training, and advice delivered to farmers mainly by development agents and other agricultural experts. The results indicated that about 89, or 51.15%, of the households' heads had extension service, while about 85, or 48.85%, had no extension service. Approximately 74, or 87.06%, of the household's heads and 11, or 12.76% of the household's heads use VC organic fertilizer. On the other hand, amongst the non-adopters of VC organic fertilizer, about 15 or 16.85% of the households and 74 or 83.15% have no access to extension services, respectively. The findings show that adopters of VC organic fertilizer had better access to extension services on average than non-adopters, implying that better access to extension services may have contributed to VC organic fertilizer adoption. Kassie *et al*., (2009) argued that farmers who have regular contact with agricultural experts are more likely to adopt agricultural technologies. Similarly, Ajewole (2010) claimed that the frequency of extension visits increased the possibility of commercial organic fertilizer adoption in Nigeria. Information can be accessed through different media such as radio, television and social media. The results indicate that about 93 or 53.45% of the sampled households had access to information through radio and television while about 81 or 46.55% did not have access to information media. According to Opara (2010), a higher proportion of households that have had access to information through radio and TV were found to be adopters of VC organic fertilizer. The results indicate that 53.45% of sampled household heads have used VC organic fertilizer, while 81.55% have not. Training users and visits to create awareness are preconditions for them to make decisions to participate in VC organic fertilizer adoption technology. The disparity between the two groups is significant, implying that training and participation of adopters are critical factors in advancing agricultural technology quickly.

According to the findings, approximately 95%, or 54.60%, of the households' head sample had access to VC organic fertilizer input materials, while approximately 81%, or 46.55%, did not. Among the adopters of VC organic fertilizer, about 75, or 88.24%, of the households' head samples had access to VC organic fertilizer, while 10, or 11.76% of the households' head samples did not have access to VC organic fertilizer input materials. In contrast, among non-adopters of VC organic fertilizer, approximately 20 or 22.47% of the household head sample had access to VC organic fertilizer input materials, while approximately 69 or 77.53% of the household head sample did not Table 3. The findings revealed that adopters of VC organic fertilizer had better access to the availability of VC organic fertilizer input materials on average than non-adopters, implying that better access to VC organic fertilizer input materials may have contributed to VC organic fertilizer adoption.

Table 2. Results of dummy variables

Variables		Adopters		Non-adopters		Total		Chi-Square
		Frequency	%	Frequency	%	Frequency	%	
SEX	1	69	81.18	63	70.79	132	75.86	2.0174
	0	16	18.82	26	29.21	42	24.14	
ACC EXT SER	1	74	87.06	15	16.85	89	51.15	34.2032***
	0	11	12.94	74	83.15	85	48.85	
TRAINING	1	73	85.88	21	23.60	94	54.02	47.0863***
	0	12	14.12	68	76.40	80	45.98	
ACC INFO MED	1	75	88.24	18	20.22	93	46.55	16.2712**
	0	10	11.76	71	79.78	81	53.45	
HH HAVE USED VC	1	72	84.71	21	23.60	93	53.45	22.0498**
	0	13	15.29	68	76.40	81	46.55	
ACC VCOFINP	1	75	88.24	20	22.47	95	54.60	25.0477
	0	10	11.76	69	77.53	79	45.40	

Source: results of Chi-square test, **, ***, Significant at 5%, 1% probability level respectively.

Results of propensity score matching for the impact of VC organic fertilizer on income

The logistic regression model used to estimate propensity scores for matching adopter households with non-adopter households was used to compute the impact of VC organic fertilizer adoption on households' farm income. All variables hypothesized to influence adoption decision were included, such as age, sex, family size, education level, total household output farm income, experience, farm size, soil fertility, number of livestock units, access to extension service, access to VC organic fertilizer inputs, access to training, access to information through television, radio and other media.

Before beginning the assessment of impact evaluation, five crucial activity steps need to be completed. These steps are estimation of the propensity score, checking for overlap (common support region), choosing a matching algorithm, checking for balance test, and sensitivity analysis. Graphically, we computed the distribution of the estimated propensity scores matching for both adopters (treated) and non-adopter (control) groups to identify the existence of a common support presented in Figure 5 using kernel density. From the figure, the normal line (the middle line) represents the total sample household head; the long (right below and left upper line) represents the propensity score of the adopters (treated) group, While the short line (left below and right upper line) representing the propensity score of non-adopters (control).

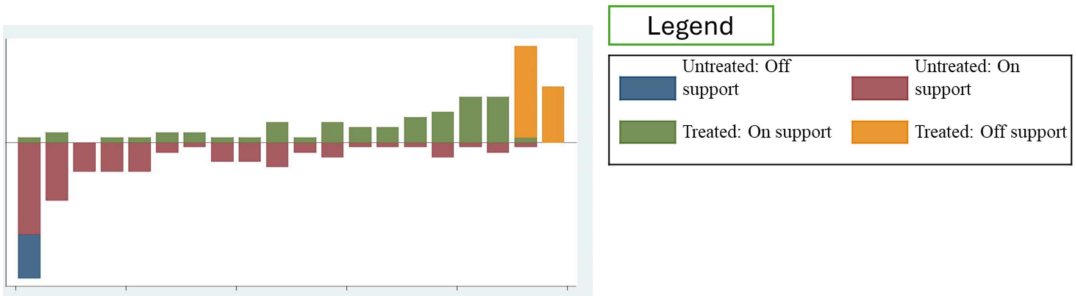

Figure.4 Kernel density of propensity scores of all households before matching

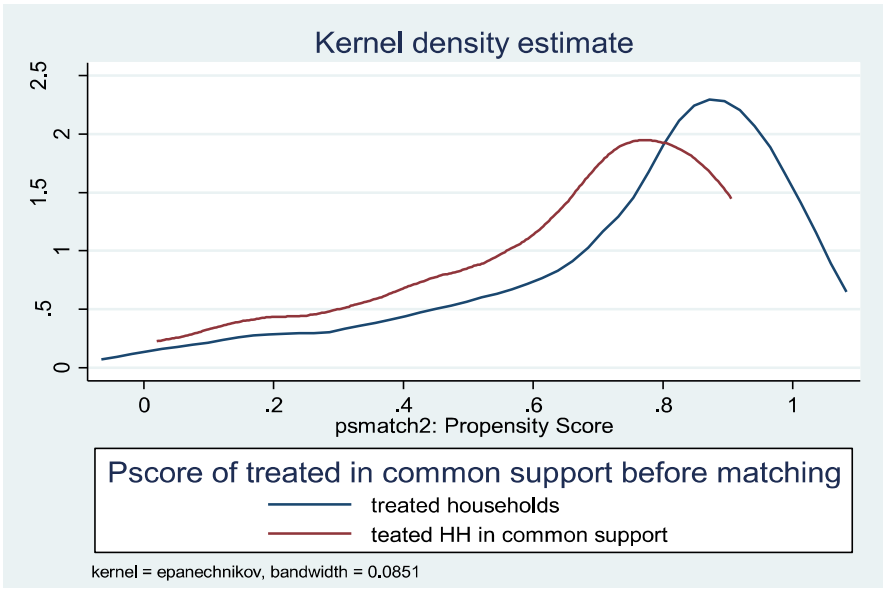

Figure 5: Common support region of propensity scores Source (source: Authors survey data, 2022)

The result accepted that there is a significant overlap in the common support region. As depicted in Figure 4, the distribution of the propensity scores of the treated and untreated individuals in both groups clearly displayed an overlap. The result also indicated that there are individuals out of the common support region. Moreover, there are treated and untreated individuals. Thus, these indicated that there was a sufficient overlap in the propensity score among the adopters and non-adopters household head farmers. Fortunately, one can observe that the upper half of the graph is for the treated or adopters' groups and the bottom half represents the untreated and the non-adopters showing the densities of the scores on the y-axis and the common support regions on the x-axis. As a result of this restriction, 38 household heads (29 from treated and 9 from control households) were dropped from the analysis because their propensity scores fell outside the region of common support. Thus, it seems that the included observations (136 households) were sufficient to predict the impact of VC organic fertilizer on households for this study.

Matching adopters and non-adopters households

Estimation of ATT and ATE are possible only in the region of common support. As shown in Table 3, the estimated value of propensity scores for sample households varies between 0.019 and 0.997 (mean=0.743) for adopter (treated) households and between 0.001 and 0.905 (mean=0.245) for non-adopter (control) households. Thus, the common support assumption is satisfied in the region of 0.019 and 0.997 with a mean of 0.743. This means that households with estimated propensity scores less than 0.019 and greater than 0.905 are not included in the matching exercise. The diagram which shows the matching distribution of propensity scores is presented in Figure 5 below.

Table 3: Distribution of the estimated propensity scores

Categories	Obs	Mean	SD	Min	Max
VCOF treated household	85	0.743	0.244	0.019	0.997
VCOF control household	89	0.245	0.255	0.001	0.905
Total household	174	0.488	0.353	0.001	0.997

Source: Author estimation result, 2022.

Testing the balancing properties of propensity scores and covariates

The balancing test ensures that propensity scores and covariates are similar between adopters and non-adopters after matching, confirming that the matching process creates comparable groups. Nearest Neighbor (3) matching outperformed other methods, achieving the lowest Pseudo R^2 (0.018) and balancing all covariates effectively. Before matching, seven variables exhibited significant differences, but post-matching, no significant differences remained, indicating a high level of covariate balance. The non-significant t-tests and low Pseudo R^2 further validated the matching process. Thus, the matching specification successfully balanced covariates, enabling a reliable comparison of VC organic fertilizer adoption outcomes.

In addition to the above results, the overall (joint) test statistics for the balancing properties showed that Pseudo-R2 was 0.054 for the matched observations which was fairly low. The p-value for the corresponding Pseudo-R2 and likelihood ratio test was insignificant at the conventional probability level ($p > chi2 = 0.998$) confirming that both the treated (adopters of VC organic fertilizer) and control (non-adopters of VC organic fertilizer) groups had the same distribution of covariates after matching. This further shows that the employed model was the most robust and complete therefore allowing comparison average of household's farm income between the adopters and non-adopters per hectare of VC organic

fertilizer who share common support in terms of propensity scores. The results of the chi-square test for the joint significance of variables are presented in Table 7.

Table 6: Propensity score and balancing test of the covariates using t-test

Variable	Sample	mean		%bias	%reduction	T-test	
		Treated	control		bias	T	p>|t|
Pscore	Unmatched	0.74334	0.24513	199.2		13.13 ***	0.000
	Matched	0.52707	0.59338	-26.5	86.7	-1.05	0.298
Age	Unmatched	44.565	49.562	-45.5		-3.00	0.003
	Matched	46.727	46.682	0.4	99.1	0.01	0.989
Sex	Unmatched	0.62353	0.51685	21.5		1.42	0.157
	Matched	0.54545	0.59091	-9.2	57.4	-0.33	0.745
Educ	Unmatched	2.247	1.764	48.2		3.19	0.002
	Matched	2.0909	2	9.1	81.2	0.34	0.737
Exp	Unmatched	0.67059	0.31461	75.8		5.00**	0.000
	Matched	0.54545	0.54545	0.0	100.0	0.00	1.000
Farmsiz	Unmatched	2.8292	2.3567	51.2		3.36**	0.001
	Matched	2.6524	2.7909	-15.0	70.7	-0.50	0.621
Famsiz	Unmatched	5.0706	5.7865	-50.9		-3.35**	0.001
	Matched	5.2727	5.3182	-3.2	93.7	-0.10	0.917
Soilfert	Unmatched	1.9176	1.8427	9.7		0.64	0.522
	Matched	1.9697	1.8636	13.7	-41.5	0.47	0.640
Livestockunit	Unmatched	5.9059	5.2809	13.7		0.91**	0.366
	Matched	5.0909	4.7273	8.0	41.8	0.30	0.766
Acctoserv	Unmatched	0.78824	0.34831	98.6		6.49**	
	Matched	0.57576	0.72727	-33.6	65.6	-1.14	0.261
Acctoinfo	Unmatched	0.72941	1.42697	64.0		4.21**	
	Matched	0.57576	0.59091	-3.2	95.0	-0.11	0.913
Acctoorginput	Unmatched	0.69412	0.31461	81.6		5.38	0.000
	Matched	0.54545	0.54545	0.0	100.0	-0.00	1.000
Acctotrain	Unmatched	0.8	0.2809	121.3		7.99**	0.000
	Matched	060606	0.68182	-17.7	85.4	-0.56	0.576

Source: Own estimation result ***and ** means significant at the 1%, and 5% probability levels, respectively

Table 7: Results of Chi-Square test for joint significance of variables

Sample	Pseudo R^2	LR *chi*^{2}	*p-value*
Unmatched	0.430	103.59	0.000***
Matched	0.054	3.98	0.998

Note, *** indicates significance at a 1% probability level

In this section, the study addresses the issue of whether the final evaluation results are sensitive with respect to the choice of the balancing scores. Matching estimators work under the assumption that a convincing source of exogenous variation of treatment assignment does not exist. Likewise, sensitivity analysis was undertaken to detect whether the identification of conditional independence assumption was satisfactory or affected by the dummy confounder or whether the estimated ATT is robust to specific failure of the CIA. Also, this section analyses the robustness of the estimated treatment effects. The main purpose of this analysis is to check or estimate the degree to which the estimated treatment effects

were free of unobserved covariates. This means, that the estimated impact of VC organic fertilizer adoption on a household's farm income would have been an unobserved confounder that can increase the relative probability of organic fertilizer adoption. Accordingly, the sensitivity analysis was done to check whether the average treatment effect that was estimated using household head farmers VC organic fertilizer was sensitive to unobserved bias using the Rosenbaum bound of gamma values between 1 and 3, by adding 0.25 on 1 and continuing up to 3 (Weiwei *et al*., 2014).

For all outcome variables estimated at various levels of the critical value of gamma, the p-critical values are significant which further indicates that our impact estimates (ATT) are insensitive to unobserved selection bias and are a pure effect. The result of sensitivity analysis indicates that all important covariates that affect the household head of the estimated average treatment effect on the treated (ATT) reports were insensitive to hidden (unobserved) bias up to (gamma value of 3). This shows that the matching results were almost insensitive to the potential unobservable bias and therefore the estimated ATT were pure effects of VC organic fertilizer adoption. On the other hand, comparing the simulated and baseline ATT, the initial estimates were free of unobserved covariates for the nearest neighbours matching.

Conclusions and recommendation

This study aimed to identify the factors affecting VC organic fertilizer adoption and its impacts on income in the Holeta district of Ethiopia. Data was collected from 174 respondents, of which 85 were adopters and 89 were non-adopters. Descriptive statistics and a logistic regression model were used for analysis. The household heads who have used VC before, farm size, family size, livestock unit (TLU), access to extension service, access to information media, and access to training all played a role in the decision to use VC organic fertilizer. Propensity score matching revealed that the adoption increased farmers' per-hectare farm income by between 45,571 ETB and 48,537 ETB. The sensitivity analysis tested whether the evaluation results of VC organic fertilizer adoption on household farm income were robust to unobserved biases and the conditional independence assumption (CIA). Using Rosenbaum bounds with gamma values ranging from 1 to 3 (incremented by 0.25), the analysis showed significant p-critical values at all levels, confirming that the estimated Average Treatment Effect on the Treated (ATT) was insensitive to unobserved confounders. This indicates that the matching results, particularly under nearest neighbor matching, were free from hidden biases and unobserved covariates, validating the estimated ATT as a pure effect of VC organic fertilizer adoption.

This finding showed that multiple variables have an effect on the adoption of VC organic fertilizer by household head farmers. Therefore, the finding is important to adopt programs to encourage the use of VC organic fertilizer, implement policies in an attempt to adapt the use of VC organic fertilizer in the Wolmera Woreda Holeta area, and critically consider these factors. Household heads who have used VC have higher access to extension visits service, and household heads who have regular contact with agricultural experts, and better information dissemination, are more likely to adopt agricultural technologies and also increase the possibility of commercial VC organic fertilizer adoption. A household head with a lower income prefers to use VC organic fertilizer compared to chemical fertilizer. It was thus concluded that lower costs in relation to the use of VC organic fertilizer on larger farm sizes encouraged farmers to use VC organic fertilizer intensively in the study area. Further, households who had adopted VC organic fertilizer earned a good average per hectare farm income compared to the non-adopters. This implies that the adoption of VC organic fertilizer had a positive impact on households' farm income in the study area encouraged to use VC organic fertilizer. Therefore, NGOs and the government should promote VC organic fertilizer adoption by improving its affordability, especially for low-income farmers, and enhancing extension services to provide regular expert support. They should launch information campaigns to highlight its

benefits, implement policies like subsidies to encourage use and support commercialization for broader availability. These efforts will boost adoption, enhance farm productivity, and increase household incomes in areas like Wolmera Woreda Holeta.

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RESEARCH PAPER

Stakeholders Training to Enhance Farmers Participation Focusing on Wheat Value Chain: the case of Ambo District, Oromia, Ethiopia

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Abstract

The study was carried out to assess the involvement of stakeholders' training to enhance farmers' participation focusing on the wheat value chain. The study has been conducted based on the information collected from 35 development agents, 35 smallholders, 2 Farmers' Cooperative Union experts, and 1 Cooperative focal person. The study employed a mixed research method. Accordingly, the following results were found. Development agents provided different kinds of training for progressive and leader farmers. Cooperative delivered market-related information, agricultural inputs, and purchased agricultural outputs from smallholders. The wheat value chain was at the initial stage and the involvement of farmers was not satisfactory.

Keywords: Community, development, cooperatives, stakeholders, training

Introduction

In Ethiopia, agriculture is the main form of livelihood for more than 80% of the population. There are more than 12 million smallholders which accounts for approximately 95 percent of agricultural GDP and 85 percent of employment (FAO, 2014 in Tafa, 2015). The agricultural sector greatly influences the economic performance of the country and accounts for about 35.8% of the national GDP, and over 90% of export commodities (CSA, 2018). Most of these export goods are low value-added agricultural products (Tigist and Samuel 2023). That affects the country's effort for development. On the other hand, the country is undergoing a rapid expansion of cities and towns mainly because of fast population growth and economic development. It is inevitable to expect a growing middle-class population with more money to spend on who wants to have processed food items, ready-to-eat meals, and one-stop shopping.

Engagement in the development of food value chain requires improvement of smallholders' productivity and accumulation of capital. Improvement of smallholders' productivity and accumulation of capital requires involvement of different actors known as stakeholders. Agricultural office and Farmers' Cooperative Union (FCU) are the two important institutions worth mentioning in this regard. The agricultural office is a public institution working with farmers through development agents and cooperative focal persons. Development agents provide training and extension services for farmers by organizing exhibits, on-farm demonstrations, and field days and facilitate farmers – to – farmers' extension. FCU is a union created by a number of Farmers' Primary Cooperatives (FPC) working on the ground to improve members' livelihood by enhancing their productivity, regulate and engage in value addition of agricultural products (IFPRI, 2010).

Cooperative focal persons are experts who are assigned by agricultural office to strengthen FPC.

FCU focuses on provision of market-related information for its members, discuss on benefits of improving the quality of farm products and mobilization of resources for wheat value addition. Value chain development aims to facilitate mutually beneficial linkage between smallholders and other chain actors, such as processors, exporters and retailers that involve in marketing agricultural products (Donovan, *et al*., 2015). The assumption behind Smallholders' participation in the value chain is, that it gives farmers the opportunity to sell their products and purchase agricultural inputs at reasonable prices, enhances their income security, and helps them to get high returns (Sevill *et al*., 2011). Smallholders' participation in value chain could also contribute to mitigate the problem of transportation in that they will get the opportunity to capture more of the marketing margin (Neven *et al*., 2009 in Sevill *et al*., 2011).

Even though food value chain has invaluable contribution to improve the livelihood of smallholders, it is not yet effective in Ethiopia generally and in Oromia particularly because of unclear institutional arrangements, poor alignment and integration with other programs and activities, insufficient financial resources, problem of infrastructure and poor market linkages. As Maijers (2011) says smallholders are suffering from a fragmented supply base leading to long and inefficient value chains, lack of access to technology and knowledge, poor logistic infrastructure and lack of access to proper value chain financing channels.

Objectives of the research

The main objective of the study was to investigate the extent of stakeholders' involvement in provision of training for smallholders focusing on the wheat value chain in Ambo District of Oromia. Review of related literature

Food value chain

Food value chain is defined as the full range of farms and firms coordinated value-adding activities that produce particular raw agricultural materials and transform them into particular food products that are sold to final consumers and disposed of after use in a manner that is profitable without permanent depletion of natural resources (Neven, 2014). Food value chain encompasses activities that take place at the farm as well as in rural settlements and urban areas. Farmers require input supplies (seeds, fertilizers, pesticides, etc.), agricultural machinery, irrigation equipment and manufacturing facilities, and continue with handling, storage, processing, packaging and distribution activities (UNIDO, 2009).

Food value chain analysis helps to break the chain into its constituent parts in order to understand its structure and functioning (Kaplinsky and Morris, 2001 in Haq, 2012). The analysis consists of identifying chain actors at each stage and discerning their functions and relationships; determining the chain governance, or leadership, to facilitate chain formation and strengthening; and identifying value adding activities in the chain and assigning costs and added value to each of those activities. Value chain analysis is a useful tool for it helps to understand the overall trends of stakeholders' participation and identify change agents and indicate areas of interventions (UNIDO, 2009). Value chain analysis reveals dynamic flow of economic, organizational and coercive activities involving actors among different sectors. It shows that power relations to understanding how entry barriers are created, and how gain and risks are distributed. By revealing strengths and weaknesses, value chain analysis helps participating actors to develop a shared vision of how the chain should perform and to identify collaborative relationships which could allow them to keep improving chain performance (UNIDO, 2009).

Efficiency of food value chain by and large depends on the competency of actors at all levels. To improve the product produced and increase profitability of processors different kinds of value chain development work have to

be done. Value chain development aims to facilitate mutually beneficial links between smallholders and other chain actors, such as processors, exporters and retailers that interact for the production and marketing of a given product (Donovan, *et al*., 2015). According to Henriksen *et al*. (2010), value chain development has become a key approach in both research and policy fields, with an increasing number of bilateral and multilateral organizations adopting it to guide their development interventions. Creating and utilizing knowledge are important sources of sustainable competitive advantage as knowledge sharing, integration and transfer helps in innovating new products/services or bring efficiency and effectiveness in the existing ones (Prahalad and Hamel, 1990; Corso *et al*., 2001 and Nonaka *et al*., 2000 in Sultan, and Saurabh, 2013). At the heart of value chain concept lays the idea of actors connected along a chain producing and bringing goods and services to consumers through a complex and sequenced set of activities. Poor agricultural producers often struggle to gain market access.

Altenburg (2007 in Henriksen *et al*., 2010) identified three different approaches of value chain development known as expert-driven, participatory and partnership approaches.

Expert-driven approaches employ diagnostic tools, manuals and guidebooks that are supposed to guide experts and practitioners conducting value chain analysis to inform projects in the pre-design phase. These include not only detailed step-wise planning procedures that situate experts at the centre of analysis, design and implementation but also detailed quasi-academic methodologies to map flows of knowledge and economic resources, measure output values at different parts of the chain, ways of covering export market potentials through development of performance benchmarks, regional transmission of value chains, inter-firm linkages and cooperation. While they vary in the level of detail and what scale and scope of analysis is required, they all require rigorous analytical work by experts who have sufficient time, resources and education to carry it out.

Participatory approaches mainly focus on interaction with and knowledge of value chain actors and partners. Some of these approaches do not limit themselves to employing participatory methods, but are also concerned with engaging stakeholders in the design and implementation phases. Experts also may play important roles in these approaches, but not the main drivers of analysis and design.

Partnership approaches take the form of supplier development and technology transfer projects that also seek to improve sourcing conditions for such large companies. This approach rests on the idea that companies know best what 'markets want' and what potential suppliers need to change in order to meet such conditions. Moreover, they are often the actors who define entry barriers and set product standards. The approach, however, is subject to the existence of lead firms in the chain.

Strategy to participate smallholder farmers in the value chain

Smallholders will benefit from participation in the value chain for it gives them access to the market, enhances income security, and has high returns (Sevill *et al*., 2011). Fair trade results in greater stability for it guarantees minimum prices and longer-term trade relationships which improve wellbeing of farmers and protect them against highly volatile price fluctuations. Smallholders' participation in the value chain can also contribute to mitigating the problem of transportation for they get the opportunity to capture more marketing margin (Neven *et al*. 2009 in Sevill *et al.*, 2011).

Smallholders can participate in value chain in either of two ways. The producer organization might want to use labor in the chain or farmers can supply their product to the chain. Access to assets by smallholders and their ability to accumulate and use those assets effectively are critical to their participation in value chains and their ability to benefit from participation (McKay 2009 in Sevill *et al.*, 2011).

Farmers' cooperative union

A Cooperative is an autonomous association of women and men, who unite voluntarily to meet their common economic, social and cultural needs and aspirations through a jointly owned and democratically controlled enterprise (International year of cooperatives, 2012). While cooperatives are also businesses, the main objective for people to set up or join a cooperative is to improve their economic and social conditions through joint action for the good of all members rather than through individual concerns (FAO, 1998).

Cooperatives are involved in agricultural activities and develop rich experience in farming and leadership training (Innocent and Adefila, 2014). Agricultural cooperatives contribute for the economic and social empowerment of smallholders and create sustainable rural employment through business models that are resilient to economic and environmental shocks (International year of Cooperatives, 2012). They provide a wide range of services such as access to markets, natural resources, information, communications, technologies, credits, training and warehouses. Cooperatives also facilitate smallholders' participation in decision-making at all levels, support them to negotiate better terms for engagement in contract farming and to get agricultural inputs such as seeds, fertilizer and equipment in a lower price (International year of Cooperatives, 2012).

Since 1994, the Government of Ethiopia made relentless efforts for establishment and functionality of cooperatives in the country (Bernard, Abate, and Lemma, 2013). Cooperatives are planned to be created in accordance with members' free will; their commitment and willingness to participate in free market; and free of government intervention in their internal affairs (Proclamation 85/1994). They are designed to play a significant role in agricultural sectors by supplying agricultural inputs, stabilizing markets, providing information and the like. Cooperatives are also expected to render vital services other than those related to agricultural marketing, including: (i) expanding financial services in rural areas; (ii) purchasing agricultural machinery, equipment and implements, and leasing them to farmers; (iii) setting up of small agro-processing industries where processed agricultural products with greater value added could be produced; and (iv) establishing various social institutions to provide different kinds of social services (FDRE 2002, 59 in Bernard *et al*., 2013).

Farmers' cooperatives contributed a lot to the provision of social protection for their members in a number of ways. Cooperatives buy products from farmers at fair prices so that they should not have to sell products at cheaper prices and sell them when the price recovers. This reduces the vulnerability of the producers not to be exploited by traders and thus provides implicit insurance for cooperative members. That means value of members' produce will not fall below the acceptable limit (Bernard et al., 2013). The services rendered to cooperative members include input supply, marketing, processing and exporting of agricultural commodities (Emana, 2009).

Research Design and Methodology

The study employed both quantitative and qualitative methodology. The objective was to provide an in-depth exploration and description of stakeholders' training on sustainable community development, focusing on the wheat value chain in Ambo district. The study has been conducted based on the information collected from 73 respondents. Of these, 35 respondents were from agricultural development agents, 35 respondents from smallholders, 2 from Ambo district FCU coordinators and 1 from Zone Cooperative focal person from Zonal agricultural office. So long as sampling strategy is concerned; the researcher employed simple random sampling, purposive sampling, quota sampling techniques and availability sampling technique. A simple random sampling technique was employed to determine rural villages known as kebeles and smallholders to be considered as the sample. Ambo district has 32 rural kebeles. Of the total number of rural kebeles, 12 of them were taken as the sample to get information from development agents and 6 kebeles to get information from smallholders. A purposive sampling technique was employed to get

information from Ambo FCU and West Showa Zone cooperative focal person. A quota sampling technique was used to determine the number of farmers selected from each Kebeles. Availability sampling techniques was used to get information from agricultural development agents from sample kebeles.

Methods of data collection

The data has been collected using a questionnaire, semi-structured interview and observation. Questionnaire was used to collect data from 70 participants (from35 agricultural development agents and 35 smallholder farmers). Semi-structured interview has been used to collect data from 2 Ambo FCU experts and 1 Zone Cooperative focal person. As far as observation is concerned,

the researcher visited the wheat mill established by Ambo FCU to get better picture about what was taking place on the ground.

Data analysis

Analysis of the study was guided by conceptualization of mixed data analysis. The process of data analysis followed data reduction, data display, data transformation, data correlation, data consideration, data comparison and data integration (Combs and Onwuegbuzie, 2010). The quantitative data were analyzed using descriptive inferential statics such as percentage, graph and pie-charts. Interview and observation were transcribed, analyzed and discussed using narration.

Results

The result of the study has been discussed under to major sub-topics known as quantitative and qualitative analysis and interpretation

Quantitative Analysis and Interpretation

Quantitative Analysis and Interpretation were carried out based on the information obtained from smallholders and development agents. The data has been tabulated, organized under different themes and converted into percentage as has been displayed in bar-graphs as follows.

Provision of training by different stakeholders

Table 1. Provision of training by different stakeholders as viewed by farmers

	Items	N	Min.	Max.	Mean	Std. D.
1	Development agents provide training to enhance smallholders productivity	35	1.00	5.00	3.29	1.47
2	FCU provides training on how farmers can add value on their production	35	1.00	5.00	2.71	1.51
3	Enterprises provide training to enhance farmers productivity	35	1.00	3.00	1.86	.85
4	Smallholders get necessary trainings to improve their productivity	35	1.00	5.00	2.43	1.46
	Valid N (listwise)	35				

Source: Survey data collected from farmers

As has been depicted in Table 1; farmers were asked if development agents provide training for smallholders and the mean score was 3.29. The response depicted that smallholder farmers somehow believe that development agents provide training on how to enhance their productivity. A standard deviation of 1.47 shows that there is variation in rating with some respondents rating the statement higher or lower than the mean. Item 2 of the table was meant to find out if farmers' cooperative unions have engaged in the provision of training on

how farmers can add value to their production. The mean score was 2.71, which shows farmers' reservations in farmers' cooperative training in the provision of training. The standard deviation has been 1.51 which shows a higher variation in respondents' rating. As far as enterprises' involvement was concerned the mean score was 1.86 and the standard deviation was 0.85 which confirms enterprises' non-involvement in provision of training to enhance farmers' productivity. Finally, the respondents were asked if they got the necessary training to enhance their productivity in either of the ways. The mean score and standard deviation were 2.43 and 1.46, respectively. The result depicted farmers' reluctance to adequacy of the training being provided for them to improve their productivity although there was variation in the respondents' response.

In summary, farmers believe that development agents provide training on how to enhance their productivity with some variation in their ratings. They are less confident in the cooperative union's involvement in providing training and affirmed that enterprises are not involved in the provision of training for farmers. As far as adequacy of the training is concerned, farmers are not satisfied with the training they received although there is some variation in their responses.

Table 2. Provision of training by different stakeholders as viewed by development agents

	Items	N	Min.	Max.	Mean	Std. D.
1	Smallholder farmers get training on how to improve their productivity	35	3.00	5.00	4.57	.61
2	Development agents provide training to enhance smallholder productivity	35	4.00	5.00	4.86	.36
3	Cooperatives provide training for smallholders on how to add value in production	35	1.00	5.00	3.43	1.58
4	Enterprises provide training to enhance smallholders' productivity	35	1.00	2.00	1.43	.50
	Valid N (listwise)	35				

Source: Survey data collected from development agents

As has been depicted in Table 2, development agents were asked if smallholders got training on how to improve their productivity. In that regard item 1 was designed to find out if stallholders get training and the mean score was 4.57, which demonstrated DAs conviction anonymously as the standard deviation was 0.61. Item 2 was designed to investigate if stallholders get training from development agents and the mean score was 4.86 which demonstrated DAs strong believe as the standard deviation was 0.36. Item 3 shows that DAs somehow believe cooperatives' involvement in value addition training for smallholders as the mean score was 3.43 although, there is significant variation in ratings as the standard deviation was 1.58. Table 2, item 4 focuses on finding out enterprises' participation in the provision of training as viewed by DAs, and the mean score was 1.43: the standard deviation was 0.50 which shows enterprises lack of involvement in provision of training.

Thus, in DAs perception smallholder farmers get training. DAs strongly believe that smallholders receive training from them on how to enhance their productivity. DAs also believe that cooperatives are involved in training, although there is some variation in their opinions. However, DAs do not believe that enterprises are involved in providing training to smallholders.

Stakeholders' participation in provision of training

The results in Table 1 and 2 show the involvement of stakeholders in the provision of training for smallholders. The finding shows that although all development agent respondents strongly believe that farmers are getting training, farmer respondents believe moderately with variation. The mismatch between the two parties might have something to do with the level of satisfaction and lack of confidence smallholders have. That is to say, the training being given to the smallholders by development agents is not up to the expectations of farmers. Farmers' cooperatives and private enterprises are other stakeholders that have a stake in the wellbeing of smallholders because the success of both the cooperatives and enterprises depends on the success of smallholders. But their effort in involving farmers in value chain development is different in that some attempts are being made by cooperatives as compared with private enterprises. Based on the reply obtained from sample farmers and development agents affirmed farmers' cooperatives' attempt to involve farmers in value chain development. An interview held with experts of Ambo Cooperative Union brought to light the level of involvement of cooperatives as it is limited to the provision of information and availing agricultural inputs so that the supply chain could be enhanced.

As far as private enterprises are concerned sample farmers, development agents and Zone cooperative agency focal person confirmed that private enterprises were not taking part in empowering smallholders. This might of course have an adverse effect not only on smallholders but also on enterprises as well because the efficiency of food processing industries among other factors is conditioned by the efficiency of farmers. If the productivity of smallholders increases both in quantity and quality all parties will enjoy the benefit and the vise-versa also holds true.

Types of training provided for smallholders

From the results presented so far, it is possible to say that two types of training known as general training and special training are given for smallholders. General training focuses on dealing with routine activities incorporated with close supervision. It consists of providing information concerning when to plough, sow and harvest based on expert information about the current fiscal year and weather conditions. Development agents visit the farm of each household that takes part in the package program to observe how farmers are doing and to discuss the problems with a view of finding possible solutions. Special training on the other hand is the type of training that focuses mainly on the introduction of new technology and methods of farming. It is offered relatively for a few farmers. The participants in the training are considered progressive farmers known as model farmers who are required to impart the new system of farming to follower farmers. The training is offered at a farmer training center.

Even if it is on small scale, limited in scope and provided only for members; primary cooperatives in collaboration with the District Cooperative Union provide relevant information mainly related quality of the product and market prices. In a way, this information is related to wheat value addition.

Access and utilization of supply

Table 3. Access and utilization of supply as viewed by farmers

	Items	N	Min.	Max.	Mean	Std. D.
1	Get supplies to improve productivity	35	1.00	5.00	3.94	1.24
2	Get training on how to use the supply	35	1.00	5.00	3.23	1.24
3	Use different strategies to increase the quality of agricultural output	35	1.00	5.00	2.74	1.20
	Valid N (listwise)	35				

Source: Survey data collected from farmers

In Table 3, item 1, farmers were asked if they get supply to improve their productivity. The mean score was 3.94. This shows that farmers get supplies to improve their productivity although there is variation among respondents as standard deviation was 1.24. In item 2 of the same table, farmer respondents have also been asked if they get training on how to use the supply. The mean score was 3.23 which shows that respondents moderately believe they obtained training on how to use the supply. The standard deviation was 1.24 which shows in rating with some ratings the statement is higher or lower than the mean score. Table 2 item 3 was designed to find out if the respondents used different strategies to increase the quality of agricultural output. The mean value was 2.73, which shows smallholders' lack of confidence in their utilization of different strategies to increase the quality of agricultural output. This of course is one of the determining factors of value chain development.

The above discussion revealed smallholder farmers generally supplies reception to improve their productivity, although there is some variation among respondents. While farmers believe they obtain training on how to use these supplies, their confidence in this training is moderate. They also lack confidence in their ability to utilize different strategies to increase the quality of their agricultural output, which is a critical factor for value chain development.

Table 4. Farmers' capability in utilization of resources as viewed by development agents

	Items	N	Min.	Max.	Mean	Std. D.
1	Smallholders get supplies to improve their productivity	35	3.00	5.00	4.26	.61
2	Smallholders are provided training on how to use the supply	35	3.00	5.00	4.11	.72
3	Farmers use different strategies to increase the quality of their output	35	1.00	5.00	3.83	1.10
	Valid N (listwise)	35				

Source: Survey data collected from development agents

Table 4 has been designed to view development agents' perceptions regarding farmers' access to agricultural inputs to improve their productivity, provision of training to use the supply if they use strategies to increase the quality of output and decrease costs of production. In this regard item, it was meant to find out if smallholders get supplies to improve their productivity. The mean score was 4.26 which implies DAs' confirmation: that farmers get supplies that contribute to enhance their productivity.

Item 2 was meant to see if smallholders get training on how to use agricultural inputs properly. The mean score was 4.11 and the standard deviation was 0.72. That clearly indicates DAs believed that farmers get training on proper utilization of agricultural inputs. As far as the issue of strategies employed to increase the quality of agricultural output was concerned, the respondents reacted positively as the mean score was 3.83.

In summary, development agents (DAs) believe that smallholder farmers get supplies to improve their productivity, receive training on how to use agricultural inputs properly and employ strategies to increase the quality of their agricultural output.

Institutional arrangement for value addition

Table 5. Institutional arrangement for value addition as viewed by farmers

	Items	N	Min.	Max.	Mean	Std. D.
1	There is institutional arrangements designed to enhance the wheat value chain	35	1.00	5.00	2.89	.93
2	Farmers believe in the possibility of processing wheat in their context	35	1.00	5.00	2.57	1.22
3	Have knowledge of the direct correlation between the price of the product and value addition	35	1.00	5.00	2.31	1.13
	Valid N (listwise)	35				

Source: Survey data collected from farmers

The development of institutional arrangements to enhance the food value chain is crucial for improving the livelihoods of smallholder farmers. In line with this table 5 has been formulated to look into the perception of farmers using the leading questions. In item 1, farmers' were asked if there was an institutional arrangement designed to enhance food value chain. The mean value was 2.89 and the standard deviation was 0.93 which showed respondents' reservation on the availability of institutional arrangements designed to enhance the wheat value chain. When farmers were asked on the possibility of processing wheat in their context and the mean score was 2.57 the standard deviation was 1.22. This shows that farmers are not confident in their capacity to enhance the wheat value chain by their own. The other point raised was to find out if the farmer respondents know value addition contributes to bringing significant changes in the price of their product. The mean score was 2.31 and the standard deviation was 1.13. This means farmers do not know the contribution of value addition to increasing the price of farm products.

Table 6. Institutional arrangement for value addition as viewed by development agents

	Items	N	Min.	Max.	Mean	Std. D.
1	Practice of stakeholders in value addition is good	35	1.00	5.00	3.86	1.12
2	There is an established organization that works to enhance the wheat value chain	35	1.00	5.00	2.89	1.35
3	Farmers know the direct correlation between value addition and price	35	1.00	5.00	2.17	1.10
4	The current context of farmers allows them to process food	35	1.00	4.00	2.43	1.01
	Valid N (listwise)	35				

Source: Survey data collected from development agents

Table 6 was designed to assess institutional arrangement for wheat value addition as viewed by development agents. In item 1, DAs were asked if the practice of stakeholders in value addition was good. the mean score was 3.86 and the standard deviation was 1.12. This implied that stakeholders' activity is good in value addition although there seems variation in DAs ratings. In item 2 of the same table, the respondents were asked if an established organization worked to enhance the food value chain. The mean value was 2.89 and the standard deviation was 1.35. This shows that in item 3 development agents were asked if farmers know there is a direct correlation between value addition and price. The mean

value was 2.17 and the standard deviation was 1.10. This shows that farmers have little or no knowledge about the correlation between value addition and price. The other point raised was meant to find out if farmers' current context allowed them to process food as viewed by development agents. The mean score was 2.43 and the standard deviation was 1.01. This implies that the situation of the farmers is not conducive to engaging in value addition to the farm product.

Key partners of smallholders

Table 7. Key partners of smallholders as viewed by farmers

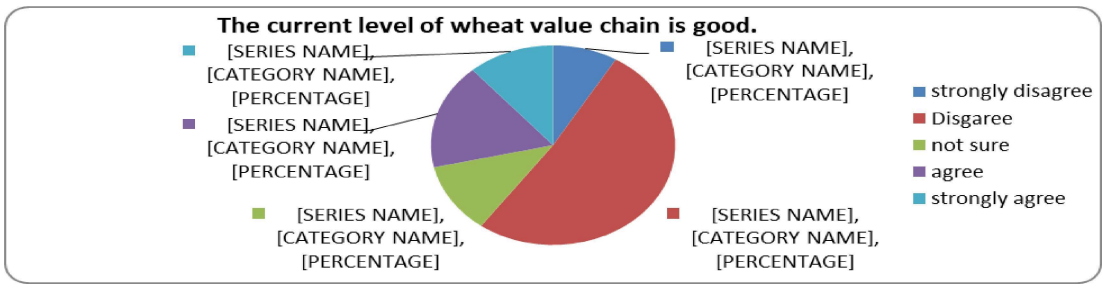
	Items	N	Min.	Max.	Mean	Std. D.
1	Enterprises are the key partners of smallholders	35	1.00	5.00	2.69	1.30
2	Farmers' cooperative union are the key partners of smallholders	35	1.00	3.00	1.97	.82
3	Farmers primary cooperatives are the key partners of smallholders	35	1.00	5.00	3.17	1.47
4	Local government agricultural office is the key partner of smallholders	35	1.00	5.00	3.66	1.41
	Valid N (listwise)	35				

Source: Survey data collected from farmers

Table 7 was designed to identify key partners of smallholders as viewed by farmers. In item 1, respondents were asked to find out if enterprises are key partners of smallholders. The mean score was 2.69 and standard deviation was 1.30. This implied that farmers are reluctant in considering enterprises as key partners although there is significant variation in rating. Item 2 was meant to find out if cooperative union were key partners of smallholders. The mean score was 1.97 and standard deviation was 0.82 which implies that farmers and farmers cooperatives union were not working together in collaboration and farmers failed to consider them as key partners. Item 3 has been designed to look at the relationship between farmers primary cooperatives and smallholders. The mean score was 3.17 and standard deviation was 1.47. This tells farmers recognition of farmers' primary cooperatives as the key partners. As far as considering government as key stakeholders is concerned, the mean score was 3.66 and standard deviation was 1.41. This revealed that farmers tend to consider government as key stakeholder even though, there is variation in ratings.

Assessment of wheat value chain

Figure 1: Farmers assessment of wheat value chain as viewed by farmers



Source: Survey data collected from farmers

Farmers were asked to express their view regarding the level of wheat value chain. As their response has been depicted in the above pie-chart: 61% (52% strongly disagree and 9% disagree) replied negatively, whereas 11% of the respondents were indifferent and 28% (17 agree and 11% disagree) responded negatively. This confirmed that majority of farmer respondents were not comfortable with status of wheat value chain.

Qualitative Analysis and Interpretation

Qualitative Analysis and Interpretation has been carried out based on the information obtained from interviewees of 2 Ambo district Farmers' Cooperative Union coordinators, 1 Zone Cooperative Agency focal person and observation.

Provision of training by different stakeholders as viewed by interviewees

According to the Zone Cooperative Agency focal person, development agents and cooperatives were the main actors that take part in training of smallholders. He said that development agents devote most of their time helping farmers on how to improve their productivity. Cooperatives on the other hand; limit themselves in providing market related information so that farmers could get fair price for their product. "Two types of training are provided for smallholders to enhance their productivity. The two types of training are known as special training and general training. Special training is the type of training which deals mainly with the introduction of new technology and methods of farming" (Zone Cooperative focal person, 2017). Special training is offered for better performing farmers known as model farmers. Special trainings are offered at farmers' training centers. The centers were organized like schools where series of teaching-learning process takes place (Cooperative Union coordinators, 2017). Development agents offered thorough training to the model farmers and work with them in the field to prove the effectiveness of the new methods of farming and to make sure that all agricultural inputs were utilized in accordance with the guidelines to achieve the desired results (Zone Cooperative focal person and Cooperative Union coordinators, 2017). Furthermore, Cooperative Union coordinators revealed that development agents tried to cascade knowledge and skills taught to follower farmers using model farmers' farm as the demonstration site. On the other hand, general training dealt with routine activities and is usually accompanied by close supervision and proper guidance. According to the interviewees, general training consisted of the provision of information concerning when to plough, sow and harvest based on the expert's information and weather forecast. Development agents visited the farm of each household took part in the package program to observe how farmers were doing and to discuss the problems farmers encountered to find possible solutions.

Access and utilization of supply

Based on the information obtained from the interviewees; farmers purchase fertilizers, pesticide, improved seeds and other necessary agricultural inputs from Ambo Farmers' Cooperative Union in collaboration with the Zone and District agencies. Development agents provided guidance and counseling service to smallholders to ensure proper utilization of all the necessary inputs in order to enhance smallholders' agricultural productivity (Zone Cooperative focal person, 2017).

Key partners of smallholders

As far as the issue of partnership with smallholders is concerned, participants of the interviewees said that district agricultural agents and farmers primary cooperatives were key stakeholders. Development agents worked to enhance farmers' productivity via providing training on how to enhance their productivity through development agents. Farmers' primary cooperatives and farmers union were also important stakeholders established by farmers and working with farmers to mitigate problems of smallholders' in different ways (Zone

Cooperative focal person and Cooperative Union coordinators, 2017). Farmers' unions avail agricultural inputs and market-related information. According to the interviewees, private enterprises have a minimal role in enhancing farmers' productivity and value chain development. They were limited to the purchase of agricultural products.

Key partners of smallholder farmers

Wheat value chain development is not something that can be performed by single body. Different actors have to participate in the activity deliberately or with a certain level of commitment. Hence farmers, consumers, enterprises, cooperatives, retailers and governments have vested interests, one might assume that they are partners who are working together for mutual benefit. But the results displayed both in table 7, 8 and the information obtained from the interviewee revealed different story. According to the findings, government is the main partner working with farmers to enhance their productivity through development agents. The second important partner rated by the respondent was farmers' cooperative union that provided different kinds of agricultural inputs and relevant information about market and related issues. Consumer cooperatives and private enterprises were not considered as important partners by the respondents mainly because their contribution in empowering farmers is very minimal.

Institutional arrangement for value addition

Interviewees from Cooperative Union said that one of the objectives of Ambo Farmers Union Cooperative is to add value on the produce of smallholders. The organization is working towards that and it started to produce flour and animal fodders as the byproduct very recently. As the researcher captured the picture displayed here under, Ambo Farmers Union have planted its own medium milling factory and started to produce flour with distinguished trade mark.

Figure 2: Ambo Cooperative Uniion Meal Factory

Thus, Ambo Cooperative Union managed to establish its own mill and started to process wheat and produce flour as the final product and animal fodder as the byproduct.

Discussion

Farmers' capability in utilization of resources

Based on the information obtained from the respondents about the accessibility of necessary supplies like fertilizers, improved seeds, pesticides and other staff majority of sample farmers, development agents and interviewees have said that they are accessible. Accessibility of agricultural inputs by itself might not be enough. Smallholders want to be capacitated in the utilization of agricultural inputs to enhance their productivity. The result obtained from sample farmers depicted that the mean score

was 2.43. This shows that farmers believe that they did not get training; although, there is greater variation in ratings. On the other hand, DAs strongly believe that smallholders get the training required to enhance their productivity as the mean score was 4.86. The mismatch between the two groups of respondents might be related to the expectations and quality of service. This means either the support they got from stakeholders is not satisfactory or not accessible to all.

The other factor that determent augment of productivity is the strategy employed by farmers: the more they diversify their strategy the more productive they will be. The respondents expressed their reservations as the mean score was 2.74. Employment of different strategies might be inhibited by factors like lack of resources, necessary skill and necessary supply. Most of the smallholders in the context of the research area have had very small plots of land and cannot afford to employ even crop rotation as the strategy. Farming practice in the area so far was being practiced traditionally and most of the farm communities were not educated. This implies that farmers and development agents are not on the same page and farmers need more support than development agents think.

Institutional arrangement for value addition

As has been seen in Figure 2, Ambo Farmers' Cooperative Union has got wheat mill. Farmers are one of the key players in value chain development. Their understanding and contribution to the value chain could affect the whole system in many ways. In contrast to the environmental analysis viewed by development agents and interviewees regarding the food value chain; the findings revealed that only 20% of the respondents believe that there is an institutional arrangement designed to enhance food value chain. This shows that even if the Ambo Farmers' Cooperative Union has been established by primary farmers' cooperatives and has owned mill; farmers in the district have very limited knowledge about it. This implies that smallholders' connection to the organization as is loose. That intern affects farmers' feeling in that they are alone by themselves and think that there is little they can do to change the situation. As a matter of fact; only 25.7% of the respondents see the possibility of food value chain development in their context. 51.4% of farmer respondents did not see the possibility of how the value addition could help to enhance their livelihood.

Wheat value chain mapping

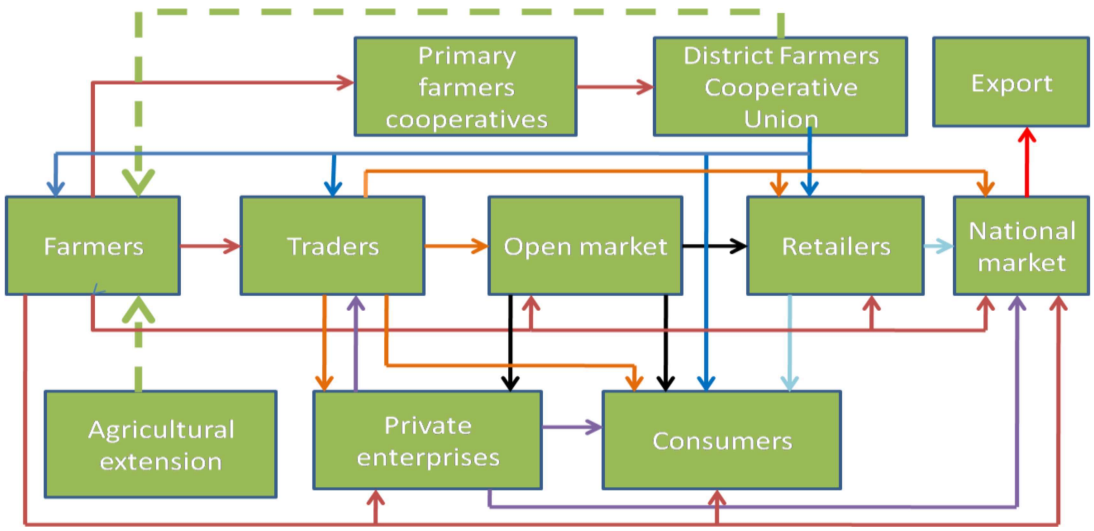


Figure 2: Wheat value chain mapping based on the observation and reflection (by author)

Figure 2 shows a simplified value chain and actors involved in producing wheat and transforming it into consumable products. It shows that number of actors are taking part along the chain. In the above discussion, it has been seen that the chain is not yet developed. Till now both private enterprises and the Cooperative Union in the district have managed to process wheat and produce flour and animal fodder as by-products. Farmers sell their products to cooperatives, private enterprises, traders, consumers and retailers at open markets. It is possible to deduce that a significant portion of the product is sold without value addition and passes through a series of transactions without value addition.

Even though the food value chain has an invaluable contribution to improving the livelihood of smallholders, it is not yet effective because of unclear institutional arrangements, poor alignment and integration with other programs.

Conclusion

The study reveals that development agents provide training to augment productivity of smallholders although significant numbers of farmers were not satisfied with the service rendered by development agents. Development agents provide two types of training, known as special training and general training. Special training is provided for progressive farmers and the general one is for follower farmers. Ambo Farmers' Cooperative Union provides market-related information, agricultural inputs and purchases of their product at fair prices. The Farmers' Cooperative Union tried to create institutional arrangements to foster wheat value chain development. Private enterprises are also active in wheat value chain development. Both private enterprises in the area and Farmers' Union Cooperatives are at the initial stage so far as the wheat value chain is concerned. So far, they only able to produce flour and animal fodder as their byproducts. Farmers however, have very limited knowledge about the food value chain and how it contributes to improving their livelihood. Smallholders were denied the opportunity to involve in food value chain development although primary cooperatives were founded by smallholders.

Recommendations

Hence better livelihood of smallholders contributes to value chain development all stakeholders should work together to enhance farmers' productivity and work out how to involve farmers in the process.

One of the limitations of training rendered by development agents is the failure to link productivity with value chain development. The findings of the research showed that farmers know very little about the correlation between the price of the product and value addition. Thus, they have to design strategies on how to connect productivity enhancement and value chain development that involve smallholders.

Farmers' cooperative union is one of the few institutions working in the community by availing agricultural inputs, purchasing their products and providing market information. Actually, it has huge potential to create meaningful links with farmers and mobilize the resources so that smallholders could be empowered. Thus, the union needs to design a plan on how to provide impact making training for smallholders and extend the value chain to a higher level.

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RESEARCH PAPER

Postharvest Management Challenges and Opportunities of Horticultural Crops in Selected Districts of Southwest Shewa, Oromia, Ethiopia

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Abstract

Initially identifying the constraints and opportunities in all the paths of horticultural crops value chain improvement targets are indispensable so as to secure food availability and accessibility. Post-harvest activities including market facilities are very important on top of productivity enhancement. Horticultural crops are highly productive compared with other crops, and also they are superior in nutrition content which is fundamental in balancing the diet. Derived from the research inquisition raised by society as a key point, the purpose of this study was to identify the post-harvest challenges and opportunities, and then generate baseline information that helps prioritize them for future intervention. Qualitative and quantitative data from both primary and secondary sources were collected from potential horticulture crops producing areas of the southwest Shewa zone, i.e., the selected three districts (Elu, Waliso and Wanchi) for this study. Finally, the data were analyzed with the help of SPSS software Version 20.0. Descriptive statistics (means, standard deviations, frequencies), and SWOT analysis for better illustration of postharvest issues such as storage, marketing, transportation, and postharvest handling were also applied. According to the study, the area has potential for producing horticultural crops on account of conducive agro-ecologies, the presence of ample labor, market options, and high interest of the farmers to produce are some of the opportunities identified. To utilize these prospects, however, there is a need for farmers' and experts' capacity building through different mechanisms such as among others training, provision and adoption of the latest technologies (e.g. cold truck), creating reasonable market alternatives, modern storage facilities, and securing crop protection programs for better prices. Conclusively, there is high potential to boost horticultural crop production. However, because of the recurrent challenges particularly marketing and price fluctuation, storage and transportation facilities were identified as major bottlenecks at postharvest.

Keywords: constraint, potential, identification, post-harvest, marketing

Introduction

Agriculture is the primary action in the Ethiopian economy and livelihood where about 84 percent of the country's population living in rural areas engaged in various agricultural activities and generate income for their household consumption to sustain their livelihood (CSA, 2015; MoANR and MoLF, 2017). It plays a prime role in a country's political, economic and social stability (CSA, 2017/18). As a consequence of the current population growth and the beginning of the industrialization tendency in Ethiopia, there is a great need to boost production and productivity in this sector; and in doing this, an affordable amount of the produce could be available for the market. Southwest Shewa zone is very potential to produce different horticultural crops including enset, potato, tomato, garlic, onion, shallot, cabbage, carrot, etc. (Ajabush, 2020; Ali and Martha, 2007). The study

conducted by Diriba *et al*. (2020) is an indication of the importance of this kind of investigation in which they identified problems and potentials in their study area which otherwise not revealed till then for professional further investigation and/or intervention. Food security can be increased by reducing postharvest losses and waste hence maximizing yield and quality; in fact, postharvest handling systems for fresh produce begin with harvesting and involve preparation for fresh market or other postharvest handling activities even at the destination including wholesale and retail marketing (Kader, 2013). Also, this scholar forwarded some of the strategies for reducing postharvest food losses including improving handling systems, especially at packaging and cold chain maintenance, overcoming socioeconomic constraints for instance inadequacies of infrastructure, poor marketing systems, and encouraging and supporting vertical integration among producers and marketers of horticultural crops. A similar study was reported by different scientists indicating the methods of handling the factors responsible for the loss of postharvest qualities and quantities of horticultural commodities (Banjaw, 2017; Nath, 2018; Negasa and Soruma, 2021).

Horticultural crops are highly productive relative to other crops, and also they are better rich in nutrition which is essential in balancing diet for health; i.e., it could have direct or indirect relation toward ensuring physical, mental, social as well as political aspects (CSA, 2017/18). These crops are significantly contributing to food security to feed the ever-rising population through increasing production and productivity. It also saves the need for high foreign currency by at least reducing crop importing from abroad. Besides, this sector contributes its part to the economy of our country, i.e. the lion's share of foreign currency which comes from the export of agricultural commodities currently contributed about 42 percent to the country's GDP (CSA, 2015). The sector unquestionably contributes to the current agriculture-led policy of our country in realizing the need for agricultural produce as raw input for the industries.

The study area is largely embracing an especially suitable agro-climatic state for the production of enset which is one of the known root and tuber horticulture crops; and it is the major enset growing area of the country (ERA, 2012; Ashenafi *et al*., 2016; Ashenafi *et al*., 2017). Their study may indicate the gap exists in this zone regarding the circumstances of other horticultural crops in particular. So, the other horticultural crops, besides enset, require attention for the promotion of production and productivity but with equal attention to postharvest issues including better marketing and also storage facilities. However, according to Alemayehu (2016), among many problems in the study area, long-chain marketing system is one of the postharvest challenging factors identified and suggested to be rectified. This could be due to a lack of managing price fluctuation by the concerned government bodies in the study area to secure a better marketing system nearby.

Identification of constraints and opportunities is the initial and essential step in development processes aiming at the improvement of crop productivity (Kraaijvanger *et al*., 2016); which should be applied across the whole value chain (through production to post-production). These investigators elaborated that intervention work intended to raise agricultural productivity in low-external input settings requires an understanding of farmers' preferences and motivations and the complex socio-cultural settings in which these farmers operate. Market availability is one of the crucial postharvest factors in agriculture particularly for horticultural crops which are naturally easily perishable. Hence, suitable storage (e.g. commodity specific cold room with optimum temperature and relative humidity) is very necessary until selling of the produce or to properly conserve before the end consumption. Generally, the major importance of postharvest technology includes reducing: postharvest losses of produces, cost of production, malnutrition, and economic loss; securing food availability; employment generation hence tackling the unemployment problem; export earnings through foreign exchange (Kiaya, 2014; Teferra, 2022; Adhiraj *et al*., 2024).

Along the chain of crop production and productivity enhancement role in general and postharvest activities scaling up strategies specifically through research and study should be started primarily by identifying the challenges and opportunities so as to ensure a high chance of success. This should be done from the grassroots most preferably through farmers' participatory method (e.g. survey) inclusion of problem identification. So, it is vital to diagnose the opportunities, constraints, and then prioritize them. This research result will certainly lay a baseline for intervention design by stakeholders (researchers, governmental bodies, NGOs and any individual stakeholders). Besides, the result will guide the researchers towards the research inquiry raised by the society/farmers in the study area to extend further investigation. Therefore, the purpose of this study was to identify and prioritize horticultural producers' marketing and other postharvest constraints and opportunities in the study area in an attempt to get a baseline for formulating future interventions..

Materials and methods

Description of Study Areas

This research was conducted in selected districts of the southwest Shewa zone during 2021/22. Southwest Shewa zone is located at 8º16´-9o 56´ N latitude and 37º 05´-38º 46´ E longitude and altitude ranging from 1600-3576 m.a.s.l. It receives annual rainfall ranging from 900 -1900 mm. The mean minimum and maximum air temperature of the area is 10ºC and 35°C, respectively (Hailu *et al.*, 2015; Alemayehu, 2016).

Types of data, source and collection methods

The central focus of the study was on the postharvest management level data collection and analysis which includes qualitative and quantitative data on the socioeconomic structure of households and farms, and postharvest (e.g. marketing) activities. In consideration of the characteristics of the target areas, both quantitative and qualitative open-ended and close-ended questions were used to gather data. Also, secondary data were collected from zonal and district agricultural offices.

For qualitative data generation, the Participatory Rural Appraisal (PRA) method was employed in order to utilize the knowledge and opinions of rural people as reference data for future planning. PRA, a qualitative survey methodology, is a process to generate genuine interdisciplinary in the formulation of problems for agricultural research and development (Ison and Ampt, 1992; Belay *et al.*, 2013). Hence, focus group discussion (FGD) having 6-12 members were used to identify and clarify shared knowledge among groups' of individuals in the communities, which would otherwise be difficult to obtain accurately with a series of individual interviews alone. Based on the points included in the questionnaire, open and rigorous discussion was conducted in each of the three districts by the FDG which was led by our research crew. Similarly, mini focus groups composed of 4 or 5 members were also used instead in some areas where the interviewed farmers were few (less than 6) due to their inconveniences.

Before conducting the survey, a preliminary visit to the selected community was made to obtain background information on the local farming system. Also, there was a direct observation, transect walking with the community key informant around crop farms and homesteads was made to have a better overview of the general horticultural products, marketing and other postharvest factors. Then, besides the questionnaire for individual interviews, the collection of data was conducted through systematic group discussions with key informants consisting of men and women to discuss extensively the problems and the available opportunities in their localities. These key informants include exemplar (role model) farmers, development agents and other horticulture experts from district agricultural offices. So, this information helped to rank the perceived constraints based on the severity and importance of constraints to horticultural crops outputs.

Sampling techniques and sample size determination

Relatively potential horticultural crops producing districts from the southwest Shewa zone were selected in consultation with the zonal agriculture offices through preliminary survey. All horticultural crops produced in the study area were considered for this survey to identify and prioritize the challenges and opportunities related to each crop. From out of 11 districts found in Southwest Shewa zone, data were collected from purposively selected districts based on the potential production of horticultural crops. Hence, three districts including Elu, Waliso and Wanchi districts which consist of 15, 35 and 23 rural kebeles, respectively were identified and used for the study. Similar to district choice from the zone, two kebeles were purposively selected in each district for the aim of quantitative data surveying through simple random sampling. Accordingly, upon determining a sample size of 20 from each kebele and a total of 120 representative households from districts were used for data collection; it was determined based on the following (Yamane, 1967) formula to calculate the total sample size (n) for households; and it was proportionally fixed for each kebele. Further, for reliable qualitative data, in particular, key informants having better knowledge and experience were also included.

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

Where, n = designates the sample size the research uses;

N = designates total number of households;

e = designates maximum variability or margin of error 5%;

1 = designates the probability of the event occurring.

Data analysis

After summarizing the data, the software SPSS Version 20.0 (IBM, 2011) was used for analysis process. Descriptive statistics (mean, standard deviation, frequency) were also applied to the analysis. Likewise, SWOT (strength, weakness, opportunity and threat) analysis was used to analyze opportunities along with the challenges critically connected to the horticultural crops postharvest factors including storage, marketing, transportation and postharvest handling.

Results and discussions

Demographic and socioeconomic characteristics of sample households

There were different key variables used to describe the demographic as well as socioeconomic characteristics of sample producers. These include family size, age, education level, marital status and gender of the household that usually influence not only postharvest activities but also crop production as well. The result showed that the means of family size, age and educational level respectively are 4.392, 43.567 and 6.79. Similarly, minimum and maximum in that order are (2, 22 and 0) and (8, 69 and 13) as indicated below. From this study result, above the good education level and sufficient family labor, most of them are on productive age average of 43.6 years old which is in agreement with Tauer (2017) that found in their study the most productive age range of 35 to 44 years. Marital status and gender of the families in the surveyed area, based on the result, 90.83% are married, and 7.5% are not married, while only 1.67% are divorced. Most of the responders' gender diversity, 94.17%, is male; females take only 5.83% (Table 1). Generally, as indicated in the result, population diversity, age and education levels are very potential not only for postharvest period but also for all agricultural activities related to the study area.

Table 1. Demographic characteristics of respondents

	N	Minimum	Maximum	Mean	Std. Deviation
Family size	120	2.0	8.0	4.392	1.5301
Age	120	22.0	69.0	43.567	9.7634
Educational level	120	0	13	6.79	3.355
Valid N (listwise)	120				

Categorical variable

Marital status and sex of respondent		District						Total	
		Elu		Woliso		Wanchi			
		No	%	No	%	No	%	No	%
Marital status	Married	34	85	38	95	37	92.5	109	90.83
	Unmarried	6	15	1	2.5	2	5	9	7.50
	Divorced	0	0	1	2.5	1	2.5	2	1.67
Sex of respondent	Male	37	92.5	38	95	38	95	113	94.17
	Female	3	7.5	2	5	2	5	7	5.83

Note: *No=sample size;* ***Source****: survey result (2021/22)*

Location and infrastructure

Mean distances from the nearest market (5.922 km) and the main road (4.954 km) are closely similar with only about 1km difference (Table 2). In both cases, the minimum distances are less than 1 km (0.2 and 0.1, respectively) while the maximums are 12 km to the nearest market and 21 km to the main road. According to Hagos et al. (2018), as the mean value indicates, farmers are dwelling in the range of nearest distances (less than 10 km) both to the market and the main road which is one of the opportunities. Similarly, according to these authors, the maximum distances are on intermediate access which is less than 31 km. Mean, minimum and maximum total farmland in hectares owned by the farmers in the study area, respectively are 2.731, 0.5 and 12.

Table 2. Respondents' distance from the market center and main road and resources holding

	N	Minimum	Maximum	Mean	Std. Deviation
Distance from the nearest market in km	120	.2	12.0	5.922	3.8797
Distance from main road in km	120	.1	21.0	4.954	4.7862
Total farmland in hectare	120	.5	12.0	2.731	1.7785
Valid N (listwise)	120				

Note: N=sample size; Source: survey result (2021/22)

Marketing constraints of horticulture crops

There are a lot of constraining factors regarding the market. Sequentially listed marketing constraints include most importantly poor linkage with different stakeholders, low price of products, lack of storage facilities and market, perishable nature of the produce, lack of transport services and market information, and quite remoteness of the marketplace. In view of that, 73.3%, 65.8%, 60%, 58.3%, 45%, 40.8%, 61.7% and 19.2% are the results obtained from the sample respondents (Table 3). Market fluctuation related to prices is a very problematic factor that forces farmers to focus

the subsequent year on producing crops that were sold at the best prices in the last year. On top of this, there is a lack of crop calendars and hence all the crop products are availed for the market simultaneously otherwise farmers have no storage alternatives to keep some of their produces until a better price comes. Likewise, owing to market instability, crops such as potato are usually left on the farm for a distinct period of time. This indicates that because of a lack of storage and/or market, farmers leave potato tubers on the farm both for seed and for consumption which widens the chance of quality deterioration.

Table 3. Marketing and other postharvest constraints of horticultural crops in the study areas

No	Major Constraints	No/Yes	Frequency	Percent	Valid Percent	Cumulative Percent	Rank
1	Low price of products	No	41	34.2	34.2	34.2	2
		Yes	79	65.8	65.8	100	
2	Perishability	No	66	55	55	55	5
		Yes	54	45	45	100	
3	Lack of storage facilities	No	48	40	40	40	3
		Yes	72	60	60	100	
4	Poor linkage with stakeholders	No	32	26.7	26.7	26.7	1
		Yes	88	73.3	73.3	100	
5	Lack of market	No	50	41.7	41.7	41.7	4
		Yes	70	58.3	58.3	100	
6	Lack of market information	No	74	61.7	61.7	61.7	7
		Yes	46	38.3	38.3	100	
7	Lack of transport services	No	71	59.2	59.2	59.2	6
		Yes	49	40.8	40.8	100	
8	Long distance of marketplace	No	97	80.8	80.8	80.8	8
		Yes	23	19.2	19.2	100	

Marketing opportunities for horticulture crops produces

In order to satisfy the market demand for horticultural produces, the area is potentially endowed with suitable agro-ecologies be it edaphic (soil factor), climatic, water, plenty of labor availability, etc for the production of horticulture crops. Moreover, there are some non-governmental organizations (NGOs) that can support agriculture sectors, particularly horticulture. Organizations namely SNV (*Stichting Nederlandse Vrijwilligers* = Foundation of Netherlands Volunteers), Save the Children and World Vision are currently doing different farmer supporting activities (production, marketing, training, etc.) in the study area. Probably the other most importantly

noted thing, though on commencement, is that the government focuses on the establishment of fruit crops production in clusters of farmers nowadays so as to fulfill the current market demand is encouraging.

Regarding marketing issues, a lot of promising motives were being identified. Access to road and transportation is better among the infrastructures required for the sector. Also, the closeness of the area to the capital, Finfinnee/Addis Ababa, and other urban (e.g. Sebeta) for easy marketing besides the presence of nearby local markets is another prospect of enhanced market access. Agro-industries are rising at Finfinnee and the surrounding, and this is a good opportunity especially if there is an intimate linkage with the farmers to reduce illegal intermediaries. There are also a few value addition works (e.g. potato chips) by some individuals around the towns that indeed require input (potato tuber) from producers so opening marketing occasion. Generally, section 3.5 below briefly summarized what was mentioned above and other information such as strengths, weaknesses, opportunities and threats at postharvest particularly storage, transportation, marketing and postharvest handling.

SWOT of horticulture crops marketing and other postharvest activities

Analyzing the SWOT of horticultural crops as a function of Storage, Marketing, Transportation, and Postharvest handling (starting at the harvesting point) was done critically by involving mainly key informants from producers and professionals from different levels of agriculture offices at the study area. The detail is briefly stated as follows:

Storage

Strength: Good experience of seed producer farmers' group on potato storage house construction (Wanchi district) from local material for better storage of their seed tubers until planting.

Weakness: Poor awareness about storage and lack of accessing storage technologies for farmers on horticulture crops; storing traditionally (e.g. in field /soil storing potato tubers).

Opportunity: Ware and seed potato storage trial at Wanchi district; local materials ease of access for storage construction; government projects for instance Agricultural Transformation Agency (ATA) and Agricultural Growth Program (AGP),) work on adopting new storage technologies for vegetables.

Threat (constraints): Unavailability of better technologies for this perishable horticultural crops storage; lack of knowledge; low government attention.

Marketing

Strength: some value addition experience (e.g. potato chips).

Weakness: Poor/lack of grading affecting the market preference for produce; market linkage lacks; well-planned market centre for vegetables is lacking.

Opportunity: Rising of Agro-industries at Finfinnee, and presence of nearby local markets; access of road and transportation; closeness to Finfinnee and other urban for better market access; Presence of collectors from few vegetable producers; availability of local markets (e.g. roadside market at Waliso district on the way to and from Finfinnee; high demand; farmers get information easily.

Threat: Fixing of price made by brokers; fluctuation of price; brokers decide price without any control; absence of price fluctuation supervision; price fall when maximum production at peak time;

Transportation

Strength: On-farm product collectors (traders) from a few farmers; few producers form groups and transport their produce.

Weakness: Improper packing/ using packing material and transporting, overloading; e.g. tomatoes using donkey back; poor damage control.

Opportunity: Accessibility of rural roads and transportation; access of roads in areas; plenty of labor for loading and unloading

Threat/constraint: Better transportation technologies are not affordable/ lacking for farmers; lack of year-round roads for some areas.

Postharvest handling (starting at harvesting point)

Strength: Some producers started proper harvesting; i.e. harvesting at proper maturity stage and method of collecting to maintain quality (e.g. onion curing) of some crops: leafy vegetable, root and tuber crops, coffee and spices; post-harvest handling awareness for a vegetable is increasing relatively.

Weakness: Not all farmers are practicing proper harvesting; farmers are not grading based on size, quality, etc.; postharvest problem; poor awareness of harvesting techniques for horticulture crops especially fruits.

Opportunity: Increasing Agro-Industries around Finfinnee that can receive quality produce for processing; labor availability.

Threat/constraint: Unavailability of improved/mechanized technologies.

Suggested key intervention points

Based on this study, the following areas of intervention have been suggested for the improvement of the horticulture sector in general and in the study area in particular; that is, due attention should be given to the postharvest (e.g. facilities such as storage, transportation, and marketing) similar to production. We believe that the direct involvement of different concerned government sectors is very imperative. Besides, these sectors should also play their role in awareness creation, mobilization and participation of others such as private sectors, NGOs, etc in order to practically improve the horticulture area. This becomes implemented if we can invest also in capacity building strategy for farmers and other postharvest actors. Thus, based on the *suggested points by the society* the below mentioned ideas should be considered: *Higher institutions and other similar sectors should support farmers* in different intervention areas for instance supply chain problems about marketing from producers (farmers) to the end users or consumers; similar study result was reported by Tadesse (2018) indicating that there should be due attention to help farmers benefited the reasonable proportion from the selling of their enset produce. *Research and/or training* have been considered to be the essential areas of concern through, for instance, *detailed market value chain investigate* besides training on market, produce quality, etc; and *clear awareness and motivation* towards making people business minded further for market instead of only producing for home consumption.

Conclusion and recommendations

In conclusion, to secure the availability of quality produce for the market demand, both pre- and post-harvest factors should be visibly considered. According to the study the following important recommendations could be forwarded: the primary important issue suggested is that all stakeholders such as governmental, NGOs, and any concerned individuals and/or professionals should seriously contact farmers to understand their needs and hence always support them. This could include financial, professional, material, and any other support required starting from the farm community across the whole value chain. There should be storage facilities that are affordable and accessible. There should also be marketing management strategies (controlling illegal intermediates, creating and/or improving market linkage, etc.). Similarly, attentively working on transportation (e.g. trucks with reasonable cost, improving road facility) is another postharvest pillar of concern.

Conflict of interest

The authors have no conflicts of interest to declare.

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RESEARCH PAPER

Milk Production, Processing and Marketing Practices in Sebeta Hawas District, Shagar City, Ethiopia

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Abstract

The study was conducted to assess milk production, processing and marketing systems in Sebeta Hawas district of Oromia, Ethiopia. A total of 139 randomly selected smallholder farmers were involved in the study from five purposefully selected kebeles of the district. Both primary and secondary data were used for the study. The data collected were analyzed using Statistical Package for Social Science (SPSS) version 24 and a z-test was employed to test the difference between rural and urban dairy production systems. Pasture was the major feed source (54.7%) of dairy animals in the district followed by crop residues (25.9%). The majority (69.1%) of the dairy farmers use free grazing while only about 26% practice stall feeding in the district. More than 2/3 (68.3%) of the dairy farmers in rural areas do not produce improved forage for their dairy cattle due to shortage of land (38.3%), shortage of forage seeds and fertilizer (36.2%) and lack of awareness (22.3%) whereas more than half (57.9%) of the dairy producers in urban areas produce improved forage for their dairy cows. Almost all (99.3%) of the milk produced in the study area was traditionally processed using hand churning. Informal marketing was the sole means of dairy products (milk, cheese and butter) marketing. Feed shortage, animal diseases, poor accessibility of AI and poor dairy marketing systems were the major milk production constraints in the study district. Thus, developing improved forage in the areas, introducing milk processing technologies, linking milk producers to formal milk marketing systems, strengthening access to veterinary services and vaccination, improving access to AI services and improving the whole extension systems were recommended to improve milk production, processing and marketing in the study district.

Keywords: Milk production, consumption, processing, marketing

Introduction

Livestock keeping is an ancient tradition in rural areas of Ethiopia. With a cattle population of more than 70 million head (CSA, 2021), Ethiopia stands first in Africa and 6th in the World. The size and diversity of livestock resources have become vital to the sustenance of rural life and the largely agrarian economy of the country. Cattle are the predominant element of livestock wealth in Ethiopia both in the agricultural highlands and pastoral and agro-pastoral lowlands, and hence the proportional contribution to the national economy is considered to be high (Yayeh et al., 2017; Getabalew *et al*., 2020).

Ethiopia holds large potential for dairy development due to its large livestock population (CSA, 2021), its favorable climate, emerging market opportunities, and the improved policy environment for the involvement of private sectors (Mebrate et al., 2019). Dairy production is an important component of livestock farming in Ethiopia (ILRI, 2015) and is used as an enterprise and economically viable and greatly contributes to poverty reduction, food security, increased family nutrition and income and job

opportunity creation (Niraji et al., 2014). It plays a vital role in economic development, especially in developing countries as both driving economic growth and profiting from it. It is a valuable device to increase income, employment, food and foreign exchange earnings as well as better nutrition as an engine of growth. The share of animal products in the total food budget increases faster than that of cereals due to the relatively high-income elasticity of demand for animal products (Dayanandan, 2011; Tadesse et al., 2020).

With a cattle population of 25.5 million, Oromia stands first in Ethiopia (CSA, 2021); the Sebeta Hawas District area contributes 151,900 cattle and it is among the highest potential areas for dairy cattle in Oromia special zone surrounding Finfinnee (SHDLFRDO, 2020). Even though milk production is an essential part of the livelihood of the rural and urban communities in the present study areas, there is no documented data on milk processing, handling, utilization and marketing systems. Developing appropriate interventions to assist smallholder dairy households and identifying those that should be targeted requires a clear understanding of the dairy production systems, and the prevailing traditional practices of milk production, processing and marketing systems. Therefore, the study was aimed at describing the milk production, processing and marketing system in Sebeta Hawas District of Oromia Regional State, Ethiopia.

Materials and methods

Description of Study Areas

Sebeta Hawas district is located on the main road of Addis Ababa - Jimma at a distance of 28 km away from Addis Ababa. It has 36 rural and 4 urban administrative sub-divisions or kebeles. The total area of the district is 73,078.048 hectares. Out of this total area, 86.7% and 5.2% are used for cultivation and grazing land, respectively. Cattle are the most important livestock species in the area. From the total number of female cattle populations of the district (61060), 60,693 are local breeds and 367 are crossbreeds, of which milking cows account for 13,777. The district has two agroecologies- midland (88%) and lowland (12%) (SHDLFRDO, 2020). Mixed crop-livestock production (90%) is the main agricultural practice in the study area.

Data and methods of Data collection

Both primary and secondary data were used for the study. Primary data was collected through a survey using pre-tested semi-structured questionnaires, while the secondary data was collected from relevant documents viz., district and zonal reports and literature. All the primary data collected were triangulated by focus group discussions and key informant interviews with district livestock heads and experts in livestock and animal health.

Sampling and selection of study households

Purposive and random sampling techniques were employed to identify kebeles and household respondents. Five kebeles (three from rural and two from urban) were purposively selected based on dairy cattle population and accessibility. Initially, study populations were defined as households that had at least one milking dairy cow both in the urban and rural kebeles, whereafter, dairy cow-owning households were randomly selected for an interview from the list.

The sample size was determined using the formula given by Yemane (1967) for homogenous experimental material with a 92 percent confidence level because the farmers are all smallholders and more or less the breed they keep and management practices are similar.

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

Where,

n = designates the sample size

N = designates total number of Agricultural households (AHH)

e = designates maximum variability or margin of error =8% (0.08)

1 = designates the probability of the event occurring

Thus, $$n = \frac{N}{1+N(e)2} = \frac{1256}{1+1256(0..08)} \cong 139$$

Accordingly, a total of 139 dairy producers were used for an interview.

Data analysis

All collected data were analyzed using SPSS version 24 Software. Descriptive statistics like frequency tables and averages were used to summarize the data. T-test analysis was employed to compare rural and urban dairy production systems.

Results and discussions

Feed resources and feeding practices of dairy cattle

The major sources of feed for cattle in the study area are shown in Table 1. Natural grazing, crop residues, hay, improved forage, agro-industrial byproducts, and non-conventional feedstuffs (*Atella*) were the major feed resources in the study area. Feed resources for dairy cattle showed a significant association ($P<0.01$) with the production system (rural and urban) of the study area.

In the rural area, the most commonly used feed resources for dairy cattle were grazing land (59.2%) followed by only crop residue (teff, wheat plus crop) (29.2%) and a mixture of crop residues, grazing and industrial by-products (11.7%). While in urban areas a mixture of crop residues, free grass grazing and industrial by-products (68.4%), grazing (26.3%), crop residue (25%) and industrial by-products (5.3%) (Table 1) were the commonly used feed sources for dairy cattle. The feeding system of dairy cattle was significantly associated with the production systems of the study area ($p<0.01$).

Mostly known feeding systems practiced were free grazing (75.8%) and (26.3 %) in rural and urban areas, respectively and grazing and stall feeding practiced (73.7%) in urban and 18% (Table 1) in rural areas. The present result was not in line with the result reported by Kassa and Dekamo (2016).

Table 1. Feed resources and feeding practices of dairy cattle in the study area

Description	Production systems		Total	Test	
	Rural	Urban		X^2	p-value
	N (%)	N (%)	N (%)		
Most commonly used feed resources for cows				**42.295****	**0.000**
Only crop residue of teff, wheat crop	35(29.2)	-	35(25.2)		
Industrial byproducts	-	1(5.3)	1(0.7)		
Grazing Land	71(59.2)	5(26.3)	76(54.7)		
Crop residues, grazing, and industrial by-products	14(11.7)	13(68.4)	27(19.4)		
Feeding practice of cattle for local and cross breed				**26.335****	**0.000**
Free grazing	91(75.8)	5(26.3)	96(69.1)		
Stall feeding	6(5.0)	-	6(4.3)		
Grazing + stall feeding	22(18.3)	14(73.7)	36(25.9)		
Other	1(0.8)	-	1(0.7)		

N= Number of respondents

Production of improved feed for dairy cattle

The practices of growing and feeding improved feeds for dairy cattle in the study area are depicted in Table 2. The current result indicated that there was a significant association between growing of improved feed within the production system ($p<0.05$). The majority (68.3%) of respondents did not practice the production of improved feed for their dairy cattle in rural areas due to insufficient land (38.3%), shortage of input like seed and fertilizer (36.2%), lack of knowledge (22.3%) and insufficient labor (3.2%) (Table 2).

Table 2. Production of improved feed for dairy cattle in the study areas

	Production systems		Total	Test	
	Rural	Urban		X^2	p-value
	N (%)	N (%)	N (%)		
Do you grow improved feed for dairy				4.944*	0.026
Yes	38(31.7)	11(57.9)	49(35.3)		
No	82(68.3)	8(42.1)	90(64.7)		
If yes, what are they?				13.923**	0.003
Fodder trees	4(10.5)	-	4(13.3)		
Improved grasses	7(18.4)	-	7(23.3)		
vetch &oats	27(71)	7(63.6)	15(50.0)		
All	-	4(36.4)	4(13.3)		
If no what are the major reasons?				1.627NS	0.653
Insufficient land	31(37.8)	4(55.6)	36(38.3)		
Insufficient labor	3(3.5)	-	3(3.2)		
Shortage of input (seed, fertilizer)	32(39.6)	2(22.2)	34(36.2)		
Lack of knowledge	17(20.7)	2(22.2)	21(22.3)		

N= Number of respondents

Preservation and processing practices of crop residues

About 89% of the respondents were storing crop residues by stocking outside (Table 3). This causes damage to crop residues due to excessive sun and rain. In comparison to rural families (9.2%), urban families (21.1%) stored their crop residues stocked under the shed. More than half (53.3%) of the crop residues were fed in the form of chopped in rural areas while 68.4% of the crop residues were fed in the form of treated in urban areas. As the result showed there was a significant association between crop residue feeding form and production system ($p<0.05$).

Both rural and urban families (66.2%) implemented the practice of treating crop residues to improve its utilization. The result showed that there was a significant association between treating crop residues and production systems ($p<0.05$). Among respondents treating crop residues 75.7% and 72.2 % of respondents said crop residues treated by mixing crop residues with *Atella*, molasses and other feeds in rural and urban, respectively and 24.3% and 27.7% was practiced treating crop residue by urea treatment in rural and urban, respectively. The result showed that there is no significant relation between the treatment method and production system ($p>0.05$). The present result was in line with the findings of Zewudie (2010) who reported about 75% of the dairy farmers in Debre Birhan and more than 65% in Sebeta offered whole straw mixed with other feeds like water, salt and local brewery by-product '*atella'*.

Table 3. Preservation and processing practices of crop residues

	Production systems		Total	Test	
	Rural	Urban		X^2	p-value
How do you store crop residues?	N (%)	N (%)	N (%)	2.407^{ns}	0.121
Stocked outside	109(90.8)	15(78.9)	124(89.2)		
Stocked under shed	11(9.2)	4(21.1)	15(10.8)		
In what form do you feed crop residues?				26.773*	0.000
Whole	28(23.3)	-	28(20.1)		
Chopped	64(53.3)	4(21.1)	68(48.9)		
Treated	20(16.7)	13(68.4)	33(23.7)		
Mixed with other feed	8(6.7)	2(10.5)	10(7.2)		
Do you have practice in treating crop residues to improve utilization?				8.016	0.005
Yes	74(61.7)	18(94.7)	92(66.2)		
No	46(38.3)	1(5.3)	47(33.8)		
If yes, which crop residue do you usually treat and what type of treatment do you use?				0.951	0.813
Urea treatment	18(24.3)	5(27.7)	23(25)		
Mix crop residues with *'Atella'*, molasses and other feeds	56(75.3)	13(72.2)	69(75)		

Feeding agro-industrial by-products

Agro-industrial by-products were not given to milking cows in rural areas as replied by 68.3% while in urban areas oppositely agro-industrial by-products were given to milking cows as mentioned by 78.9% of respondents as shown in Table 4. This might be due to urban area families' access to agro-industrial by-products. Agro-industrial by-products, such as brewery (from Meta Beer factory), oil seed cake and wheat bran were more common animal feed in this study area. Commonly agro-industrial by-products are not highly accessible in both rural and urban areas of the study area. The main cause for the non-accessibility of agro-industrial by-products in the study area might be due to the high price of agro-industrial by-products as mentioned by 71% of respondents in rural and 76.9% of respondents in urban areas. This current result was greater than the results of (2.2%, and 46.7%) reported by Ayelaw (2017) in the South Wollo zone. This might be due to the fact that the current study area is near (short distance) to agro-industries.

Table 4. Feeding agro-industrial by-product

	Production systems		Total	Test	
	Rural	Urban		X^2	p-value
	N (%)	N (%)	N (%)		
Do you give agro-industrial byproducts to your milking cows?				15.543**	0.000
Yes	38(31.7)	15(78.9)	53(38.1)		
No	82(68.3)	4(21.1)	86(61.9)		
Are agro-industrial by-products accessible in your area?				0.370NS	0.543
Yes	30(25.0)	6(31.6)	36(25.9)		
No	90(75.0)	13(68.4)	103(74.1)		
If not, what is the reason?				28.016**	0.000
High price	64(71.1)	10(76.9)	23(20.9)		
Shortage on market	20(22.6)	1(7.7)	21(19.1)		
Lack of awareness	6(6.6)	2(15.4)	66(60.0)		

Water sources and watering system

The source of water for cows is mostly ponds (60%) followed by nearby river water (38.3%) for rural areas and pipeline water (68.4%) followed by ponds (21.1%) for urban areas as indicated in Table 5. In contrast to the present result, Getachew et al., (2012) reported river water as a major source of water for dairy cows in Urban (85.9%) and mixed crop-livestock (79.5%) systems of Debre Zeit areas. The present result showed that there was a significant association between the source of water supply and the production system ($p<0.05$). In rural areas, means of transportation of water to cow or cow to water are nearly equal with 55.9% transporting water to animals and 44.1% bringing cows to where water is found while in urban areas, water is mostly transported to where cows are reared. Either water transportation to cows or cows to the area of the water source has no impact on the production system ($p>0.005$). Average dairy cow travel has a direct correlation with the production system ($p<0.05$). The watering frequency of dairy animals varies by season (wet and dry), and from one production system to another. Water was provided once per day (47.5%), once per two days (26.6 %), free access (10%) in rural areas and twice per day (63.2), and free access in 31.6 % (Table 5) in urban areas. According to the focus group discussion, there was a scarcity of drinking water in the areas during the dry season.

Table 5. Water sources and watering systems in the study areas

	Production systems		Total	Test	
	Rural	Urban		X^2	p-value
What are the sources of water for your cow?	N (%)	N (%)	N (%)	75.957	0.000
Pipeline water	2(1.7)	13(68.4)	15(10.8)		
Nearby river water	46(38.3)	2(10.5)	48(34.5)		
Ponds	72(60.0)	4(21.1)	76(54.7)		
If you use water sources from river, pond or well, do you usually transport the water or bring the animals to the rivers, pond, or well?				0.647	0.421
Transport water to the animal	66(55.9)	4(66.6)	70(56.8)		
Bring the animals to the river or pond	52(44.1)	2(28.6)	54(43.2)		
If you take your dairy cattle for water what is the average distance to the watering point?				9.750	0.021
<1km	14(26.8)	2(100.0)	16(29.6)		
1-4km	20(38.4)	-	20(37)		
4-10km	18(34.6)	-	18(33)		
How frequently do you provide water for your cattle?				30.112	0.000
Free access	13(10)	6(31.6)	27(19.4)		
Once per day	57(47.5)	1(5.3)	58(41.7)		
Twice per day	18(15.0)	12(63.2)	30(21.6)		
Once per two days	32(26.6)	-	24		

Traditional milk processing practice

According to the present study, almost all dairy cattle owners (99.3%) process milk traditionally by hand (Table 6). The present result is in agreement with the findings of Zelalem (1999), Lemma (2004) and Alganesh (2002) who reported that almost all the respondents in the central highlands, east Shewa zone and east Wollega zone, respectively process milk into butter and cheese. The source of milk for processing was significantly associated with the production system ($p<0.01$). In rural areas of Sebeta Hawas, the majority of dairy cattle producers use milk from local cattle breeds for processing (71.4%) and only a few of them use milk of crossbreed (10.9%) and from both cross and local cattle breeds (17.6%). Whereas the urban dairy cattle owners (66.7%) in the district process milk of both local and cross breeds. In the study area, churning by hand was the only method used for processing milk into varieties of products.

Table 6. Milk processing practice in the study area

	Production systems		Total	Test	
	Rural	Urban		X^2	p-
Do you process milk?				0.159	0.690
Yes	119(99.2)	19(100.0)	138(99.3)		
No	1(0.8)	-	1(0.7)		
If yes, do you process milk from?				15.472	0.000
Crossbreed	13(10.9)	-	13(9.9)		
Local breed	85(71.4)	11(57.8)	96(69.9)		
Both	21(17.6)	8(42.1)	29(22.1)		
Why do you need to process milk?				0.323	0.570
Shortage of raw milk market	70(50.7)	1(5.3)	8(8.5)		
To gain cheese and butter	68(49.2)	18(94.7)	86(91.5)		
What method do you use for milk processing?					
Churning by hand	119(100.0)	19(100.0)	138(100.0)		

Dairy product marketing

During the survey period, dairy farmers in the study area practiced an informal dairy products marketing system. Milk, cheese, and butter were the major dairy products sold to consumers, retailers, and traders in the study area. In the rural areas, the majority (60.5%) of the respondents indicated that there is no nearby market for milk selling. In contrast to rural areas, the majority (68.4%) of urban dairy producers have nearby markets for selling their milk (Table 7). The target markets for urban milk producers are mostly urban cafeterias and individual consumers. Due to the shortage of raw milk market, about ¾ of the respondents in rural milk producers preferred to sell processed milk. In conformity to the present result, Zewdie (2010) reported that butter was the main product sold (56%) followed by both butter and Ayib (42.4%) in the central highlands of Ethiopia. According to the same author, 92.9 % of urban milk producers preferred to sell raw milk due to the high demand for raw milk. During FGD, milk and butter prices fluctuate in the dry and wet seasons, in holidays and festivals, and in non-fasting periods.

Table 7. Dairy product marketing system in the study areas

	Production systems		Total	Test	
	Rural	Urban		X^2	p-value
Do you have a nearby market for milk?				5.578*	0.018
Yes	47(39.5)	13(68.4)	60(43.5)		
No	73(60.5)	6(31.6)	78(56.5)	4.655*	0.031
If yes, who is your target market?					
Individual consumer	17(36.2)	8(61.5)	21(36.2)		
Urban /Cafeterias	32(71.1)	5(38.5)	37(63.8)	34.674**	0.000
Prefer to sale					
Raw milk	22(19.0)	13(92.9)	35(26.9)		
Processed milk (butter and ayib)	89(74.7)	1(7.1)	90(69.2)		
Do not sell	9(7.5)	-	5(3.8)	64.00	0.000
Why?					
because of the lack of raw milk market	58(69.1)	-	38(59.4)		
due to the high price of processed milk	37(30.9)	-	17(26.6)		
high demand for raw milk	25(20.8)	9(100.0)	9(14.1)		

The income gained from the sale of milk products is used to purchase farm inputs like feed, fertilizer and improved crop varieties, food and non-food items like education materials for their children as well as house construction and for expansion of their farm. This finding was in line with the findings of Asaminew (2007) in the Mecha and Bahir Dar Zuria district and Kassa and Dekamo (2016) in the Bona Zuria district of Sidama Zone, Southern Ethiopia.

Dairy marketing constraints in the study areas

Dairy marketing constraints in the study area were shown in Table 8. Dairy marketing constraints in the study area mainly occur during fasting time. About 70 % and 78.6% of the rural and urban respondents reported that there was less demand for milk and milk products during fasting time while the remaining respondents reported that there was a problem of milk product marketing throughout the year. The study revealed that dairy products are marketed informally via different channels and are mainly hampered by many constraints. Low amount of milk produced, low price of milk, distance to marketplaces and lack of market information were the major constraints of milk marketing in the study areas. The present result is in agreement with the findings of Amanuel *et al*., (2018) who reported a low amount of milk produced, distance to the market and high cost of transport in the Gimbi district of west Wollega Zone.

Table 8. Problems associated with dairy product marketing

	Production systems		Total	Test	
	Rural	Urban		X^2	p-
Is there any period that you have the problem of marketing your milk and				19.454	0.000
Yes	30(25.0)	14(73.68	44(31.6		
No	90(75.0)	5(26.32)	95(68.3		
If yes, which month				0.354	0.552
Fasting month	21(70.0)	11(78.6)	32(72.7		
In all months of the year	9(30.0)	3(21.4)	12(27.3		

Constraints of dairy production in terms of feed

Unavailability (49.6%) and high cost of feed (43.9%) were the major feed-related problems in the study areas (Table 9). The high cost of feed (73.7%) was majorly an issue in urban areas compared to rural areas as urban dairy farmers mostly depend on purchased feed. There is a need to develop improved forage and improve the productivity of grazing land in order to overcome the scarcity of feed in the rural areas. Improved forage development and productivity of rural grazing land could also contribute to reducing the high cost of feed in urban dairy production systems as the rural dairy farmers sell their surplus production to urban areas. The present result is in conformity with the findings of Debir (2016) and Tolera et al., (2012) who reported feed shortage as the major constraint of livestock production in Sidama Zone and Burji woreda of SNNPR, Ethiopia.

Table 9. Feed and feeding constraints of dairy production in the study areas

	Production systems		Total	Test	
	Rural	Urban		X^2	P-value
What are your major problems with dairy cattle feed and feeding?				8.290	0.082
Availability	64(53.3)	5(26.3)	69(49.6)		
Cost	47(39.2)	14(73.7)	61(43.9)		
Quality	2(1.7)	-	2(1.4)		
Technical knowledge about fodder production, handling and feeding	6(5.0)	-	6(4.3)		
Others	1(0.8)	-	1(0.7)		

Cattle disease

Almost all the respondents in both the production systems reported Anthrax, Bloating *'Bokoksa',* and Blackleg *'Arebajele*' diseases as the major cattle diseases in the study areas (Table 10). The majority of the respondents in the study areas reported the presence of veterinary centers/services and vaccination schedules. These services were provided by the government and private sectors.

Table 10. Cattle diseases

	Production systems		Total	Test	
	Rural	Urban		X^2	p-value
Major dairy cattle disease					
Anthrax, 'Bokoksa', 'Arebajele'	120(100.0)	19(100.0)	139(100.0)		
Is there an animal health center?				4.364*	0.037
Yes	97(80.8)	19(100.0)	116(83.5)		
No	23(19.2)	-	23(16.5)		
Do you have vaccination accessibility?				0.037NS	0.847
Yes	97(80.8)	15(78.9)	112(80.6)		
No	23(19.2)	4(21.1)	27(19.4)		

Constraint of Artificial insemination

As indicated in Table 11, the lack of AI technicians was the main problem both in urban and rural areas followed by cow infertility and size. About 13.3% of the rural dairy farmers had no access to artificial insemination (AI) services which could affect the genetic improvement of our local animals in rural areas. In addition to this, about 9.35% of the respondents in the study areas had no awareness about the importance and services of AI which again has negative connotations on genetic improvement. From these results, it was suggested that access to AI services and awareness creation on the importance of AI need to be emphasized in order to improve the genetic and milk production potential of our indigenous animals. The result shows that there was no significant association between the constraints of artificial insemination and production systems ($p>0.05$).

Table 11. Artificial Insemination related constraints in the study areas

	Production systems		Total	Test	
	Rural N (%)	Urban N (%)	N (%)	X^2	p-value
What are the problems related to AI?				5.739ns	0.219
Lack of AI technician	45(37.5)	11(57.90)	56(40.30)		
Infertility of cow	30(25.0)	5(26.32)	35(25.18)		
Unavailability of AI service	16(13.3)	-	16(11.51)		
Lack of awareness	10(8.3)	3(15.78)	13(9.35)		
Small size of cattle	19(15.9)	-	19(13.66)		

Conclusions and Recommendations

Dairy production in the study district was not market-oriented. The pasture was the major feed source of dairy animals in the district

followed by crop residues. The majority of the dairy farmers use free grazing while only a few practice stall feeding in the district. Almost all the dairy producers process milk traditionally and hand churning was the only method used for processing milk into dairy products. Informal marketing was the sole means of dairy product marketing. Feed shortage, animal diseases, poor accessibility of AI and poor dairy marketing systems were the major milk production constraints in the study district.

Based on the above conclusions, the following recommendations are forwarded:

- There is a need to develop improved forage in order to overcome the scarcity of feed in rural areas.
- Milk processing technologies be introduced in these areas in order to improve the efficiency of milk processing (to improve product yield, quality and processing time)
- Milk producers in the areas be linked to a formal milk marketing system
- Access to veterinary services and vaccination be strengthened to control disease problems in the areas.
- Access to AI services and awareness creation on the importance of AI need to be emphasized in order to improve the milk production of the study areas.
- In nutshell, the extension systems be improved in order to develop dairy production in the study areas

Conflict of interests

The authors have declared no conflict of interest.

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RESEARCH PAPER

Phytochemical Characterization and Invitro Evaluation of Antibacterial and Antioxidant Activities of *Dodonaea angustifolia* Leaves in Ambo District, Ethiopia

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Abstract

Medicinal plants contain a wide range of secondary metabolites that can be used to treat infectious diseases. Such natural sources can be a well-intentioned starting point in the search for new drugs since they are rich in phytochemicals that may possess antimicrobial and antioxidant activity. Thus, the objectives of this study were to characterize phytochemicals and to evaluate the antimicrobial and antioxidant activities of leaf extracts of Dodonaea angustifolia in a laboratory. The plant material was collected, dried, and powdered, then subjected to successively extraction with n-hexane, chloroform, and methanol using the maceration technique meanwhile it was concentrated by rotary vapor. The crude extracts were evaluated for their antibacterial activities against standard strains of Staphylococcus aureus (S. aureus), Streptococcus pyogenes (S. pyogenes), Escherichia coli (E. coli), and Klebsiella pneumonia (K. pneumonia). All extracts were assessed with different concentrations (200mg/ml,100mg/ml,50mg/ml,25mg/ml). The chloroform extract has shown superior activities against all the strains at all concentrations. The extracts were also screened for potential antioxidant activity based on the method of competitive reaction of radicals with the antioxidants. It was evaluated using 2,2-diphenyl-1-picrylhydrazyl radical (DPPH) and the methanol extract of the leaves exhibited the highest antioxidant activity in DPPH. Based on their TLC profile, phytochemical screening, and antibacterial test of the chloroform extract was subjected to fractionation using column chromatography over silica gel. It was eluted with n-hexane containing increasing amounts of ethyl acetate and has resulted in compounds denoted as DA1, DA2, DA3, and DA4. Among these, the pure compound DA3 was characterized by using the spectroscopic technique (1H-NMR, 13C-NMR, and DEPT-135 and FTIR), and the structure was proposed as β–Stigmasteryl (9Z, 12Z) - pentadeca-9,12-dienoate. The most dominant compounds obtained from chloroform crude extracts of gas chromatography-mass spectroscopy analysis were Caryophyllene, β-Phellandrene, and α-Pinenenoic acid. The findings from the phytochemical screening tests of the plant leaves indicate that these leaves are abundant in secondary metabolites. This abundance correlates with enhanced antioxidant activity, which in turn contributes to improved antibacterial activity.

Keywords: Antibacterial, Antioxidant, Phytochemical, Medicinal plants, Dodonaea angustifolia

Introduction

Medicinal plants are regarded as a source of diverse bioactive compounds with possible biological functions. According to the World Health Organization, traditional medicine is the totality of knowledge, skills, and practices based on theories, beliefs, and experiences unique to various cultures. Whether or not these practices can be rationalized, they are utilized in the maintenance of health as well as in the prevention, diagnosis, improvement, or treatment of physical and social imbalances. Traditional medicine relies heavily on real-

world experience and observation, which have been passed down from generation to generation. This body of knowledge is characterized by its cultural specificity and diverse applications, reflecting the unique historical and social contexts from which it arises. While the efficacy of traditional medicine may vary, its significance in the health practices of many communities cannot be understated. In summary, traditional medicine encompasses a wide range of practices that are deeply rooted in cultural beliefs and experiences, playing a crucial role in healthcare for numerous populations around the world (WHO, 2013). Traditional medicine, which is mostly based on plants, has frequently been supported by phytochemical analyses, pharmacological research, and clinical trials, sparking additional research on medicinal plants around the globe. More research is needed to ensure the effectiveness and safety of traditional medicine and methods employed by traditional medicine practitioners and customers. However, occasionally, utilizing conventional medications can be harmful (Beshah *et al*., 2020).

Understanding the specific chemical components of a medicinal plant is essential for refining extraction processes, grasping pharmacological activity, and identifying potential toxicity and drug interactions. For example, Aloe vera is one of the most widely used medicinal plants worldwide. It is highly valued for its healing, anti-inflammatory, and soothing properties, particularly in treating skin conditions such as burns, wounds, and irritation. Beyond skincare, Aloe vera is also used in traditional medicine for its digestive and immune-boosting benefits. Its widespread use spans many cultures, making it one of the most recognized medicinal plants globally (Surjushe, *et al*.,2008). In addition, Dodonaea plants could deliver several medical advantages; native people crosswise the plant's area have used them. It is a popular traditional drug that can be ingested or administered topically to treat a variety of ailments. Recent investigations on phytochemicals have confirmed a positive link between several active phytoconstituent groups and ethnopharmacological use (Anode *et al*., 2018). The leaves of Dodonaea angustifolia are recognized for their rich content of flavonoids and their derivatives, which serve as the primary bioactive compounds. Therefore, the study aimed to extract phytochemicals with antifungal and antibacterial properties from the stem bark of Monsonia angustifolia and the leaves of Dodonaea angustifolia (Beshah *et al*., 2020).

Infectious diseases caused by bacteria, fungi, viruses, and parasites continue to pose a threatening challenge to public health. The indiscriminate and incorrect use of current antimicrobial medications is blamed for the rising problem of bacteria developing resistance to antimicrobial treatments. Drug resistance presents an ever-increasing global health threat that involves all major microbial pathogens and antimicrobial drugs. These are difficult to treat and are responsible for a variety of infectious diseases (Salam *et.al*.,2023). The formation of reactive oxidative species (ROS) can lead to oxidative stress and the destruction of unsaturated lipids, DNA, proteins, and other essential molecules. ROS plays an important role in aging and the development of degenerative and chronic diseases such as atherosclerosis and cancer. The harmful and pathological effects of free radicals can be blocked by antioxidants. Antioxidants inhibit oxidation, reduce the concentration of free radicals in the body, and chelate metal ions to prevent lipid peroxidation (Putri *et al*., 2018). Therefore antioxidants are important in maintaining good health and there is a growing interest in the investigation of the antioxidant activity of secondary metabolites from medicinal plants for compounds with higher potency and lower toxicities than the synthetic ones currently available (Bhatti *et al*., 2015).

Understanding the fundamental chemical procedures involved in the screening of bioactive small-molecule compounds presents a substantial challenge for researchers working on medication development. Synthetic medication's declining efficacy and increased toxicity are exacerbating the problem.

Researchers are now looking to herbal medicines for therapy because it is now recognized that they are crucial in the development of effective treatments (Anand *et al*., 2019). The leaf content of Dodonaea angustifolia is known for the presence of flavonoids and their derivatives, which are the major bioactive components (Beshah *et al*., 2020).

Though traditional medicinal plants in particular Dodonaea angustifolia have long been used across cultures, there is a lack of comprehensive scientific validation regarding their bioactive compounds, efficacy, and safety. Furthermore, the rising global threat of antimicrobial resistance and oxidative stress-related diseases underscores the need for more targeted studies on the phytochemical properties of these plants. Limited research has thoroughly investigated the specific mechanisms by which these plants' bioactive compounds function as antimicrobial agents and antioxidants, especially in comparison to synthetic drugs. Therefore, this research targeted to fill the gap by identifying and characterizing the bioactive compounds of Dodonaea angustifolia for its antibacterial and antioxidant activities. Hence, the expected outcome is to provide scientific evidence supporting its traditional uses, highlighting its potential as an alternative treatment for infectious diseases and oxidative stress-related conditions. Additionally, the study aims to contribute to drug development efforts by exploring the therapeutic potential of this plant in addressing drug resistance and toxicity concerns associated with conventional medications.

Materials and methods

Chemicals and apparatus

Solvents and chemicals used for this study were methanol (98%, Merck), n-hexane (99%, Sigma), Chloroform (95%, Sigma), Silica gel 60-120 mesh, DPPH, DMSO, and ethyl acetate. The other chemicals used for phytochemical screening were 1% ammonia, 5% Ferric chloride, sodium hydroxide, potassium hydroxide, Hydrochloric acid, sulfuric acid, Wagner's reagent (KI and I2), Standard drugs discs such as ciprofloxacin(10µg) disk and L-ascorbic acid(10µg) for comparison of biological activities were purchased from the commercial market as required with standard purity.

Items used for extraction and isolation of compounds include Rota vapor (Labo Rota 4000, Heidolph Instrument), Orbital mini-shaker, Incubator TLC plates, Erlenmeyer flask, Vacuum pumps for filtration (Germany), Watchman filter papers-No1, Funnels, Beakers, Petri dish of medium size, column chromatography larger and smaller size, Test tube, Water bath, Refrigerators, Stand, Round bottom flask, Spatula, Stirrer, Sterile Cotton /Gauze, Analytical balance, Capillary tube, Oven, Ruler, Pencil, Pen, Reagent bottle, Pasture pipette, Dropper, and others.

Plant collection and identification

The plant material, D. angustofolia local name 'Itacha' (Afan Oromo), and 'Kitkita' (Amharic) was collected from their natural habitat, Ambo Town, Ambo referral hospital in January 2023. The plant was identified by the Botanist Mr. Wayessa Fikadu, and the plant was deposited at the Biology Department, College of Natural Computational Science, Ambo University, Ethiopia.

Extraction of compounds

The plant material samples of D. angustifolia were surface rinsed with tap water then with distilled water to remove surface dust and other solid contaminants and then dried under shade. The shade-dried leaves were ground to powder using an electric blender. The powdered plant material was stored in a plastic bag until used for extraction.

The powdered leaves (500 g) were macerated for 48hr through occasional shaking at 230 rpm using an orbital mini-shaker with n-hexane at room temperature. The extract was filtered by Whatman no.1 filter paper mediated by vacuum pumps and concentrated by a rotary evaporator at a reduced temperature (40 °C). The marc left was further extracted using chloroform and

then concentrated by the same procedure. Similarly, the marc from chloroform extraction was further extracted by the same procedure using methanol, filtered, and concentrated to get methanol extract. TLC analyzed the crude extracts (n-hexane, chloroform, and methanol) (Putri *et al*., 2018).

Phytochemical screening

Preliminary phytochemical screening tests on crude extracts and different fractions of the plant were carried out. Qualitative screening of various extracts of the plant was performed for the identification of various classes of chemical constituents in the plant based on the standard procedures with slight modifications as required (Kumar *et al.*, 2014).

Test for alkaloids

Wagner's reagent: A few drops of Wagner's reagent (purchased) were added to each extract of 1mL and observed for the formation of a reddish-brown precipitate which may indicate the presence of alkaloids (Guyasa *et al*., 2018)

Test for anthraquinones

One milliliter of plant extracts from each solvent was added in a dry test tube and 10 ml of chloroform was added and shaken for 5 min. The extract solution was filtered, and the filtrate was shaken with an equal volume of 10%v/v ammonia solution. A pink-violet or red color in the ammoniacal layer indicates the presence of anthraquinones (Anode *et al*., 2018).

Test for glycosides

One milliliter of plant extracts from each solvent was dissolved in 5 ml of glacial acetic acid containing 1 drop of ferric chloride solution. This was then under-layered with 1 ml of concentrated sulfuric acid. A brown ring at the interface indicated the presence of a deoxysugar characteristic of glycosides (Anode *et al*., 2018)

Test for flavonoids

Alkaline reagent Test: The extracted sample is treated with a few drops of sodium hydroxide solution. The formation of an intense yellow color, which becomes colorless with the addition of dilute acid, indicates the presence of flavonoids (Kumar *et al*., 2014).

Test for phenolic

Ferric chloride test: 1 ml of the extract was treated with a few ml of 5% neutral ferric chloride. A dark blue or bluish-color product showed the presence of tannins or phenolic compounds (Beshah *et al*., 2020).

Test for saponins

About 1 ml of the extract was diluted separately with 20 ml of distilled water and shaken in a graduated cylinder for 15 minutes. A 1 cm layer of foam indicated the presence of saponin (Geetha, 2014).

Test for steroids

Two milliliters of acetic anhydride were added to 2 ml of plant extract of each solvent sample along with 2 ml sulfuric acid. Color change from violet to blue or green indicates the presence of steroids (Kumar *et al*., 2014).

Test for tannins

One milliliter of plant extracts from each solvent was added to 20 ml of water in a flask and a few drops of 0.1% ferric chloride were added and observed brownish-green or blue-black coloration (Beshah *et al*., 2020).

Test for terpenoid

Five milliliters of chloroform and 3 ml of concentrated sulfuric acid were added to 1 ml of plant extract from each solvent in the test tube. The appearance of the monolayer of reddish brown color indicates the presence of triterpenoids (Beshah et al., 2020).

Isolation of compounds

As described earlier, the crude extracts were analyzed by TLC to choose the best mobile phase for column chromatography. Then, 10 g of Chloroform crude was adsorbed on an equal amount of silica gel (mesh size 60-120) and subjected to silica gel chromatography (150 g silica gel) using n-hexane for column packing and elution. The experiment was carried out with an increasing gradient of ethyl acetate in n-hexane as eluent (Table 1). Different fractions were collected and concentrated in a fume hood. The composition of the fractions collected was monitored by TLC and characteristics color. The spots were detected by their UV absorption and fluorescence under 254 and 365 nm respectively, as well as by spraying 1% vanillin in sulfuric acid and iodine chamber for UV inactive constituents. Fractions that showed the same Rf value and the same characteristic color on TLC were combined and further purified. The column was then eluted with the increasing polarity of the solvent system. Purification of compounds was done using column chromatography over silica gel (60-120 mesh). The NMR spectrum was measured using Bruker Avance 400 spectrometer operating at 400 MHz, using $CDCl_3$ as a solvent and TMS as an internal standard for recording chemical shifts in ppm respectively..

Table 1. Chromatographic fractionations of the chloroform leave crude extract.

Solvent system	Ratio of solvent	Fractions collected	Volume (mL) in each fraction
n-hexane	100%	F1-F14	25
n-hexane/EtOAc	90:10	F15-F34	25
n-hexane/EtOAc	80:20	F35-F44	”
n-hexane/EtOAc	70:30	F45-F51	”
n-hexane/EtOAc	60:40	F52–F64	,,
n-hexane/EtOAc	50:50	F65 –F73	“
n-hexane/EtOAc	40:60	F74 –F86	,,
n-hexane/EtOAc	30:70	F 87-F98	,,
n-hexane/EtOAc	20:80	F98 –F110	,,
n-hexane/EtOAc	10:90	F111 –F118	,,
n-hexane/EtOAc	0:100	F119 –F125	,,

Purification of compounds from fractions

TLC analysis of the fractions was done and some of the fractions that have the same TLC profiles were combined. Further purification was done using repeated column chromatography and Preparative Thin-Layer Chromatography (PTLC) to get a single pure compound from the collected fractions.

Characterization of the isolated compound

Column chromatographic separation of the chloroform extracts of the leaf of D. angustofolia has resulted in the isolation of four compounds which are coded as DA1, DA2, DA3, and DA4. The purity of the isolated compounds was monitored by TLC analysis. The structural elucidation of the compound DA1 and DA3 was performed by NMR (1HNMR, 13CNMR, and DEPT-135) at Addis Ababa University, IR spectroscopic at Addis Ababa Science and Technology University and comparison with reported literature data.

Antibacterial activity

Preparation of test solutions

Test solutions were prepared by dissolving 200 mg of each of the crude extracts in 1 mL of dimethyl sulfoxide. The standard microorganisms used for antibacterial activities of the crude extracts were two gram-positive bacteria (Staphylococcus aureus (ATCC25923), and Streptococcus pyogenes (ATCC2228) and two gram-negative bacteria (Escherichia coli (ATCC25922) and Klebsiella

pneumoniae (ATCC700603). These were gained from the Department of Biology, Microbiology Laboratory, Ambo University. Chloramphenicol disk was used as a positive control for the antibacterial susceptibility test whereas a solvent dimethyl sulfoxide served as a negative control test.

Preparation of Inoculum

The microbial stock cultures were maintained at 4 °C on the slopes of Muller Hinton Agar, MHA. Active cultures for experiments were prepared by transferring a loopful of cells from the stock culture to the test tubes containing Muller Hinton broth and incubated without agitation for 24 h at 37 °C. To 5 mL of Muller Hinton Broth, 100µL of culture was inoculated.

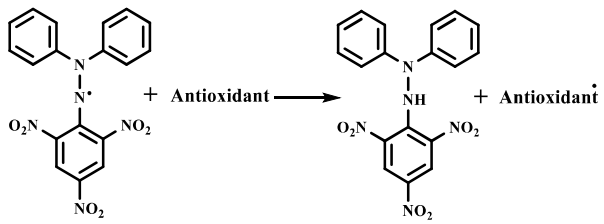
Agar well diffusion method

Agar Well diffusion assay with MHA medium was used to analyze the antimicrobial activities of n-hexane, Chloroform and Methanol crude extracts of D. angustifolia leaves. Muller Hinton Agar was melted and then cooled and finally poured into sterile Petri dishes to get a solid plate. Then, the fresh culture of bacteria was used for inoculum preparation. Using a sterile cotton swab, bacterial cultures were swabbed on the surface of sterile agar plates. The dried extracts of test solution (200mg/mL, 100mg/mL, 50mg/mL, and 25mg/mL) in dimethyl sulfoxide were prepared, and Sterilized 5mm wells were inoculated with 50µL of crude extracts of each concentration and placed on the surface of agar plates inoculated with a microbial culture. The diameter of the inhibition zones was measured in millimeters. Triplicate was kept in each case and average values were taken.

Antioxidant Investigation Test

Evaluation of the DPPH radical scavenging assay

Antioxidants play an important role as health protection factors. Scientific evidence suggests that antioxidants reduce the risk of chronic diseases including cancer and heart disease the DPPH assay was used to assess the free radical scavenging activity of crude and isolated pure compounds. With this method the radical scavenging power of an antioxidant compound was measured with the principle of a decrease in absorbance due to the donation of hydrogen from the sample to DPPH radical to produce stable DPPH-H and the color change from purple to yellow was observed as shown in (Figure 1) below (Kalbessa *et al*., 2019).



Purple color Yellow (λ_{max}=517nm)

Figure 1.The structure of the DPPH radical and the scavenged radical.

The radical scavenging properties of the n-hexane, chloroform, and methanol extracts of D. angustifolia leaves were determined using 2, 2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity as described by (Brand-Williams *et al*., 1995). Sample stock solutions (200 mg/mL) were diluted to final concentrations of 100, 50, 25, 12.5, and 6.25 mg/mL in ethanol. 3mL samples were added to 1 mL of 50mg freshly prepared in 250mL ethanol DPPH. The mixture was shaken and left to stand at room temperature in the dark. After 30 min, absorbance was measured at 517nm against a blank containing ethanol using the UV-Vis spectrophotometers. Ascorbic acid was used as a positive control (as a standard) with a similar concentration to the plant test sample.

$$\% \text{ free radical scavenging activity} = \frac{A-B}{A} \text{ X } 100$$

Where: - A = is the absorbance of pure DPPH in oxidized form

B = is the absorbance of a sample taken after 30 minutes of reaction with DPPH.

Results and Discussion

The yield of Dodonaea angustifolia leaves extract.

Successive extraction of 0.5 Kg leaves powder of Dodonaea angustifolia gave the highest yield with methanol (22 g) followed by chloroform (15 g) and n-hexane (6.5 g) as shown in Table 3

$$\% \text{ Yield} = \frac{\text{Mass of extract}}{\text{Mass of sample}} * 100 \ldots\ldots\ldots eq1$$

Table 2. Percent yield of different solvent extracts of D. Angustifolia leave.

Solvent system/ Compounds	Mass of extract/Compounds (g)	% Yield
n-Hexane	6.5	1.3
Chloroform	15	3
Methanol	22	4.4

As Table 2 states, among the three solvents used for extraction, the methanol extract gives the highest yield in the crude extract of the leaf plant. This observation is common to the extraction of most bioactive compounds and relates to the ability of methanol to dissolve polar compounds and also some non-polar groups. Besides water, methanol with a polarity index of 5.1 was chosen as the extraction solvent for the extraction of bioactive compounds (Abdisa and Kenea, 2020)

Phytochemical analysis of crude extracts

Table 3. Phytochemical analyses of crude extracts

S. N	Phytochemicals	Type of tests	Color	Solvent system		
				hexane	chloroform	Methanol
1	Alkaloids	Wagner's	reddish brown	+	+	-
2	Anthraquinone	Chloroform	A pink violet	-	+	+
3	Glycosides	Ferric chloride test	brown ring	+	-	-
4	Flavonoids	Alkaline test	intense yellow	+	+	-
5	Phenolics	Ferric chloride test	bluish black	-	+	+
6	Tannins	Ferric chloride test	brownish green	-	+	+
7	Terpenoids	Sulfuric acid	reddish brown	+	+	+
8	Saponin	Water	White	-	+	+
9	Steroids	Sulfuric acid	blue or green	+	+	-

Key: (+) - Phytochemicals were detected, (-) - Phytochemicals were not detected.

Table 3 shows the phytochemical screening test performed on crude leaf extracts of n-hexane, chloroform, and methanol extracts of the D. Angustifolia plant. Most of the secondary metabolites were found in chloroform extract as compared to the other two extracts according to the phytochemical screening result. Glycosides were absent in both chloroform and methanol extracts, but flavonoids alkaloids, and steroids were not only found in methanol extract, again phenols and tannins are found in chloroform and methanol except in n-hexane extract whereas terpenoids were found in n-hexane, chloroform, and methanol extracts possess a variety of biological activities. Flavonoids have been reported to have both antibacterial and antifungal activities. The flavonoids and terpenoids properties in plants have been reported to exert multiple biological effects including antioxidant, free radical scavenging abilities, and reduction in cell damage. Alkaloids present in both stems and leaves play a metabolic role in controlling development in living systems (Geetha *et al.*, 2016).

GC-MS analysis of chloroform crude extract

The results of the GC-MS analysis of chloroform crude extract are tabulated in Table 4, the medicinal roles of each compound in GC-MS are indicated in Table 4 and Figure 2 represents the GC-MS profile of the chloroform crude extract of D. *angustifolia*.

Table 4. The gas chromatography-mass spectrometry profile of crude extract of *D. angustifolia* showing retention time, name of the compound, molecular formula, and peak area

S/No	RT	Name of compounds	Formula	Area
1	4.938	α-Pinene	$C_{10}H_{16}$	1.63E+09
2	5.141	Camphene	$C_{10}H_{16}$	34977900
3	5.487	β-Pinene	$C_{10}H_{16}$	1.78E+08
4	5.589	β-Myrcene	$C_{10}H_{16}$	58487358
5	5.8	α-Phellandrene	$C_{10}H_{16}$	26685672
6	5.876	3-Carene	$C_{10}H_{16}$	46397952
7	6.036	p-Cymene	$C_{10}H_{14}$	87956996
8	6.104	β-Phellandrene	$C_{10}H_{16}$	6.46E+08
9	6.433	γ-Terpinene	$C_{10}H_{16}$	59839074
10	6.594	o-Cymene	$C_{10}H_{14}$	21163491
11	6.864	Linalool	$C_{10}H_{18}O$	81287266
12	7.151	Benzene,1,2,3,5- tetramethyl	$C_{10}H_{14}$	47775103
13	7.675	Isoborneol	$C_{10}H_{18}O$	56734208
14	7.776	Terpinen-4-ol	$C_{10}H_{18}O$	55929327
15	7.827	2-Hexadecanol	$C_{16}H_{34}O$	67012396
16	7.903	α-Terpineol	$C_{10}H_{18}O$	93152935
17	8.435	2-Butanone, 4-phenyl-	$C_{10}H_{12}O$	46922242
18	9.744	α-Copaene	$C_{15}H_{24}$	2.60E+08
19	10.191	Caryophyllene	$C_{15}H_{24}$	4.22E+08
20	10.664	γ-Muurolene	$C_{15}H_{24}$	2.52E+08
21	10.867	di-t-butyl-phenol	$C_{14}H_{22}O$	2.48E+08
22	11.044	γ-Cadinene	$C_{15}H_{24}$	1E+08
23	11.095	δ-Cadinene	$C_{15}H_{24}$	1.67E+08
24	11.619	1-Hexadecanol	$C_{16}H_{34}O$	1.82E+08
25	11.821	Isoaromadendrene epoxide	$C_{15}H_{24}O$	2.28E+08
26	14.009	1-Octadecanol	$C_{18}H_{38}O$	1.81E+08
27	14.752	Neophytadiene	$C_{20}H_{38}$	2.54E+09
28	15.52	Methyl 10,11- tetradecadienoate	$C_{15}H_{26}O_2$	7.94E+08
29	18.037	Hexadecanoic acid, ethyl ester	$C_{18}H_{36}O_2$	2.04E+08

The details presented in Table 4 show that there are twenty-nine very important molecules such as α-Pinene, Camphene, β-Pinene, β-Myrcene, α-Phellandrene, 3-Carene, p-Cymene, β-Phellandrene, γ-Terpinene, P-Cymene, Linalool, Benzene, 1,2,3,5- tetramethyl, Isoborneol, Terpinen-4-ol, 2-Hexadecanol, α-Terpineol, 2-Butanone, 4-phenyl-, α.-Copaene, Caryophyllene, γ-Muurolene, di-t-butyl-phenol, γ-Cadinene, δ-Cadinene, 1-Hexadecanol, Isoaromadendrene epoxide, γ-Muurolene, 1-Octadecanol, Neophytadiene, Methyl 10,11-tetradecadienoate and Hexadecanoic acid, ethyl ester which have medicinal values such as antioxidant and antimicrobial. These molecules indicate the medicinal roles of Dodonaea recognized by ethno-pharmacological uses.

The medicinal roles of some of the molecules such as α-Pinene, Camphene, α-Phellandrene, 3-Carene, γ-Terpinene, P-Cymene, Linalool, Terpinen-4-ol, α-Terpineol, α-Copaene, Caryophyllene, γ-Muurolene, γ-Cadinene,

Isoaromadendrene epoxide, Hexadecanoic acid, Neophytadiene.

Table 5. The medicinal roles of each molecule shown in the gas chromatography-mass spectrometry profile leaves of Dodonaea angustifolia chloroform crude extract

SN	Compound	Medicinal role	References
1	Camphene	Antibacterial, antifungal, anticancer, antioxidant, antiparasitic, antidiabetic, anti-inflammatory, and hypolipidemic activities.	(Hachlafi *et al.*, 2021)
2	3-Carene	anti-inflammatory, antimicrobial, and anxiolytic effect	(Woo *et al*., 2019)
3	α -Copaene	the cytotoxic, genotoxic/ antigenotoxic, and antioxidant/oxidant activity	(Türkez *et al*., 2014)
4	Caryophyllene,	anti-inflammatory, antiviral, and immunomodulatory properties	(Jha *et al.*, 2021)
5	Isoaromadendreneepoxide	general toxicity, anti-proliferative, antibacterial, and antioxidant properties	(Movahhedin *et al*., 2017)
6	Linalool	antimicrobial, anti-inflammatory, anticancer, antioxidant properties, and central nervous system	(Agrawal *et al*, 2018)
7	γ-Muurolene	antibacterial, antifungal, and antiviral activity	(Perigo *et al*., 2016)
8	Neophytadiene	Antibacterial, antifungal, antioxidant, anti-inflammatory, antidiuretic, antidiarrheal, lowering blood LDL-C level, insulin level booster, antiproliferative, and anti-cancer.	(Pratama *et al*., 2019)
9	P-Cymene	Antioxidant, anti-inflammatory, antiparasitic, antidiabetic, antiviral, antitumor, antibacterial, and antifungal activities, and act as an analgesic, ant nociceptive, immunomodulatory, vasorelaxant, and neuroprotective agent.	(Balahbib *et al*., 2021)
10	Terpinen-4-ol	anxiolytic analgesic, sedative, and anticonvulsant activity	(Nóbrega *et al*., 2014)
11	α-Phellandrene	analgesic, anti-inflammatory, bactericidal, veridical, fungicidal, antiparasitical, anti-malarial, anticancer, antioxidant, anticonvulsant, and antifungal activity	(Lima *et al*., 2012)
12	α-Terpineol	Possess anticonvulsant activity in animal experiments and is widely used in the perfumery, cosmetic, and soap industries. It is also used as a scenting agent in household products (e.g., disinfectant sprays)	(De Sousa *et al*., 2007)
13	γ-Cadinene	noticeable antimicrobial, and antioxidant activities and largely utilized in perfumes, make-up products, and sanitary products, in the food industry as food additives, in dentistry as natural remedies, and in agriculture as green pesticides	(Zeng *et al*., 2011)
14	γ-Terpinene	possess Diuretic, Antioxidant Activity, Ant-diabetic Anti-convulsant activity, Sedative Hypnotic Activity, Antimicrobial Activity, Anti-mutagenic, Anthelmintic activity	(Patel *et al*., 2011)

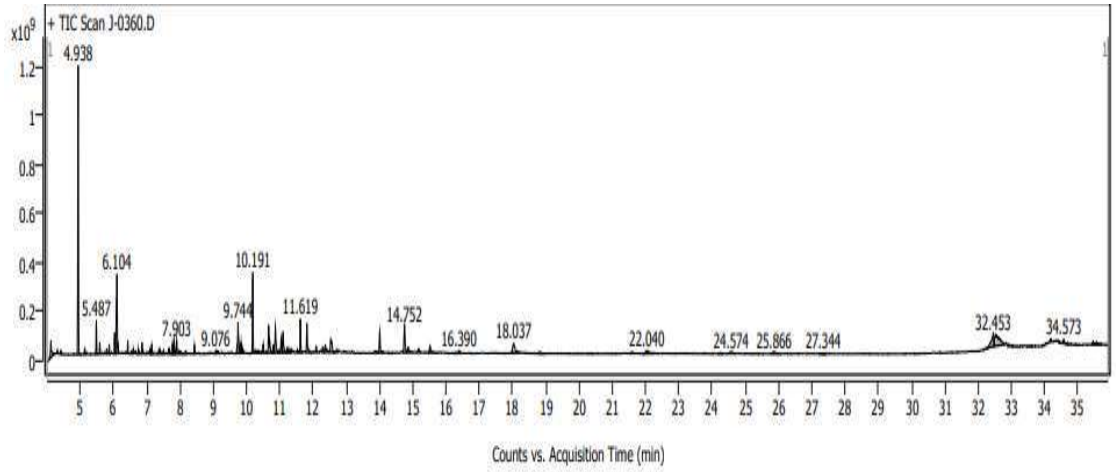


Figure 2: The gas chromatography-mass spectrometry graph of D. angustifolia.

Isolated Compounds

A total of 125 fractions each with 25 mL volume were collected. Among these fractions, based on the TLC profile, a fraction (F18 -34, 65mg) with an RF value of 0.72 labeled as DA -1 and (F 52 - 64,20 mg) with an RF value of 0.64 labeled as DA-2 solid yellow pure compounds were obtained as pure compound based on TLC profile. Again, some fractions (F 111-118) of the first elution were collected for further purification based on their TLC similarities (F 111-118) and combined, mixed with silica gel, and subjected into small columns. Then, elution was continued with n-hexane in ethyl acetate for further purification. Fraction (F 65 -69, 19mg) with RF value of 0.38, labeled as DA-3 Orange semi-solid pure compound obtained by elution with 9:1 ethyl acetate and n-hexane. Fraction (F70-73, 9mg) with an RF value of 0.8, labeled as a DA-4 greenish compound was obtained with 100% ethyl acetate. The level of separation was monitored by TLC analyses. At the same time, the detection of the spot was done using UV (254 and 366 nm).

Structural elucidation of isolated compounds

In the case of the good separation thin layer chromatography, the effect of phytochemical screening and antibacterial activities than the other two solvents, the chloroform fractions of the leaf part of Dodonea Angustifolia was subjected to repeated silica gel column chromatography which led to the isolation of four compounds coded as DA1 (65mg), DA2 (20 mg), DA3 (19mg), and DA4 (9mg), The purity of the isolated compounds was monitored by TLC analysis. Here is the description of the characterization of each compound. Fractions of (F52-64, 20 mg) with RF of hexane /EtOAc 7: 3 DA-2 (yellowish), and DA4 (greenish 100% ethyl acetate). Among these, currently, only two compounds (DA1 and DA3) were analyzed for structural determination. Structural elucidation of these compounds was performed by NMR (^{1}H NMR, ^{13}C NMR, and DEPT-135), FTIR, and GC-MS spectroscopic and comparison with reported literature data. However, the isolated compound DA1 has a good effect on FTIR and no good effects on NMR (1HNMR, ^{13}C NMR, and DEPT-135) spectroscopies.

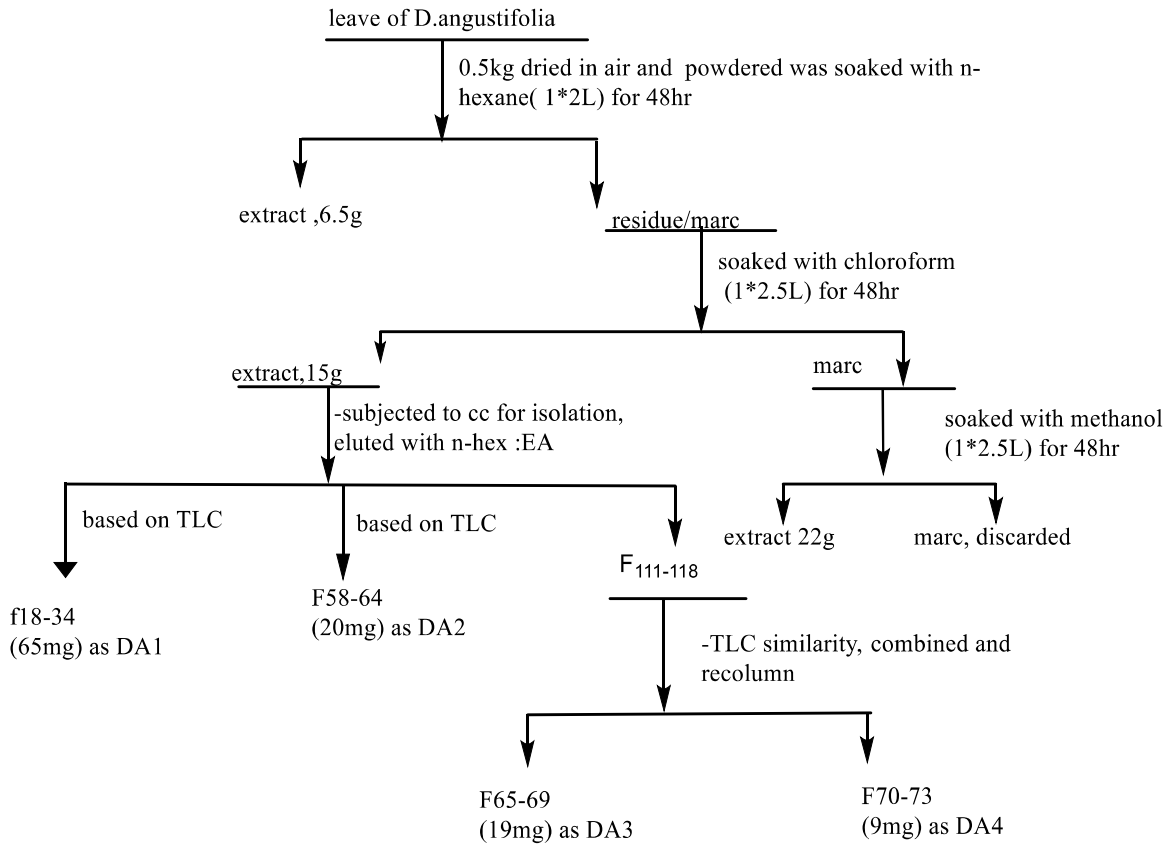


Figure 1: Flow chart for extraction leaves of *D. Angustifolia* and isolation pure compound

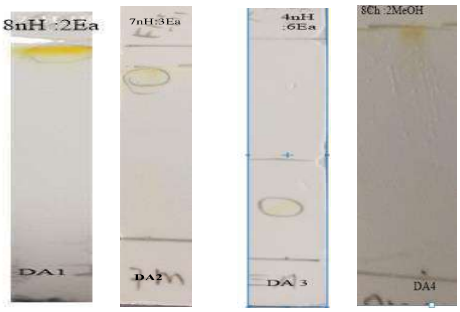


Figure 4: The TLC profiles of isolated compounds from a leave of D. angustifolia.

Characterization of compound DA3

DA3 was obtained as an Orange semi-solid from the CC of the chloroform fraction of the leaf extracts of D. Angustifolia.

FTIR characterization of DA3

The FTIR spectrum of compound DA3 in Table 6 displayed absorption bands indicating the presence of the carbonyl stretch C=O of aliphatic esters (1724 cm^{-1}), the methyl and methylene C-H stretching a sharp peak at 2919 cm^{-1} and 2830cm^{-1}, respectively and 11757 cm^{-1} shows the C–O single bond. The possible frequency ranges of these functional groups are listed in Table 6.

Table 6. Typical Infrared (IR) absorption frequencies of the compound DA3

Observed frequency (cm^{-1})	Possible Frequency Range (cm^{-1})	Function type
24	1730–1715	The carbonyl stretches C=O of aliphatic esters
2919, 2852	2850–2950	the methyl C–H stretching a sharp Peak
1157	1000 – 1300	for C–O single bond
721	675–1000	–CH vibration of an unsaturated part.

NMR characterization of DA3

The ^{1}H-NMR spectrum (Table 7) of compound DA3 showed the presence of resonances for three olefinic methine protons at δ_H 5.35 (^{1}H, dd, H-6), 5.15 (^{1}H, dd, H-22), and 5.02 (^{1}H,d, H-23); a carbonyl proton at δ_H 3.53 (m); and six methyl protons at δ_H 0.70 (s), 0.80 (t), 0.83 (d), 0.84 (d), 1.01 (s) and 1.02 (d).

The ^{13}C NMR spectrum gave 44 signals; containing 7 methyl (CH_3) groups, 18 methylene (CH_2), 15 methine (CH), seven olefinic, and four quaternary carbon atoms which are corroborated by DEPT-135 spectrum further indicating the steroidal nature of the compound. C-NMR spectral data (Table 7) indicated resonances for twenty-nine carbon atoms with the following functionalities: four olefinic carbons (δδ 122.2(C-6), 129.6(C-23), 138.5(C-22), 141.2(C-5)); a carbonyl carbon (δ179.4); seven methine carbons (δδ 31.9 (2 x), 40.5, 50.1, 51.2, 55.9, 56.8); two quaternary carbons (δδ 36.5, 42.19); nine methylene carbons (δδ 21.06, 24.4, 25.4, 28.9, 31.6, 31.9, 37.2, 39.7, 42.27); and six methyl carbons (δδ 12.04, 12.3, 18.97, 19.4, 21.09, 21.2).and for ester bonded unsaturation substituent is 130.6(C-13'), 130.4(C-10'),128.5(C-9'), 128.3(C-12'). These are characteristic resonances of stigmasterol compounds and ester bonded substituent.

The signals at 19.8 and 12.5 correspond to the angular carbon atom at C-15' and C-14' respectively and the peaks at (44.6and 36.9 ppm) and (141.2 and 178.9 ppm) were assignable to saturated and unsaturated quaternary carbon atoms, which are confirmed by the absence of corresponding signals from the DEPT-135 spectrum. The resonance at δ72.4 (C-3) is due to the C-3 β-hydroxyl group further suggesting the compound is a stigmasterol derivative (Haque *et al*., 2019).

From the DEPT-135, a peak at 12.5, 19.8, 21.6, 18.9, and 12.7 ppm is consistent with six methyl carbon atoms. Peaks at 37.7, 32.3, 42.64, 32.4, 20.9, 40.2, 25.2, 29.9, and 25.8 showed methylene carbon atoms. Furthermore, peaks at 72. 4, 32.3, 50.6, 57.3, 56.4, 40.9, 51.7, 31.9, 138.7, and 129.7 indicated the presence of sp^3 and sp^2 carbon atoms.

Therefore, based on spectroscopic data (Table 7) and compared with the reported literature (Haque *et al*., 2019),(Horník *et al*., 2013),(Feyera Fufa *et al*., 2018) the compound was proposed to be a stigma sterol derivative, β–Stigmasterol (9Z, 12Z) - pentadeca-9,12-dienoate.

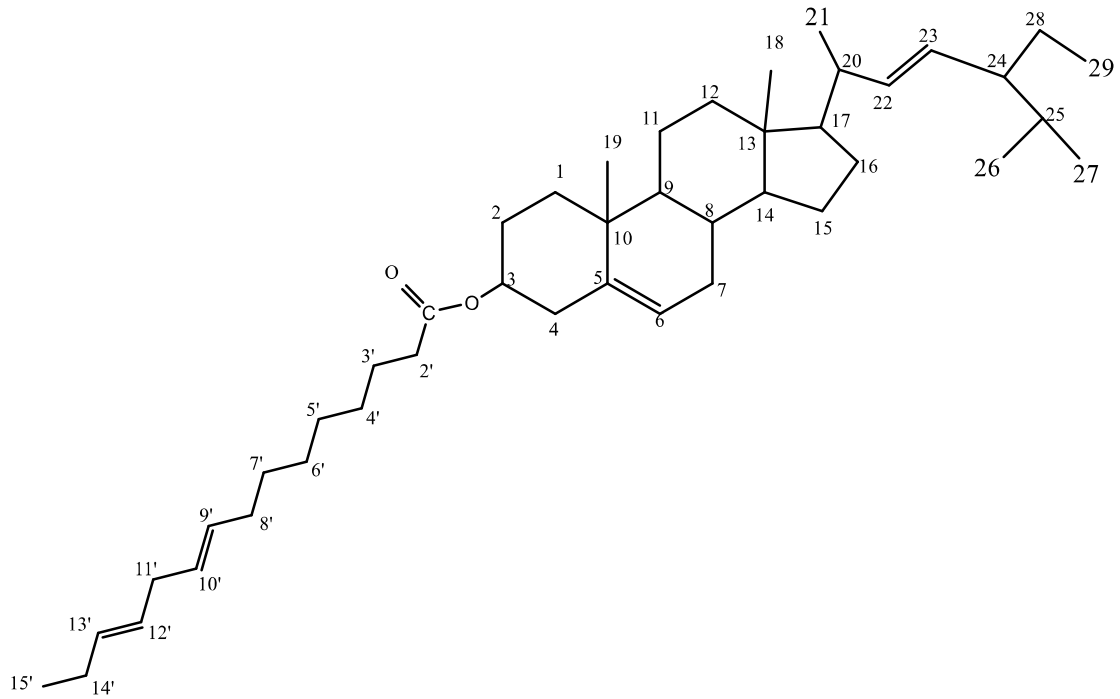
Evaluation of antibacterial activities of crude extract of D.Angustifolia.

Agar well diffusion methods

The antibacterial activities of the crude extract of D. Angustifolia against four bacterial species namely two- gram-positive bacteria Staphylococcus aurous (AT25923), and Streptococcus pyogenes (AT2228). And gram-negative bacteria Escherichia coli (AT25922) and Klebsiella pneumonia (AT700603) as shown in Table 9. All the solvent extracts showed antibacterial activity compared to DMSO (negative control) which had an inhibition zone of 5.0-8.0 mm (size of formed well). Gram-positive bacteria (Staphylococcus aureus (AT25923), and Streptococcus pyogenes (AT2228) showed higher susceptibility than gram-negative bacteria (Escherichia coli (AT25922), and Klebsiella pneumonia (AT700603)) to all extracts. n-hexane extract represented a lower inhibition zone than the two other extracts. The bacterial strains S. aureus and S. pyogenes were more susceptible to chloroform extract than methanol, and n-hexane of D. Angustifolia leaf extract. Whereas the bacterial strains E. coli was highly susceptible to methanol extract than n-hexane and chloroform extracts. However, all bacterial strains were highly susceptible to the reference chloramphenicol (10µg/well) antibiotic drug except K. pneumonia. The bacterial growth inhibition activity of chloramphenicol, n-hexane, chloroform, and methanol extracts was visible in Figure 6 and Table 8 using the agar well diffusion method.

Table 7. ^{1}H and ^{13}C NMR Chemical shifts values (δ) in ppm for compound DA3

Carbon atom	^{13}C-NMR Experimental	^{13}C-NMR Literature	^{1}H-NMR Experimental	^{1}H-NMR Literature	Nature of Carbon
C-1	37.7	37.2			CH_2
C-2	32.34	31.7			CH_2
C-3	72.3	71.8	3.53m,1H	3.51tdd,1H	CH
C-4	42.64	42.3			CH_2
C-5	141.15	140.7			C=C
C-6	122.14	121.7	5.3-5.4 m(5H)	5.35S,1H	CH
C-7	32.36	31.7			CH_2
C-8	30.1	31.9			CH
C-9	50.6	50.2			CH
C-10	36.9	36.16			C
C-11	20.9	21.12			CH_2
C-12	40.16	39.7			CH_2
C-13	44.36	44.56			C
C-14	57.31	56.8			CH
C-15	25.15	24.4			CH_2
C-16	29.36	28.2			CH_2
C-17	56.4	56.1			CH
C-18	12.4	12.06	0.71s ,3H	1.29d,3H	CH_3
C-19	19.82	19.4	0.99s, 3H	0.74d,3H	CH_3
C-20	40.93	40.5			CH
C-21	21.52	21.09	1.03d,3H	0.91d, 3H	CH_3
C-22	138.75	138.4	5.16dd ,1H	4.98 m, 1H	CH
C-23	129.71	129.34	5.03dd,1H	5.14m, 1H	CH
C-24	51.68	51.26			CH
C-25	31.96	34.01			CH
C-26	21.66	21.12	0.88d,3H	0.84,3H	CH_3
C-27	19.42	18.97	0.87d,3H	0.83 d,3H	CH_3
C-28	25.86	25.4	1.15m,2H	1.15 m,2H	CH_2
C-29	12.63	1 2.3	0.82t,3H	0.80 t,3H	CH_3
(C-1′)	179.4	173.25			C
(C-2′)	34.4	34.72	2.33 (m),2H	2.32m, H-2′	CH_2
(C-3′)	26.1	25.6	1.67m,2H	1.67m,2H	CH_2
(C-4′)	29.7	29.7	1.27- 1.33m,2H	1.29-1.33m,2	CH_2
(C-5′)	29.6	29.6	1.27-1.33m,2H	1.27-1.33m	CH_2
(C-6′)	29.6	29.6	1.27-1.33m,2H	1.27-1.33m	CH_2
(C-7′)	29.5	29.5	1.27-1.33m,2H	1.28-1.33m,2H	CH_2
(C-8′)	29.3	27.8	2.02-2.08 m,2H	2.02-2.08 m, 2H	CH_2
(C-9′)	130.2	130.2	5.3-5.4m,1H	5.3-5.4m,1H	CH
(C-10′)	128.5	1227.9	5.3-5.4m,1H	5.3-5.4m,1H	CH
(C-11′)	25.9	25	2.78t,2H	2.79t,2H	CH_2
(C-12′)	128.3	127.8	5.3-5.4m,1H	5.3-5.4m,1H	CH
(C-13′)	130.4	130.15	5.3-5.4m,1H	5.3-5.4m,1H	CH
(C-14′)	27.6	27.4	2.02-2.08 m,2H	2.02-2.08 m, 2H	CH_2
(C-15′)	14.1	14.1	0.83 m,3H	0.83 m,3H	CH_3



B–Stigmasteryl (9Z, 12Z) - pentadeca-9, 12-dienoate

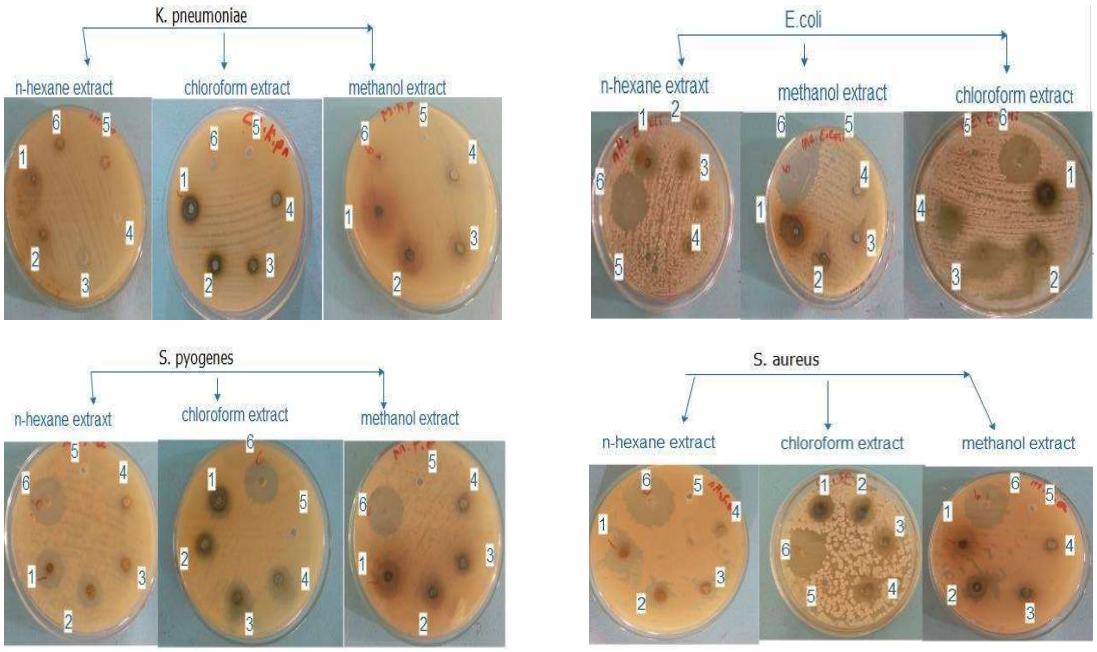
Figure 5: Proposed structure of compound DA3

Table 8: Inhibition activity of leave extracts of *D. Angustifolia* against bacterial species

SN	Extracts and compounds	Conc. (mg/ml)	Mean zone of inhibition			
			Gram-positive bacteria		Gram-negative bacteria	
			S. aureus	*S. pyogenes*	*E. coli*	*K. pneumonia*
1	n-Hexane	200	22	17.5	14.5	10.5
		100	18	15	12	8.75
		50	15	13.5	10	6.5
		25	12.	11	8	6
2	Chloroform	200	23	20.5	16.5	12
		100	20.5	18.25	14	9.75
		50	18	16	12	8.25
		25	16.5	12	9.5	8
3	Methanol	200	21.5	19	18.5	12 .5
		100	20	17.5	15.35	10.5
		50	18.75	15	13	9
		25	16.5	13	10	7
4	Chloramphenicol		30	28	24.5	8
5	DMSO		8	8	8	5

Table 9 showed the antibacterial activity of different solvent extracts of *D. Angustifolia* leaves against S. aureus, and E. coli, and was found to display inhibition zones within the range between 6 and 23 mm. The highest zone of inhibition was found in the chloroform extract (23,20.5, 16.5, and 12 mm) followed by methanol extracts (21.5, 19, 18.5, and 12.5 mm) while there was a lower zone of inhibition in the n-hexane extract (22, 17.5, 14.5 and 10.5

mm) against S. aureus, S. pyogenes, E. coli and K. pneumonia respectively. The reference chloramphenicol (10µg/well) gave the highest inhibition zone compared to all extracts against all bacterial strains (S. aureus, S. pyogenes, and E. coli, except K. pneumoniae).



Key: 1=200mg/mL concentrations, 2= 100mg/mL concentrations, 3=50mg/mL concentrations, 4=25 mg/mL concentrations, 5 is DMSO and 6 is chloramphenicol in each extract

Figure 2: Antibacterial activities of solvent extracts

This study also showed that chloroform extract was relatively more effective than methanol extract against S. aureus and E. coli bacterial strains. While the methanol extract was to be relatively more effective than chloroform and n-hexane extracts against bacteria. So, the crude chloroform extract of the D. Angustifolia plant was selected as the best candidate for column chromatography to isolate bioactive compounds. Because the inhibition zone of chloroform extract was the highest value in the three bacteria species except in bacterial strains except K. pneumonia (Table 9).

Antioxidant Investigation test

DPPH Radical Scavenging Assay

The scavenging of DPPH radicals by antioxidants is due to their hydrogen or electron-donating ability. In an alcoholic solution, DPPH gives a strong absorption band at 517 nm. When the odd electron becomes paired off in the presence of a scavenger, the absorption reduces and the DPPH solution is decolorized as the color changes from deep violet to light yellow (Perigo, 2016).The percentage of DPPH radical scavenging activities of the n-hexane, chloroform, and methanol extracts of D. angustifolia left at different concentrations are shown in Figure 7, and Table 9.

Table 9. Absorbance of standard ascorbic acid, solvent extracts, and % Radical scavenging activities of *D. angustifolia*

Conc. (mg/L)	**Absorbance (λ_{max} =517nm)**				**DPPH % inhibition**			
	Ascorbic acid	n-hexane	chloroform	methanol	Ascorbic acid	n-hexane	chloroform	methanol
6.25	0.093	0.625	0.519	0.479	90.58	36.7	47.42	51.47
12.5	0.09	0.576	0.447	0.441	90.90	41.64	54.70	55.32
25	0.087	0.412	0.346	0.315	91.25	58.26	64.94	68.10
50	0.083	0.321	0.305	0.257	91.60	67.45	69.12	74.00
100	0.067	0.223	0.254	0.213	93.21	77.4	74.27	78.42
200	0.053	0.205	0.201	0.170	94.63	79.23	79.64	82.78
Control	0.987							

Table 9 showed the absorbance of DPPH free radical was decreased by the addition of crude n-hexane, chloroform, and methanol extracts as its concentration increased. Due to the presence of a higher amount of phenolic in chloroform, methanol and flavonoids in n-hexane and methanol extract play a great role in decreasing the absorbance of DPPH free radical by transfer of proton or the greater value absorbance of DPPH free radical, they should be confirmed that the lower the scavenging activity of the plant extract. The lowest absorbance of DPPH free radical was found in the extract of methanol followed by chloroform extract, while the highest absorbance was obtained in n-hexane extract in all concentrations studied. As shown electron to DPPH radical (scavenging its free radicals), and DPPH radical became quenched. Therefore, its absorbance was decreased if the solvent extract constituents of concentration increased from lower to higher. This evidence was the violet color of DPPH was completely fading into yellow as its antioxidant-like property molecules (extracts) concentration increased(Kiren *et al*., 2014).

The percentage of inhibition was observed in all the antioxidant models that free radicals were scavenged by the all-crude extracts in a concentration-dependent manner up to the given concentration. The data were compared to those obtained with the reference compound L-ascorbic acid. The entire investigation of crude showed moderate to high radical scavenging activities compared with the absorbance of the control (0.987). The DPPH radical scavenging activities at 200µg/mL were 82.78%, 79.23%, 79.64%, and 94.63% for methanol, n-hexane, chloroform, and ascorbic acid respectively. From the result view methanol extracts have comparable antioxidant effects which could be attributed to their hydrogen-donating ability. The others of n-hexane and chloroform show moderate antioxidant tendency when compared to methanol.

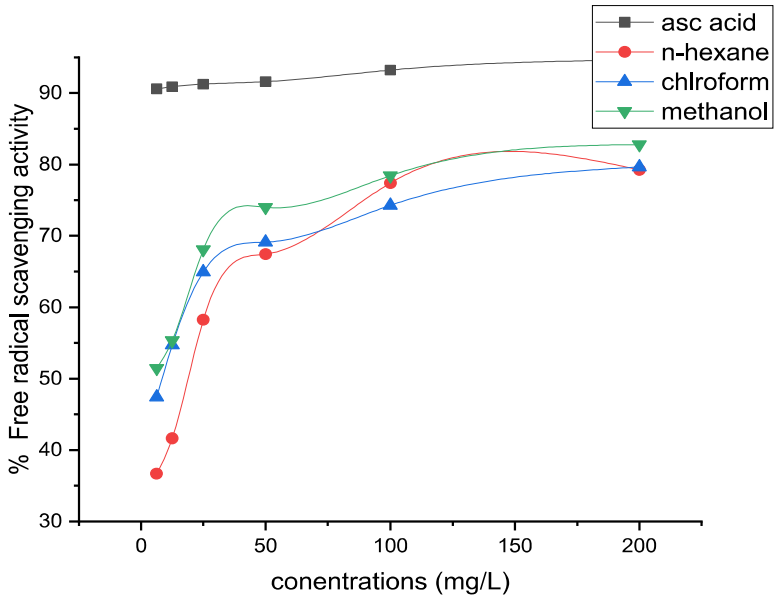


Figure 3: Percentage of free radical scavenging activity of the standard and the solvent extracts.

CONCLUSIONS

In this study, the phytochemical screening tests showed that extracts of leaves of the plants were rich in flavonoids, saponins, phenols, tannins, terpenoids, steroids, etc., and Chromatographic isolation of the crude extracts compound coded as DA3 has characterized as β–Stigmasteryl (9Z, 12Z) - pentadeca-9,12-dienoate. The results revealed that the highest zone of inhibition was found in the chloroform extract (23, 20.5, 16.5, and 12 mm) against S. aureus, S. pyogenes, and E. coli and K. pneumoniae respectively. The reference chloramphenicol (10µg/well) gave the highest inhibition zone compared to all extracts against all bacterial strains (S. aureus, S. pyogenes, and E. coli, except K. pneumoniae). The radical scavenging activities at 200 µg/mL of crude extract were promising with percentage activities of methanol (82.78%) being the strongest inhibition values and attributed to its hydrogen-donating ability compared to the standard.

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RESEARCH PAPER

Status of molecular marker utilization in conventional maize breeding in Ethiopia

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Abstract

The demand for maize (Zea mays L.) has been steadily growing in Ethiopia. It contributes to the greatest share of production and consumption along with other major cereal crops such as tef (Eragrostis tef (Zucc.) Trotter), wheat (Triticum aestivum L.), and sorghum (Sorghum bicolor L.). Three-fourth of the maize produced is consumed at the household level by the small-scale producers themselves. According to recent reports, it was grown by 10.2 million households in the country, which constituted 64.7% of the total cereal producing households. Besides, it contributed to 35.0% of the total cereal production in the country with an average national yield of 4.24 t ha-1, which is among the top three highest national average yield reported in Sub-Saharan Africa (SSA). However, the national average productivity is still low as compared to the world average yield of 5.8 t ha-1, which is attributed to several production constraints. Despite all the efforts and progress made in the development and dissemination of maize technologies for different maize growing agro-ecologies, the biotic and abiotic constraints remained the major limiting factors for maize production and productivity. Genetic improvement provides an option to address some of the constraints facing maize production and productivity in Ethiopia today, but mainly relies on the presence of genetic diversity, systematic characterization, and effective use of available germplasm. To this end, the use of molecular tools in the Ethiopian maize breeding programs has enhanced the breeding selection process; however, a much more effort is need to further consolidate with the conventional schemes. The objective of this manuscript is, therefore, to review the status of molecular markers' contribution to the conventional maize breeding in Ethiopia.

Keywords: Conventional breeding, Maize, Marker assisted breeding, Molecular markers

Introduction

Maize is a widely cultivated crop that is a staple food in many countries of the world, including the United States, Africa, and other areas of the world (Abbas *et al.*, 2022) signifying its global and regional importance to millions of people who rely on the crop in pursuit of food security and livelihoods.

Increased production and consumption trends of maize have been observed in sub-Saharan Africa (SSA) over the past years. In the region, maize is the dominant staple crop grown by the vast majority of rural households (DeVries and Toenniessen, 2001). In SSA, maize is the primary source of calories (466.5kcal/capita/day) and is the second most important source of protein (12g/capita/day) only after wheat (http://faostat.fao.org). Sub-Saharan African countries, however, do not produce enough maize to meet their needs and therefore import more than three million tonnes of maize annually (Pingali and Pandey, 2001). Accordingly, demand for maize in sub-Saharan Africa is projected to increase nearly twofold

by the year 2030 (Bigirwa *et al*., 2003). As Ethiopia is the second highly populated country next to Nigeria in Africa, maize is considered as strategic food security crop to feed the fast-growing population of the country in the short- and long-terms. In addition to strong demand for maize as a staple food, there is also the potential for maize to become an increasingly important non-traditional agricultural export crop.

Similarly, the demand for maize has been steadily growing in Ethiopia. It contributes to the greatest share of production and consumption along with other major cereal crops such as tef (*Eragrostis tef* (Zucc.) Trotter), wheat (*Triticum aestivum* L.), and sorghum (*Sorghum bicolor* L.). Three-fourth of the maize produced is consumed at the household level by the small-scale producers themselves (CSA, 2017). The maize grain is consumed in different forms of food; the stover is used as feed, fuel, and construction material. Besides, it serves as a major source of income and means of employment for tens of millions of farming and business communities. Its production has also been increasing over the years in the major maize producing regions of Ethiopia. In the 1980s, the total production was below 2 million tonnes, and the maize area was slightly more than 1 million hectares (Kebede *et al*., 1993). However, a significant increase in production of 2.34 million tonnes was observed in the 1990s. From 1995-2000, the annual growth rates of yield per hectare, maize area, and total production were 3.10%, 7.10%, and 11.30%, respectively (Mosisa *et al*., 2002). Reports of the Central Statistical Agency (CSA) of Ethiopia showed that maize was produced on about two million hectares with a total production of about 6 million tonnes in 2011/12 main cropping season. During the same year, an average national yield of 2.95 t ha^{-1} was recorded (CSA, 2011). From these data, it could be depicted that the area under maize increased by about 50% and production by 66%, with the national average yield increments from 1.60 to 3.00 t ha^{-1} in 2010 (CSA, 2011). According to recent reports of CSA (2021), maize was grown by 10.20 million households in the country, which constituted 64.70% of the total cereal producing households. In the same year, it occupied 23.97% of the area allocated to cereals and thus contributed to 34.95 % of the total cereal production in the country with an average national yield of 4.24 t ha^{-1}, which is the second highest national average yield reported in Sub-Saharan Africa (SSA), only after South Africa. It was also indicated that maize was produced on about 2.53 million hectares of land and total production of 10.55 metric tons (MT) in the same report. Improved hybrids and open pollinated varieties (OPVs) developed by the national maize breeding program, in conjunction with introduced hybrids by multi-national seed companies, have significantly contributed to such a rapid increase in maize production in the country (Tsedeke *et al*., 2015). However, the national average productivity of maize is still low as compared to the international average yield of 5.75 t ha^{-1} (http://faostat.fao.org), which is attributed to the undermentioned production constraints.

Despite its wide adaptation, maize production in Ethiopia is constrained by several biotic and abiotic constraints. Most of these constraints are common to all maize growing agro-ecologies (e.g., shortage of improved varieties and soil fertility problems), while some of them are particularly important to specific agro-ecologies (e.g., drought). The major abiotic and biotic constraints include factors such as, drought, nutrient deficiencies, diseases, weeds, and insect pests (Ransom *et al*., 1993; Mosisa *et al*., 2012). Among abiotic constraints, drought is the major problem, particularly in areas that receive minimum amounts of annual rainfall as low as 200 mm (Mandefro *et al*., 2002). The second most important abiotic stress is soil nutrient deficiency, and it is a serious problem in most of the potential maize producing areas (Mosisa *et al*., 2002, 2012). This problem is attributed, in part, to the low input purchasing power and lack of cultural practices such as crop rotations and fallows exercised by farmers (Ransom *et al*., 1993). Among the biotic factors, diseases are the principal problems. The most economically significant diseases and their respective causative agents in Ethiopia's maize production system include grey leaf spot (*Cercospora*

zeae-maydis), turcicum leaf blight (*Exserohilum turcicum*), streak disease of maize (Maize streak virus), common leaf rust (*Puccinia sorghi*) (Mosisa *et al*., 2012; Tewabech *et al*., 2012), maize lethal necrotic disease caused by the coinfection of *maize chlorotic mottle virus* (MCMV) and *sugarcane mosaic virus* (SCMV) (Mahuku *et al*., 2015), *maize yellow mosaic virus* (MaYMV), *maize streak dwarfing virus* (MSDV), rotting diseases (ear, kernel, and stalk), maize weevil, stalk borers, fall armyworm, and striga. These diseases are known to cause significant yield losses in cases where environmental conditions are favorable (Demsachew *et al*., 2018, 2019b; Tolera *et al*., 2018).

Apart from the biotic and abiotic factors hindering maize production and productivity, there exist policy and institutional constraints (Alene *et al*., 2000; Tsedeke *et al*., 2015). Among these constraints, the most important ones are limited capacity in research and extension services, insufficient production and distribution of seeds, constrained access to rural credit, and limited competition in input supply markets. Furthermore, the unavailability of improved seed has proved to be a major constraint for the adoption of the newly released improved varieties, a fact that calls for improvements in improved seed delivery to cope effectively with the demands of small farmers.

On the other hand, although biotechnological tools help to solve some of the biotic and abiotic constrains mentioned above, maize biotechnology research activity was lately started (2005) in Ethiopia focusing on the comparison of SSR markers and morphological characters in knowing genetic diversity among maize accessions collected from highland environments of the country (Yoseph *et al*., 2005). Subsequent research also continued with validation of different molecular markers, and it was revealed that molecular markers were more efficient than morphological traits in establishing genetic diversity in maize breeding lines. It was unanimously understood that molecular markers could complement conventional breeding through identification of heterotic germplasm and predicting heterosis (Melchinger, 1999a), genetic finger printing and tracking varietal adoption, and genetic purity and quality control in the development of inbred lines. The objective of this manuscript is, therefore, to review the status of molecular markers' contribution to the conventional maize breeding in Ethiopia.

Materials and methods

Considering the current average research yield of maize and the actual yield obtained on farmers` fields (Table 1), there is still huge potential to improve maize production and productivity. However, several biotic and abiotic factors are hindering further progress beyond the current levels of productivity. To overcome these constraints, it is mandatory to complement the current breeding methods with modern biotechnology tools such as genotyping/diversity study, marker-assisted selection, genomic selection, and the cutting-edge molecular applications. This review was, therefore, conducted based on secondary data obtained from different sources and document review. The historical data on maize production, area coverage, productivity was collected from the Ethiopian Statistical service (formerly known as Central Statistical Authority) website (https://www.statsethiopia.gov.et) and FAO website (https://www.fao.org/faostat/en/#data/QCL). In addition, the data characterizing the improved maize cultivars over the decades were obtained from the Ministry of Agriculture, Variety Registry Book. The information for the major part of this review work, which are about the status of applications of molecular tools in Ethiopian maize breeding, were compiled using individual papers published in a reputable journal by local and international Ethiopian researchers and scientists.

Results and discussion

Highlights of maize breeding efforts and gaps in Ethiopia

Maize is broadly divided into temperate, subtropical, and tropical germplasm depending on latitudinal variations and environmental characteristics (Paliwal *et al.,* 2000). Tropical maize is further classified into lowland, midaltitude, and highland. The diversified nature of maize agro-ecologies and the environmental variability (both natural and due to management) that prevails within each maize agro-ecology in Ethiopia calls for continuous research aimed at developing high yielding varieties adapted to the different environmental conditions. According to Lynch (1998), there are three approaches of germplasm improvement for grain yield in the farmers' field: (1) improving yield response to high levels of input, (2) improving yield under low input availability, and (3) improving yield under both low and high input availability. Improving crop yield only under high levels of input may result in varieties unsuitable for low input conditions, which occur frequently in resource poor farming conditions. Similarly, improving crop yield when only under low levels of input may result in non-responsive crop types. Generally, the National Maize Research Program has followed the third option for maize improvement (Mosisa *et al*., 2007).

The maize program is the first program of cereals research to start agro-ecology-based research under the Ethiopian Institute of Agricultural Research. It has been undertaking maize research country-wide in four broadly classified major maize agro-ecologies each having specific limitations and potentials, namely: mid-altitude sub-humid (1000-2000 meters above sea level [m.a.s.l.]), highland sub-humid (1800-2600 m.a.s.l.), lowland moisture stress areas (300-1500 m.a.s.l.), and lowland sub-humid (<1000 m.a.s.l.) (Frew and Girma, 2002; Abiy *et al*., 2019). Maize research and development was started in 1950s in the country to enhance its productivity, targeting the needs of small-scale farmers who produce more than 90% of maize (Benti and Ransom, 1993; Mandefro and Tanner, 2002). The subsequent participation of the country in the "East African Cooperative Maize Variety Trial" in the late 1960s and early 1970s enabled the identification of high yielding composites and hybrid varieties that were better adapted to the local growing conditions than those acquired in the 1950s (Benti *et al*.,1993), which was mainly due to agro-ecological similarities. In the 1980's, the national breeding program started to introduce tropical maize germ plasm from CIMMYT, IITA and other national programs in eastern Africa (Benti *et al*., 1993). The introduction and evaluation of a wide range of maize genotypes over the years has enabled the national maize breeding program to develop and release several open pollinated varieties (OPVs) and hybrids for commercial production. In the 1970s and 1980s, locally developed improved OPVs were released for wide area production at different agro-ecologies in Ethiopia. In the late 1980s, the first locally developed non-conventional hybrid was released for the mid-altitude sub-humid maize growing areas. Since then, many improved OPVs and hybrids with pest resistance/tolerance were released (Table 1) for large scale production across different agro-ecologies by the National Maize Research Project of the Ethiopian Institute of Agricultural Research (EIAR). Currently, the National Maize Research Program has three main breeding stations located in the above three major agro-ecologies to address specific demands of variety development for the agro-ecologies.

The mid-altitude sub-humid agro-ecology is a high potential area for maize production in Ethiopia. It is the leading maize growing agro-ecology contributing the largest share of maize produced in the country (Benti and Ransom, 1993; Mandefro and Tanner, 2002; Mosisa *et al*., 2012; Abiy *et al*., 2019). However, production and productivity of maize in this and other agro-ecologies are constrained by several factors. These include unavailability of improved varieties, limited access to improved seeds, diseases such as gray leaf spot caused by *Cercospora zeae-maydis*, Turcicum leaf blight (*Exserohilum turcicum*) and common rust (*Puccinia sorghi*), field and storage insect pests (e.g., maize stalk borers and the maize weevil), low soil fertility and poor market development (Mosisa *et al*., 2002, 2012). Therefore, there is

a need to develop improved maize varieties and their production packages for sustainable maize production in the country.

The lowland moisture stress agro-ecology is the other maize producing agro-ecology of Ethiopia. This agro-ecology encompasses drought affected areas occupying over 40% of the area in the country and contributing 20% of the total maize production (Mandefro *et al*., 2002). However, recent reports indicated that the lowland moisture stress maize agro-ecology occupies up to 20% (Tsedeke *et al.,* 2015; Abiy *et al.*, 2019). In addition to the above constraints, recurrent drought is the most important challenge for maize production and productivity in this agro-ecology (Benti and Ransom, 1993; Mandefro and Tanner, 2002).

The high altitude sub-humid agro-ecology, including the highland transition and true highlands, is next to the mid-altitude agro-ecology with greater maize area and production share in Ethiopia. This agro-ecology covers an estimated 20% of the land area devoted to annual maize cultivation and consisting of more than 30% of small-scale farmers who depend on maize production for their livelihoods (Twumasi *et al*., 2002; Abiy *et al*., 2019). The Ethiopian highland maize breeding program is situated at Ambo to coordinate maize research and technology development for the highland agro-ecology. This program was initiated in 1998 in collaboration with the International Maize and Wheat Improvement Center (CIMMYT) and National Agricultural Research Systems (NARS) of east and central African countries including Ethiopia, Kenya, Tanzania, Uganda, Rwanda, and Burundi (http://www.cimmyt.org.com). Research and variety development of highland maize has generally lagged behind other agro-ecologies before the launch of this breeding program (Twumasi *et al*., 2002).

Table 1. Released maize varieties of public research centers and Universities with their agro-ecological adaptations and some agronomic characters (until 2022)

Crop	Variety	Year of release	Altitude (m)	Rainfall (mm)	Plant height (cm)	Ear Placement (cm)	Days to Maturity	Seed Colour	Yield (Qt ha^{-1})		Disease Reaction			
									Research Station	Farmers field	MSV	GLS	TLB	CLR
	BH-140	1988	1000-1700	1000-1200	240-255	105-120	145	White	75-85	47-60	-	MT	MT	MT
Hybrids	BH-660	1993	1600-2200	1000-1500	255-290	145-165	160	White	90-120	60-80	-	T	T	R
	BH-540	1995	1000-2000	1000-1200	240-260	110-120	145	White	80-90	50-65	-	MT	MT	MT
	BH530	1996	1000-1300	1000-1500	200-230	110-120	140	White	80-90	50-60	-	MT	MT	MT
	BH-541	2002	1000-1800	1000-1200	-	-	150	White	65-75	-	-	T	T	MR
	BHQP-542*	2002	1000-1800	1000-1200	220-250	100-120	145	White	80-90	50-60	-	T	MT	MS
	BH-543	2005	1000-2000	1000-1200	250-270	140-150	148	White	85-110	55-65	-	MT	MT	T
	BH-544	2006	1000-2000	1000-1200			147	White	70-80		-	S	S	T
	BHQPY-545*	2008	1000-1800	1000-1200	250-260	120-140	144	Yellow	80-95	55-65	-	T	MT	MT
	BH-670	2002	1700-2400	1000-1500	260-295	150-165	165	White	90-120	60-80	-	T	T	R
	BH546	2013	1000-1750	500-1000	280	140	140	White	85-115	65-75	-	R	R	R
	BH547	2013	1000-1800	500-1000	250	120	140	White	85-115	65-75	-	R	T	R
	BH661	2011	1600–2200	1000-1500	280	170	160	White	95–120	65–85	-	R	R	R
	SPRH1	2015	1000-1800	1000-1200	280	140	145	White	75-85	55-65	-	R	T	R
	SBRH1	2015	1000-1800	1000-1200	280	140	145	White	75-85	50-60	-	T	T	R

	BHQP548*	2015	1000-2000	1000-1200	265	150	145	White	75-85	65-75	-	R	T	R
	BH549	2017	1500-1800	1000-1200	220	114	145	White	90-120	65-80	-	R	R	R
	BH520 W1	2020	1000-1800	900-1500	237	134	155	White	90-130	76-100	-	R	R	R
	BH5211	2022	1000 - 1800	900 - 1500	244	118	155	White	90	88	-	T	T	T
	BH5212	2022	1000 - 1800	900-1500	239	116	155	White	91	80	-	T	T	T
	BHA5211	2022	1000-1800	900-1500	240	115	155	Orange	80	75	-	T	T	T
	MH130	2012	1200-1750	500-800	180	85	120	White	65-75	50-60	-	-	MR	MR
	MHQ138*	2012	1000-1800	500-1000	200	100	138	White	85-100	70-80	-	-	MR	MR
	MH140	2013	1000-1800	500-1000	200	100	140	White	90-100	77-80	-	-	T	T
	MH141	2020	1000-1800	500-1000	181	100	141	White	92.5	65	-	-	R	R
	AMH-800	2005	1800-2500	1000-1200	205-225	105-125	175	White	70-80	55-65	-	MR	MR	MR
	AMH-850	2007	1800-2600	1000-1200	220-235	120-130	183	White	80-120	60-80	-	MR	T	R
	AMH-851	2009	1800-2600	1000-1200	220-235	120-130	178	White	80-120	60-80	-	R	R	R
	AMH760Q*	2012	1650-2400	1000-1200	245	143	183	White	90-120	80-100	-	T	MS	T
	AMH852Q*	2016	1800-2600	1000-1200	250	145	182	White	90-100	75-85	-	MR	MR	R
	AMH853	2016	1800-2600	1000-1200	229	168	179	White	90-120	80-90	-	T	MR	R
	AMH854	2022	1800-2600	1000-1200	245	145	190	White	85-125	80-93	-	MR	R	R
	Hora (Amb02syn1)	2005	1800-2400	1000-1200	200-215	100-120	170	White	60-70	40-45	-	MR	MR	MR
OPVs	Kuleni	1995	1700-2200	1000-	240-265	130-145	150	White	60-70	40-45	-	T	T	R

				1200										
	Katumani	1974	1000-1700	450-550			110	White	22.5		-			
	Alemaya Composite	1973	1600-2200	1000-1200	280-300	160-190	163	White	50-70	38-42	-	T	T	T
	A-511 (AwARC)	1973	500-1800	800-1200	230-250	130-145	150	White	50-60	30-40	-	MT	MT	MT
	Gibe-1	2001	1000-1700	1000-1200	240-260	130-140	145	White	60-70	40-45	-	MT	MT	T
	Gibe-2	2011	1000-1800	1000-1200	224	122	143	White	65-70	45-50	-	T	T	T
	Gibe-3	2015	1000-1700	1000-1200	238	123	145	White	65-75	45-55	-	T	T	T
	Gutto	1988	1000-1700	800-1200	165-190	90-110	126	White	30-50	25-30	-	MT	MT	MT
	Morka (improved UCB)	2008	1600-1800	1200-2000	270-300	145-180	180	White	70-90	40-60	-	T	T	T
	Rare-1	1997/98	1600-2200	900-1200	250-270	130-150	163	White	60-70	40-45	-	T	T	T
	ACV3 (Fetene)	1996	-	-	-	-	100	-	-	-	-	-	-	-
	ACV6 (Tesfa)	1996	-	-	-	-	110	-	-	-	-	-	-	-
	Melkasa-1	2001	1000-1700	600-1000	140-160	65-70	90	Yellow	35-45	25-35	-	-	T	T
	Melkasa-1Q*	2013	1000-1800	700-1200	190	103	130	Yellow	35-45	25-35	-	-	T	T
	Melkasa-2	2004	1000-1700	600-1000	170-190	80-90	130	White	55-65	45-55	-	-	T	T
	Melkasa-3	2004	1200-1700	600-1000	170-175	75-80	125	White	50-60	45-50	-	-	T	T
	Melkasa-4	2006	1200-1700	600-1000	160-170	70-80	105	White	35-45	30-35	-	-	T	T
	Melkasa-5	2008	1200-1700	600-1000	180-190	80-90	125	White	40-50	35-40	-	-	T	T
	Melkasa-6Q*	2008	1200-1700	600-1000	165-175	70-75	120	White	45-55	30-40	-	-	T	T

	Melkasa-7	2008	1200-1700	600-1000	170-182	80-90	115	Yellow	45-55	30-40	-	-	T	T
	Abo-Bako	1986	300-1000	900-1200	220-230	120-130	112	White	50-60	35-45	T	T	T	T
	Gambella Comp-1	2002	300-1000	900-1200	200-220	105-115	116	White	60-70	40-50	R	T	T	T
	HrU22 (Bate)	2017	1300-2000	650-1200	180	95	145	White	45-60	35-45	-	-	T	T
	HrU28(Afran Qallo)	2017	1300-2000	650-1200	180-220	95-120	148	Yellow	45-60	35-50	-	-	T	T
	BOS20W1 (sweet)	2020	1000-1800	900-1500	220	112	140	White	51.1	-	-	R	R	R
	BOS20Y1 (sweet)	2020	1000-1800	900-1500	212	104	140	Yellow	57.4	-	-	R	R	R
	Gibe-awash Fendisha	2012	1000-1800	700-1200	190	103	130	Yellow	36	30	-	T	MS	T

Note: * = QPM, T= tolerant, R= resistant, MT= moderately tolerant, MS= moderately susceptible, S= susceptible, MR= moderately resistant, MSV= maize streak virus, GLS=gray leaf spot, TLB=turcicum leaf blight, CLR=common leaf rust. Source: Ministry of Agriculture- variety release registry books of different years.

Some limitations of the conventional breeding approaches and the need for molecular marker application in the Ethiopian maize breeding programs

Despite all the efforts to develop maize germplasm for the various agro-ecologies of Ethiopia by the National Maize Breeding Programs, maize productivity remains still far below the potential due to several factors responsible for the yield gap, some of which were mentioned above as constraints. Though initial adoption of hybrids by resource poor farmers was very slow, the demand for hybrid seeds has gradually increased in Ethiopia as a result of changes in government policy including the establishment of several local seed companies and the launching of a national extension program by government and non-governmental organizations (NGOs), such as Sasakawa Global 2000 (Tsedeke *et al.,* 2015). The rapid adoption of some of the hybrids, however, brought a major concern on the quality of hybrid seed sold to resource poor farmers. Farmers reported a high level of mixture of plants in their fields and low yield in a given area. Despite increased number of actors in the seed production and marketing venture, a vibrant national seed regulatory body to undertake effective seed quality assurance, including seed inspection and certification has been creating a huge gap in the sector (Berhanu *et al*., 2015). Routine inspection of the initial parental seed (breeder, pre-basic and basic seeds) produced by different actors in the seed value chain is critical and often done by inspecting production fields at vegetative and flowering stages. However, inspection of seed production fields based on a limited number of morphological and agronomic traits is time consuming, laborious, expensive, and at times can lead to inaccurate conclusions. The verification of seed lots and seed production fields could have been effectively improved through the use of quality control (QC) genotyping using molecular markers (Kassa *et al*., 2012a; Berhanu *et al*., 2015).

The other gap filling advantages of molecular tools is that maize breeders often use a number of phenotypic traits and combining ability studies for evaluating maize germplasm as well as assigning inbred lines into distinct heterotic groups. Expression of phenotypic traits, however, are often influenced by environmental factors, which may affect the consistency and reliability of combing ability-based classification. Therefore, use of molecular markers to characterize locally available inbred lines can complement and fine-tune the combining ability based heterotic grouping of inbred lines (Berhanu *et al*., 2017; Demissew *et al*., 2018; Dagne *et al*., 2019). In the work of Demissew *et al*., (2015), conversions of non-quality protein maize (non-QPM) into QPM had been done using phenotypic selections without monitoring the genetic backgrounds. Consequently, recombinants were selected and a very small portion of the genome of the recurrent parents was recovered, and hence suggested the use of marker-assisted backcross or marker-assisted selection (MAS) in the future. Because marker-assisted breeding and/or MAS would be used to facilitate background selection and avoid disruption of the newly established heterotic groups.

Molecular marker applications in maize breeding

Genetic improvement provides an option to address some of the constraints facing maize production and productivity in Ethiopia today, but mainly relies on the presence of genetic diversity/variability, characterization and systematic classifications, and effective use of available germplasm. Table 2 shows the status of molecular work done using introduced and locally developed maize germplasm of Ethiopia. Each of the published molecular works listed in this table is further narrated one by one after the table in different headings based on the sequence of the studies.

Table 2. Summary of studies conducted in and out of Ethiopia on molecular marker applications for maize germplasm developed and/or used in Ethiopia

No.	Maize type	Molecular marker type and application	Reference
1	Tropical highland adapted maize accessions	AFLP and SSR (comparison of the two marker systems for diversity study)	Yoseph *et al.*, (2005)
2	Tropical highland adapted maize accessions	AFLP (genetic diversity study)	Yoseph *et al.*, (2006)
3	Tropical highland adapted maize inbred lines	SSR (genetic diversity study)	Legesse *et al.*, (2006)
4	Tropical highland adapted maize inbred lines	AFLP (genetic diversity study)	Legesse *et al.*, (2008)
5	Tropical mid-altitude QPM maize inbred lines	SSR and RAPD (comparison of the two marker systems in the power of detection of polymorphism)	Demissew *et al.*, (2012)
6	Tropical mid-altitude maize inbred lines	SSR (genetic variability study)	Wende *et al.*, (2013)
7	Tropical highlands adapted QPM and conventional maize inbred lines	SSR (genetic variability study and population structure)	Demissew *et al.*, (2015)
8	Tropical mid-altitude maize hybrids and inbred lines	SNP (genetic purity and identity study using GBS markers)	Berhanu *et al.*, (2015)
9	Tropical mid-altitude maize inbred lines	SNP (genetic variation and population structure study using GBS markers)	Berhanu *et al.*, (2017)
10	Tropical mid-altitude conventional & QPM maize inbred lines	SSR and phenotypic traits association study	Demissew *et al.*, (2018)
11	African highland adapted maize inbred lines	SNP (genetic purity, genetic variability, and population structure study using GBS selected markers)	Dagne *et al.*, (2019)
12	Tropical yellow maize inbred lines	SNP (Association study between functional DNA markers and quality trait- using GBS selected markers)	Girum *et al.*, (2013)
13	Tropical mid-altitude DH lines	SNP (GWAS & genomic prediction to identifying QTLs regions associated with agronomic traits under optimum & Low-Nitrogen)	Berhanu *et al.*, (2020)
14	Tropical drought tolerant maize inbred line and OPV	Maize genetic transformation study to transfer genes for marker assisted breeding	Bedada *et al.*, (2016, 2018)

Genetic diversity studies

Maize and wheat have been extensively exploited in genetic and cytogenetic studies compared to other cereal crops. Maize is one of the domesticated crop species with the highest level of molecular polymorphism. Nucleotide diversity of more than 5% has been reported at some loci of the maize genome (Henry and Damerval, 1997), and has been verified by high genetic variability both within and among maize populations as revealed by several genetic diversity studies. The molecular diversity of maize is approximately three to tenfold higher than that of other domesticated grass species (Buckler *et al*., 2001).

Molecular markers such as RAPD, AFLPs, SSRs, and SNPs are proposed to be an appropriate tool not only for breeding lines and hybrids (Bastia *et al*., 2001) and cultivars (Mohanty *et al*., 2001) but also facilitate the monitoring of introgression, mapping of QTLs (Paterson *et al*., 2003) and the assessment of genetic diversity (Warburton *et al*., 2002; Kassahun and Prasanna, 2003; Legesse *et al*., 2007; Yoseph *et al*., 2006; Pooja and Singh, 2011; Demissew *et al*., 2015; Berhanu *et al*., 2017; Dagne *et al*., 2019) in different crops

including maize. Several DNA marker technologies have been developed and are available to study genetic diversity. The genetic diversity/variability studies on maize in Ethiopia using the different markers are summarized as follow:

Yoseph *et al*., (2006) analysed 62 traditional Ethiopian highland maize accessions collected from different parts of Ethiopia using 20 simple sequence repeat (SSR) markers and 15 morphological traits with the objectives to assess genetic diversity and relationships among the accessions and to assess the level of correlation between phenotypic and genetic distances. Their finding showed that the average number of alleles per locus was 4.9. Pair-wise genetic dissimilarity coefficients ranged from 0.27 to 0.63 with a mean of 0.49. Ward minimum variance cluster analysis showed that accessions collected from the Northern part of the country were distinct from the Western and Southern parts. However, there was no differentiation between the Western and Southern accessions. This suggested gene flow between these regions. The relationship between morphological and SSR-based distances was significant and positive ($r = 0.43$, $p = 0.001$). The high genetic diversity observed among these set of accessions suggests ample opportunity for the development of improved varieties for different agro-ecologies of Ethiopia. From a conservation perspective, sampling many accessions from all agro-ecologies would be an effective way of capturing genetic variation for future collections and conservation.

Yoseph *et al.,* (2006) also did the same work on the 62 Ethiopian highland maize accessions but using a different marker platform known as amplified fragment length polymorphism (AFLP) markers and morphological traits. Eight *EcoRI/MseI* primer combinations and 15 morphological traits were used. Of a total of 650 AFLP markers scored, 89.5% were polymorphic. The authors found out that the relationship between morphological and AFLP-based distances were significantly positive and concluded as saying that regardless of the large variation in environmental conditions between agro-ecologies where the accessions were collected, only 9% of the total genetic variation was found between agro-ecologies, while 91% was found within the maize agro-ecologies in Ethiopia. The authors further suggested implications for this finding could probably be explained by long distance seed exchange, continuous seed introduction and gene flow between agro-ecologies. A similar work was done on genetic diversity of 56 highland and mid-altitude maize inbred lines obtained from CIMMYT and EIAR breeding programs in Ethiopia and Zimbabwe by Legesse *et al*., (2006). The inbred lines were genotyped using 27 SSR loci. In total, 104 SSR alleles were identified with a mean of 3.85 alleles per locus from the work. The average polymorphism information content (PIC) was 0.58. Genetic distance expressed as Euclidean distance varied from 0.28 to 0.73 with an average of 0.59. From the results obtained, the authors concluded that the variability detected using SSR markers could potentially contribute towards effective utilization of the inbred lines for the exploitation of heterosis and formation of genetically diverse source populations in Ethiopian maize improvement programs.

On the other hand, Legesse *et al.,* (2008) also conducted a study on the relationship between hybrid performance and AFLP-based genetic distance in highland maize inbred lines to estimate genetic distance (GD) among the inbred lines and tester parents and to investigate the relationship of GD with hybrid performance and mid-parent heterosis. From the AFLP analysis it was depicted that 32 parental genotypes produced a total of 601 bands, of which 80.5% were polymorphic. Polymorphism ranging from 42 (AGG/CGA) to 66 (ACA/CCC) bands with a mean of 50 was detected across nine primer combinations. Polymorphic information content values ranged from 0.25 to 0.40. Genetic distance calculated in terms of dissimilarity for all possible combinations among 32 genotypes ranged from 0.40 to 0.72 with an average of 0.59 units. Genetic distance estimates for the 26 female and six male parent combinations varied from 0.63 to 0.72 with a mean of 0.67. With further sub-groupings of the pairwise combinations into population testers and line testers, mean GD values for population tester and line tester combinations were 0.68 and 0.66, respectively.

Finally, the authors concluded the effectiveness of AFLP markers for diversity analysis in that the relationships between GDs of population tester combinations with their corresponding F1 grain yield, plant height, and mid-parent heterosis were negatively correlated. On the contrary, GDs of inbred line tester combinations showed positive and significant correlation coefficients with F1 performances and mid-parent heterosis for most traits but with low magnitude to warrant prediction of hybrid performance.

Additional studies of genetic variability using molecular markers had also been conducted by Wende *et al*., (2013) and Demissew *et al*., (2015). Wende *et al*., (2013), in their study of genetic interrelationships among 20 elite intermediates to late maturing tropical maize inbred lines, used 20 selected SSR markers. The 20 SSR primers identified 108 alleles among the 20 maize inbred lines. The number of alleles scored across SSR loci ranged from 1 to 11, with a mean of 5.4 alleles. The two loci (*Phi 037, Umc1296*) revealed one allele, and the maximum numbers of alleles were detected at the *Bnlg 2190, Umc2214* and *Umc1153* loci. The PIC estimated for all loci ranged from 0.0000 to 0.8028 with a mean of 0.54. Expected heterozygosity (He) values, as a measure of allelic diversity at a locus, varied from 0.0000 to 0.8395 with an average of 0.5774. These values were well-correlated with the number of alleles. Ten SSR loci (*Umc1568, Nc003, Umc2214, Umc2038, Phi085, Umc1153, Bnlg238, Phi054, Bnlg2190, and Bnlg240*) manifested a PIC value of more than 0.6, reflecting their potential to detect differences between the inbred lines. From the results, the authors found out that the genetic diversity existing in the study materials was the most important factor limiting the number of alleles identified per microsatellite locus during screening. However, other factors such as, the number of SSR loci and repeat types, and the methodologies employed for the detection of polymorphic markers, have been reported to influence allelic differences.

Similarly, in their study of genetic purity and patterns of relationships among tropical highland adapted 36 quality protein and normal maize inbred lines (30 QPM and 6 non-QPM), Demissew *et al*., (2015) used 25 microsatellite markers. A summary of the 25 SSR markers used in the study is given in Table 3. There were two to four pairs of markers for each chromo-

Table 3. Summary of the 25 SSR markers used in the Demissew et al., (2015) study

Marker	Chromosome	Bin number	Repeat length	Repeat motif	Annealing temperature (°C)	Minor allele frequency	Number of alleles	Observed heterozygosity	PIC
nc130	5	5.0	3	AGC	54	0.056	3	0.000	0.404
nc133	2	2.1	5	GTGTC	54	0.143	3	0.000	0.454
phi029	3	3.0	4	AGCG	56	0.029	3	0.029	0.410
phi046	3	3.1	4	ACGC	60	0.028	3	0.000	0.412
phi056	1	1.0	3	CCG	56	0.121	4	0.030	0.633
phi065	9	9.0	5	CACTT	54	0.028	4	0.056	0.604
phi072	4	4.0	4	AAAC	56	0.014	4	0.056	0.401
phi075	6	6.0	2	CT	54	0.097	3	0.028	0.354
phi076	4	4.1	6	GAGCGG	60	0.029	6	0.143	0.663
phi079	4	4.1	5	AGATG	60	0.056	5	0.028	0.690
phi084	10	10.0	3	GAA	54	0.333	2	0.056	0.346
phi102228	3	3.1	4	AAGC	54	0.083	3	0.000	0.337
phi114	7	7.0	4	GCCT	60	0.061	4	0.000	0.524
phi123	6	6.1	4	AAAG	54	0.167	3	0.000	0.505
phi299852	6	6.1	3	AGC	58	0.028	7	0.028	0.735
phi308707	1	1.0	3	AGC	56	0.167	3	0.000	0.541
phi331888	5	5.0	3	AAG	58	0.028	4	0.028	0.512
phi374118	3	3.0	3	ACC	54	0.083	4	0.000	0.542
phi96100	2	2.1	4	ACCT	56	0.125	4	0.083	0.659
umc1161	8	8.1	6	GCTGGG	56	0.015	8	0.091	0.577
umc1304	8	8.0	4	TCGA	54	0.014	3	0.143	0.380
umc1367	10	10.0	3	CGA	62	0.028	4	0.000	0.303
umc1545	7	7.0	4	AAGA	54	0.029	5	0.000	0.423
umc1917	1	1.0	3	CTG	52	0.057	4	0.029	0.497
umc2250	2	2.0	3	ACG	58	0.500	2	1.000	0.375
Mean						0.093	3.92	0.073	0.491

some except chromosome 9 that had only a single marker. The number of alleles scored for each marker varied from 2 in *phi084* and *umc2250* to 8 in *umc1161*. The 25 markers amplified a total of 98 alleles, with an average of 3.9 alleles per marker. Minor allele frequency (MAF) was the lowest (0.014) in *umc1367* and *phi072* and the highest (0.500) in *umc2250*, and the overall average was 0.093. The polymorphism information content (PIC) ranged from 0.303 (*umc1367*) to 0.735 (*phi299852*), and the overall average was 0.491. The authors also described the importance of PIC in that it provides an estimate of how informative a particular marker is by considering both the number of alleles that are expressed and the relative frequencies of those alleles (Smith *et al*., 1997). For example, in the present study, PIC values ranged from 0.303 (less discriminative marker– *umc1367*) to 0.735 (highly discriminative marker– *phi299852*) with a mean of 0.491. According to Botstein *et al*., (1980) PIC guideline, 14 markers were reasonably informative (0.30< PIC <0.50) and the remaining 11 markers were highly informative (PIC > 0.50). It was noted that the relatively smaller PIC values in the study could be due to the presence of only a single di-nucleotide repeat SSR as opposed to more di-nucleotides used or lower genetic variability among the germplasm used for the study.

Comparison of two marker systems (SSRs and RAPDs) for determining the power of detection of polymorphism was also studied by Demissew *et al*., (2012). The study revealed that the RAPDs produced several polymorphic bands although the resolution power of the agarose gel electrophoresis was not good enough to allow the bands of both marker systems to be seen clearly. In this study, a total of 31 alleles were detected for the 25 polymorphic RAPD loci, at an average of 1.24 alleles per locus, which is also equivalent to 80.7% polymorphic loci. Thirty-seven out of 40 RAPD primers showed a monomorphic banding pattern, while three RAPD primers exhibited polymorphic bands. The results were consistent with the findings of Asif *et al*., (2006). However, the PIC value was greater for the SSR marker, suggesting better discriminating power of SSR markers over RAPDs that makes them ideal for use in fingerprinting of maize lines, as was reported by Smith *et al*., (1997) and Liu *et al*., (2003).

Association of phenotypic and genotypic data

Morpho-agronomic characters of crop plants have traditionally been used for germplasm identification. However, identification based on these characters is not efficient and reliable as they are highly affected by environmental factors. Despite the limitations, morphological traits are useful for preliminary evaluation because they are fast, simple, and can be used as a general approach for assessing genetic diversity among morphologically distinguishable accessions. Since the late 1980s, different electrophoretic (Zillman and Bushuk, 1979; Tkachuk and Mellish, 1980) and reversed-phase high performance liquid chromatography (RP-HPLC) (Marchylo *et al*., 1988; Scanlon *et al*., 1989) of seed storage proteins have been developed and are considered effective methods for cultivar identification. But the ability of the techniques to discriminate among cultivars is limited. On the other hand, DNA-based molecular markers are breeding tools, which are capable of providing high discrimination power (Perry, 2004). They are used in the identification of specific sequence variation between two or more genotypes and, in many cases, are more effective than biochemical assays (Lorz and Wenzel, 2008). Molecular markers are not influenced by environmental factors and are also fast, efficient, and more sensitive than field evaluation for the detection of large numbers of distinct differences between genotypes at the DNA level (Melchinger, 1999a).

Several DNA marker technologies have been developed and are available for studying genetic variability. The choice of the most appropriate marker system greatly depends on the species, the objective of the marker analysis, and the available resources (Lorz and Wenzel, 2008). PCR-based markers are widely preferred for genotype characterization in diverse crop species, including maize, as they are relatively simpler to use, non-distructible,

and require a smaller amount of DNA, thus permitting many reactions from a single sample (Powell *et al*., 1996; Soleimani *et al*., 2002). In addition, genetic distance estimates using molecular markers are reportedly helpful to identify the best parent combinations for new pedigree starts and to assign lines into heterotic groups (Melchinger *et al*., 1990; Benchimol *et al*., 2000; Reif *et al*., 2003a; Reif *et al*., 2003b; Bertan *et al*., 2007; Flint-Garcia *et al*., 2009; Lu *et al*., 2009; Demissew *et al*., 2015).

A comparative study of molecular and morphological methods for describing genetic relationships in traditional Ethiopian highland maize was conducted using a total of 15 morphological traits, eight AFLP primer combinations, and 20 simple sequence repeat (SSR) loci by Yoseph *et al*., (2005) to: (i) study the morphological and genetic diversity among 62 selected highland maize accessions, and (ii) assess the level of correlation between phenotypic and genetic distances. Summary of results from the study exhibited that the mean morphological dissimilarity (0.3 with a range of 0.1-0.68) was low in comparison to mean dissimilarity calculated using SSR markers (0.49 with a range 0.27-0.63) and AFLP markers (0.57 with a range 0.32- 0.69). Mantel's, (1967) test of correlation between the morphological dissimilarity matrix and the matrices of genetic dissimilarity based on SSR and AFLP markers was 0.43 and 0.39, respectively (p = 0.001). Whereas the correlation between SSRs and AFLPs dissimilarity matrices was 0.67 (p = 0.001). Therefore, the authors concluded that the correlation between SSR and morphological data analysis was higher than between AFLP and morphological data analysis, indicating that SSR markers may be a better choice for marker-trait association genetic studies in open pollinated maize accessions than AFLP. Moreover, Ethiopian highland maize accessions appear to be environmentally more stable, as observed by the good agreement between phenotypic and molecular distances suggesting that the observed phenotypic variation was at least partly caused by genetic factors. The correlation between the two molecular markers was also higher than the correlation with morphological traits depicting that when compared with DNA fingerprinting techniques, morphological traits are relatively less reliable and efficient for precise discrimination of closely related accessions and analysis of their genetic relationships.

Another similar work on the phenotypic characterization of elite QPM inbred lines adapted to tropical highlands and the association studies using SSR markers was reported by Demissew *et al*., (2018). The objectives of the study were to characterize newly developed QPM inbred lines adapted to tropical highlands using phenotypic traits and to determine the association with SSR markers. Accordingly, thirty-six maize inbred lines (30 QPM and six non-QPM) adapted to tropical highlands of Ethiopia were evaluated using 18 phenotypic traits and 25 selected SSR markers. The results of the study showed that significant phenotypic variations were observed among inbred lines for all measured traits from both phenotypic and molecular marker analyses. Dendrograms constructed using the phenotypic traits and the SSR markers classified the test inbred lines into four genetic groups for systematic selection (Fig. 1). The findings of the study further revealed that although the diversity analysis based on phenotypic or molecular markers resulted in a similar number of distinct groups and a similar concentration of genotypes in each group, the correlation between the two markers system was low. According to Demissew *et al*., (2018), the suggested reasons for the lack of significant association between the phenotypic and SSR data could, in part, be attributed to the relatively small number of SSRs used in this study, and the molecular markers did not adequately sample the genomic regions that were responsible for the phenotypic variation among the inbred lines (Alves *et al*., 2013). The authors further added that several factors such as the distribution of markers in the genome, the number of markers used, and the nature of the evolutionary mechanism underlying the variation measured can affect the genetic distance estimates (Powell *et al*., 1996).

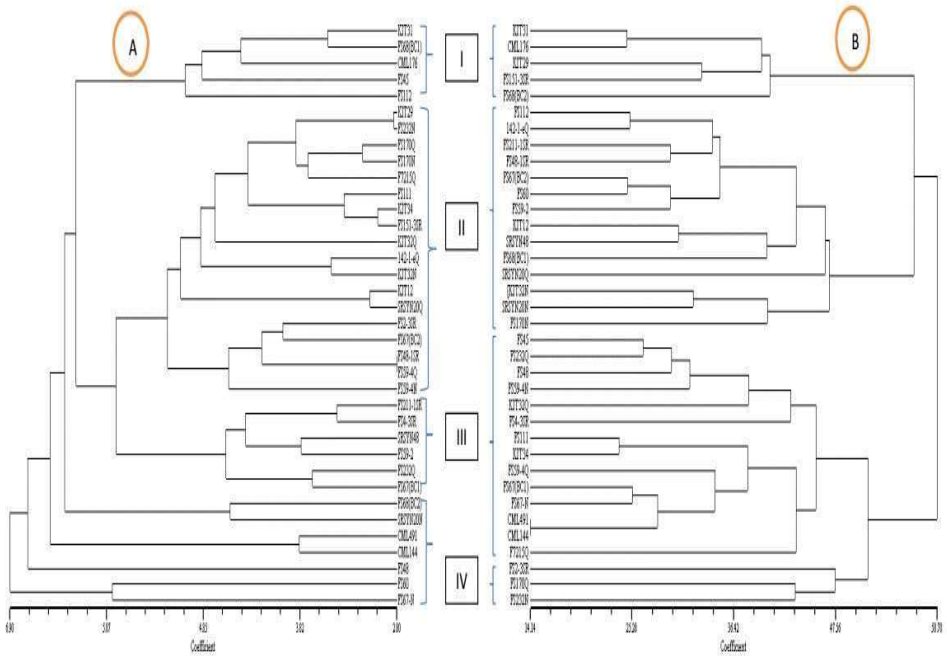

Fig 1. Dendrogram of 36 (30 QPM and six non-QPM) maize inbred lines constructed using UPGMA cluster analysis based on Euclidean genetic distances of phenotypic data combined across two locations (A) and SSR markers (B). Source: Demissew et al., 2018.

Population structure and heterotic grouping

Estimates of genetic distances are indicators for the presence or absence of relationships among genotypes. The estimates can be made using different types of molecular markers, including restriction fragment length polymorphism (RFLP), AFLP, SSR, and SNPs). As heterotic group assignment is made based on combining ability from combining ability experiments, several authors suggested the use of molecular markers in heterotic grouping (Melchinger *et al.*, 1990; Benchimol et al., 2000; Reif *et al.*, 2003a; Reif *et al.*, 2003b; Yoseph *et al.*, 2005; Flint-Garcia *et al.*, 2009; Lu *et al.*, 2009; Demissew *et al.*, 2018).

For example, Yoseph *et al.*, (2005) conducted a comparative study of molecular and morphological methods of describing genetic relationships in Ethiopian highland maize accessions. They analysed a representative sample of 62 Ethiopian highland maize accessions using a total of 15 morphological traits, eight AFLP primer combinations and 20 simple sequence repeat (SSR) loci to classify the accessions into groups based on molecular profiles and morphological traits. The study allowed the identification of three groups of maize accessions with distinctive genetic profiles and morphological traits. The first group constitutes the early maturing, short-statured accessions (cluster I), which were collected from the northern agroecology from which they probably acquired earliness. The second group includes the tall, high yielding varieties (cluster II), which are currently the most important landraces grown in the southern and western parts of Ethiopia. The third group includes tall, late maturing and low yielding accessions (cluster III), which are being cultivated in some parts of the northern,

western and southern highlands of Ethiopia. The authors suggested that accessions from the northern agro-ecology may be used as base materials for the development of improved varieties for the drier parts in the highlands of Ethiopia, as the accessions were able to grow and produce seed under very harsh environmental conditions (drought, poor soils, excessive radiation, etc) and had adaptation traits (e.g., short flowering, short ear, and plant height narrow leaf), while accessions from the western and southern agro-ecologies can be used for the development of high yielding varieties suitable for high potential maize growing regions of Ethiopia.

The study by Demissew *et al.*, (2015) also investigated the extent of genetic differentiation, population structure, and patterns of relationship among 36 maize inbred lines developed from CIMMYT source germplasm with 25 SSRs using model-based population structure analysis, neighbour-joining cluster analysis, and principal coordinate analysis. All these different multivariate methods revealed the presence of two to three primary cluster groups, which was in general agreement with pedigree information and partly with the putative heterotic groups. The model-based population structure analysis in the same study assigned about half of the inbred lines into their putative heterotic group defined by breeders. There were 17, 14 and 5 inbred lines in cluster groups I, II and III, respectively. Cluster Group I was dominated by six lines from Ecuador heterotic group, four from Kitale group, two from Pool 9A group, and three from previously uncategorized lines. Cluster Group II was dominated by five lines extracted from Kitale heterotic group, four from Ecuador, four Pool9A, and one previously uncategorized line. In cluster Group III, two previously uncategorized lines, one from Kitale and one from Pool9A were all included in this group. However, the authors further explained that genotypes having the same name may be grouped differently in other studies at times. Such incongruities in assigning inbred lines into heterotic groups may occur due to seed handling or pollination errors (Rajab et al., 2006). It may also be caused by differential selection of the different lines in different environments, genetic drift, and mutation (Senior *et al.*, 1998). Legesse *et al.*, (2006), in their study entitled 'Genetic diversity of maize inbred lines revealed by SSR markers', managed to group 56 highland and mid-altitude adapted tropical maize inbred lines derived from local sources and CIMMYT origin using 27 SSR loci. Accordingly, cluster analysis using average linkage method (UPGMA) suggested five groups among the inbred lines. Most of the inbred lines adapted to the highlands and the mid-altitudes were positioned in different clusters with a few discrepancies. The pattern of groupings of the inbred lines was mostly consistent with available pedigree information.

Dagne *et al.*, (2019) analysed high-density genotyping by sequencing data from 298 African highland maize inbred lines, assessing genetic purity, relatedness, and population structure using 955,690 SNPs from Cornell University. The study selected 237,018 SNPs with a minor allele frequency (MAF) of $\geq$0.05 and a maximum missing data of 20%. The results showed that the log probability of the data (LnP(D)) and ad hoc statistics ΔK obtained from the model-based population structure analysis suggested that the 298 lines could be divided into two or three possible groups or sub-populations. However, when the results at various K values were compared with their pedigree information and breeding history, the groups obtained at K=3 were considered as the best possible number of groups. The proportions of inbred lines assigned to Group-1, Group-2, and Group-3 were 64%, 23%, and 12%, respectively, with only two lines belonging to a mixed group (Fig 2). According to the model-based structure, the neighbour-joining (NJ) tree constructed from the genetic distance matrix grouped 296 of the 298 inbred lines into three major groups and five sub-groups (Fig 3).

Another study by Berhanu *et al.*, (2017) on genetic variation and population structure of 265 maize inbred lines adapted to the mid-altitude sub-humid maize agro-ecology of Ethiopia used 220,878 SNP markers obtained through GBS. In this study, the population structure of the inbred lines was assessed using

Principal Component Analysis (PCA), discriminant analysis of principal components (DAPC), and the model-based structure. All the three methods revealed the presence of three distinct groups, with 94% agreement on group membership predicted by the different methods. Using DAPC, the first group was composed of 175 quality protein maize (QPM) and non-QPM inbred lines that were mainly extracted from broad-based pools and populations, such as PooL9A for non-QPM lines and Pop 62 and Pop 63 for QPM inbred lines. The authors finally concluded their work by suggesting the incorporation of high-density molecular marker information in future heterotic group assignments.

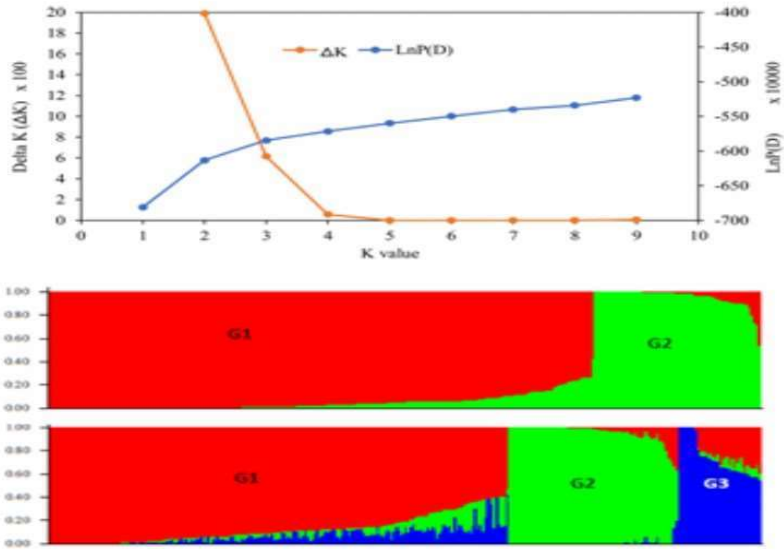

Fig 2. Population structure of 298 maize inbred lines based on 22,500 SNPs in Dataset-3: (a) plot of LnP(D) and a ΔK calculated for K ranging from 1 to 10, with each K repeated thrice; (b) population structure of the 298 inbred lines at K = 2 and K = 3. Every line is represented by a single vertical line that is partitioned into K colored segments on the x-axis, with lengths proportional to the estimated probability membership (y-axis) to each of the K inferred clusters. Source: Dagne et al. (2019).

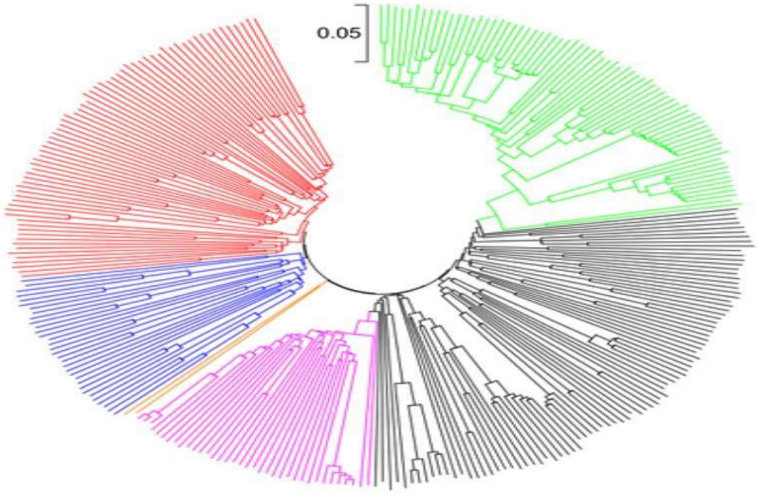

Fig 3. Neighbour-joining tree of 298 inbred lines based on identity-by-state genetic distance matrix computed from 235,019 SNPs, each with minor allele frequency >0.05. Line colors are as follows: Group-1A (black); Group-1B (red), Group-1C (blue), Group-2 (green), Group-3 (pink) and ungrouped (orange). Group-1, Group-2, and Group-3 were obtained based on the model-based STRUCTURE. Source: Dagne *et al*. (2019)

Genetic purity and quality control

Marker-based quality control (QC) is essential for ensuring purity and true-to-type maize genetic material within maize breeding programs. Mainstreaming QC using DNA markers provides breeders with rapid and cost-effective tests of the homozygosity of inbred lines, the homogeneity of populations, and the fidelity of crosses (Melaku and Abebe, 2019). Attempts to utilize markers for QC have been initiated in the era of low-throughput SSR marker assays (Semagn et al., 2012a). The rapidly declining cost of SNP based genotyping has opened up an opportunity for the routine use of SNP markers for quality control (QC) analysis, which is an important component in maize breeding and seed systems (Kassa et al., 2012a). Demissew et al., (2015) conducted a study to: i) understand the genetic purity existing in the maize inbred lines, ii) determine the effect of conversion of normal maize lines to QPM, and iii) patterns of relationships among 36 white maize inbred lines (30 QPM and 6 non-QPM) using 25 SSR markers. The study revealed a heterozygosity range of 4 to 16.7 % in the inbred lines with an average 7.9 %. More than half of the tested inbred lines had higher than the expected (6.25 %) mean residual heterozygosity for inbred lines developed after four generations of selfing.

Genotyping by next-generation sequencing (GBS) is an emerging method of SNP genotyping, which is being increasingly adopted for discovery applications, but exploration of its suitability for QC analysis has been limited (Brehanu et al., 2015). The same authors evaluated the magnitude of genetic purity and identity among two to nine seed sources of 16 inbred lines (including parental lines of eight popular Ethiopian hybrids (BH140, BH540, BHQP542, BH543, BHQPY545, BH660, BH670, and BH661) and different sources collected from the maize breeding program of the EIAR, seed companies, the Ethiopian Institute of Bio-diversity Conservation (IBC), and CIMMYT (Berhanu *et al*., 2015). The study used 191 Kompetitive Allele Specific PCR (KASP) and 257,268 GBS markers, compared the correlation between the KASP-based low and

the GBS-based high marker density on QC analysis. The authors revealed that the genetic purity and identity among two to nine seed sources of 16 inbred lines using 191 KASP and 257, 268 GBS markers varied from 49 to 100% for KASP and from 74 to 100 % for GBS. Almost all the inbred lines obtained from CIMMYT showed 98 to 100 % homogeneity irrespective of the marker type. In contrast, only 16 and 21 % of the samples obtained from EIAR and partners showed ≥95 % purity for KASP and GBS, respectively. The genetic distance among multiple sources of the same line designation varied from 0.000 to 0.295 for KASP and from 0.004 to 0.230 for GBS. The correlation between the 191 KASP and 257,268 GBS markers was 0.88 for purity and 0.93 for identity. A reduction in the number of GBS markers to 1, 343 decreased the correlation coefficient only by 0.03. Their results revealed high discrepancy both in genetic purity and identity by the origin of the seed sources irrespective of the type of genotyping platform and number of markers used for analyses. The conclusion from both methods was basically similar, which clearly suggested that smaller subsets of preselected and high-quality markers are sufficient for QC analysis that can easily be done using low marker density genotyping platforms, such as KASP.

Genome-Wide Association Study (GWAS)

Genome-wide association study is becoming a powerful tool to address interspecies relationships based on genotype by sequencing and phenotype data association study (Huang and Han, 2014). Genotyping by sequencing (GBS) is a next-generation sequencing (NGS) based genotyping approach that has dramatically facilitated large-scale genome-wide marker development and GWAS in crop species (Varshney et al., 2014). Several loci associated with agronomic traits such as plant height, yield and yield components, flowering time and plant architecture in a range of crops, including maize (Wang et al., 2012). Girum et al., (2013) also identified functional DNA markers such as crtRB1-5′TE and crtRB1-3′TE associated with provitamin A content across the tropical maize inbred lines. Berhanu et al., (2020) studied the nitrogen use efficiency in tropical adapted maize germplasm under optimum and low-nitrogen stress environments using GWAS and genetic prediction. Their study helped to identify most QTLs conferring tolerance to nitrogen stress were on a different chromosome position under optimum conditions. Such types of studies indicate the importance and wider application of GWAS in maize. However, application of GWAS and genetic prediction on complex traits in Ethiopia is limited. Combining GWAS and GS (genomic selection) with marker-assisted selection (MAS) accelerates maize breeding to develop improved cultivars with better performance for grain yield and other complex traits under diverse management conditions.

Genetic transformation attempts in maize

Over the last few decades, considerable research progress in plant biotechnology has allowed the development and formation of genetically modified maize varieties that have shown a significant yield improvement worldwide. In 2019, research reports indicated that 30% of the maize growing areas were covered by genetically modified maize varieties (ISAAA database, 2022), which contained transgenes associated with biotech traits such as herbicide, insect, disease resistance, abiotic stress tolerance, yield, improved nutritional quality, and were traits expected to be introduced into the market soon (Simmons et al., 2021; ISAAA database, 2022). The summary of research progress in maize genetic transformation protocols, applications, status, and regulatory issues in Ethiopia are briefly discussed below.

In Ethiopia, before starting genetic transformation techniques to develop and adopt any genetically modified organisms (GMOs), approval and written consent must be issued from the Ethiopian Environmental Protection Authority (EPA), according to the Biosafety Proclamation No. 896/2015, which is ratified by the Ethiopian House of Peoples Representatives. Legal permission and opinions could be granted by the EPA based on data provided by the applicant, inspection of

laboratories, and field trial sites. Additionally, approval should also be admitted from the Ethiopian National Biosafety Advisory Committee (NBAC) following the Council of Ministers of FDRE under Council of Ministers Regulation No. 411/2017.

Bedada et al., (2016) conducted a genetic transformation study on locally adapted African tropical maize genotypes by transferring the isopentenyl transferase gene to develop drought-tolerant tropical maize. The transferred (IPT) gene codes for the isopentenyl transferase enzyme, which catalyzes the rate-limiting step in the biosynthesis of cytokinin and has the function of delaying drought-induced leaf senescence. This study has the objective to investigate if the IPT gene can be useful in enhancing drought tolerance in locally adapted African tropical maize genotypes. The tropical maize inbred line CML216 was transformed with the IPT gene using the Agrobacterium-mediated transformation method. The study revealed that five transgenic lines were stably transformed through Southern blot analysis with copy numbers of two to four per event. Also, the drought assay carried out in the glasshouse, showed transgenic lines expressing the IPT gene are tolerant to drought as revealed by delayed leaf senescence compared to the wild-type plants. In addition, the study indicated that transgenic plants maintained higher relative water content and total chlorophyll during the drought period and produced significantly higher mean grain yield of 44.3 g/plant than the wild type (1.43 g/plant). This study suggested the transgenic lines developed need to be further tested for tolerance to drought under contained field trials to be used in maize breeding programs.

In another maize transformation study, Bedada et al., (2018) were able to evaluate the genetic transformability of regenerable tropical maize genotypes using the Agrobacterium-mediated transformation method and identify genotype(s), which can be used as better transgene recipients for future research. In this study, Agrobacterium strain EHA 101 was used to infect immature zygotic embryos using the phosphomannose-isomerase gene as a selectable marker. The transgenic plants were analyzed using PCR, Southern blot, and semi-quantitative RT-PCR and the result revealed the presence, stable integration, and expression of the transgene. Also, in this study, the author showed the genotype-dependent response of African tropical maize to Agrobacterium-mediated genetic transformation. Among the tested six maize genotypes, the CML216 (CIMMYT inbred line) and Melkassa-2 (Ethiopian open-pollinated variety) produced normal and fertile transgenic plants and were suggested for future use in genetic transformation research.

Conclusion and recommendations

In spite of all the efforts and progress made in the development and dissemination of maize technologies for different agro-ecologies in Ethiopia, the biotic and abiotic constraints remained the major limiting factors for maize production and productivity. The use of molecular tools in the Ethiopian maize breeding programs at small-scale has so far contributed to the enhancement of the breeding selection processes to some extent. Particularly, the relationships between molecular markers and phenotypic traits could be a significant diagnostic tool in marker assisted maize selection/breeding. The efficiency of the markers in different genetic backgrounds as well as their usefulness in breeding programs for the development of inbred lines and hybrid maize cultivars with different features need to be further demonstrated for wide applications of marker-assisted breeding techniques to enhance the breeding efficiency of maize improvement in Ethiopia.

Some recommended applicable areas, but not limited to, where molecular tools such as marker assisted breeding (MAB) are useful to maize breeding in Ethiopia can also be mentioned as future research directions. For example, several desirable traits in maize start to express only when the crop has reached flowering or get matured. But understanding a plant's genetic make-up before flowering or at seedling stage using MAB could be useful to make crossing plans between selected parents faster than the conventional approach. The other important area of application is that

environmental variations in the field reduce a trait's heritability, especially the low heritable traits, because complications in phenotypic selections of the traits are compounded by environmental variation, experimental error, or genotype x environment interaction, whereby MAB could be an effective method to make progress in phenotypic selections under various stresses and environmental conditions. Besides, there can be some desirable agronomic or quality traits in maize that may be governed by recessive genes and are of interest for use through conventional breeding. In conventional backcross breeding, plants with recessive genes are identified by progeny testing after inbreeding or testcrossing to a recessive tester. However, this process can be done within a short period of time by applying MAB to detect recessive genes linked to specific markers. Genetic purity and quality assurance tests using molecular techniques for commercial cultivars have been an untapped potential in seed business in Ethiopia, and hence need to be widely adopted.

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RESEARCH PAPER

Opportunities and Challenges in Implementing Active Learning Methods in English as a Foreign Language Classroom: The Case of Selected Government Secondary Schools in Bole Sub-City, Addis Ababa

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Abstract

This study was aimed at investigating opportunities and challenges in implementing active learning methods in EFL classrooms: the case of Grade 11 Selected Government Secondary Schools in Bole Sub-city, Addis Ababa in 2024/25. Subjects of the study were teachers, students, principals, and supervisors of the academic year 2024/25. An explanatory research design was also employed to achieve the objectives of this study. Different sampling techniques such as convenience, random, and availability sampling were used to include the school, teachers, students, principals, and supervisors. The data was collected by using questionnaires, interviews, and classroom observation. The collected data were analyzed quantitatively and qualitatively. This study showed that teachers' practice of active learning methods was low. The study also identified challenges such as large class size, time constraints, shortage of resources and materials, teachers' lack of interest in active learning, students' lack of self-direction, collaboration, or independent problem-solving skills, and teachers' lack of necessary training as the challenges that affect their implementation of active learning and teaching methods. The identified opportunities for implementing active learning methods were administrative support, availability of professional development, students' engagement, adaptability, teacher collaboration, curriculum flexibility and using existing opportunities. In addition to this, active learning is successfully implemented if the challenges are minimized and opportunities are maximized. Therefore, teachers, principals, and supervisors should work cooperatively for the successful implementation of active learning and teaching methods.

Keywords: opportunities, challenges, implementing, active learning methods

Introduction

Teaching English as a foreign language world has expanded with the increasing international demand for English (Melchers and Shaw, 2011). In Africa, where English is often learned as a lingua franca, continental practices may focus on addressing the challenges faced by learners from diverse linguistic backgrounds. Efforts are made to promote multilingualism, maintain and develop indigenous languages while teaching English, and ensure that English instruction is culturally relevant and inclusive. Generally, these international, regional, and continental practices in the teaching of English acknowledge the importance of context, learner needs, and cultural diversity. They aim to provide effective language instruction, foster communicative competence, and empower learners with the skills and knowledge necessary for global communication and intercultural understanding.

Hence, in Ethiopia, there has been a growing emphasis on active learning methods in recent years. The Ethiopian education system has

undergone reforms to promote learner-centered approaches, and active learning is seen as a means to achieve this goal. The Ministry of Education in Ethiopia has introduced policies and guidelines that emphasize the use of active learning strategies in classrooms. These initiatives aim to enhance student engagement, critical thinking, and practical application of knowledge (Ethiopia Education Policy, 2015).

The English language is omnipresent in cityscapes around the world. Its expansion is ever more extensive. This extensive growth is also regional. It is seen as a key language to serve Ethiopia as a medium of international communication. English language expansion is also in an intensive manner. One can experience the intensification of it in different ways such as through media, the internet, YouTube, Facebook, Twitter, etc. (Tolera and Jim, 2024). All international organizations, most non-governmental organizations, and Ethiopian Airlines, the Commercial Bank of Ethiopia and the Ethiopian Insurance Corporation use English. To this end, to improve students' English proficiencies, the implementation of an active learning method is paramount.

Different methods introduced over several decades contributed to the teaching and learning of English. Here are some of the various methods and approaches that have been introduced in the field of English language teaching over the decades, each making unique contributions to the teaching and learning process. To begin with, the grammar-translation method, direct method, audio-lingual method, communicative language teaching, task-based language teaching, Content-Based instruction, Natural Approach, Silent Way, Suggestopedia (Richards and Rodgers, 2014; Yüksel and Caner, 2014; Willis and Willis, 2007) were some of them.

The theories of teaching and learning can be passive approaches or active approaches in terms of active learning methods. Passive approaches to language teaching refer to instructional methods that focus on the passive reception of language input rather than active production and engagement, whereas active approaches focus on student-centered approaches, active learning, and the development of critical thinking skills (Richards and Rodgers, 2014). We can observe that the centuries between 18th to early 20th are known as the time of traditional theories. However, mid-20th century onwards theories are considered modern/current or contemporary theories in education. Theories such as: behaviorism, essentialism, grammar translation method, audio-lingual method, reading and listening-only instruction, teacher-centered instruction, rote memorization, etc. are traditional approaches. However, constructivism, social constructivism, cognitive theory, inquiry-based learning, experiential learning, connectivism etc. are contemporary approaches in the eyes of active learning methods (Narayan *et al*., 2013).

These theories represent a range of perspectives on education, with traditional theories often being foundational but sometimes criticized for their limitations in addressing the diverse needs of learners. Current theories aim to address these limitations by promoting student-centered approaches, active learning, and the development of critical thinking skills. It is important to note that there is ongoing debate and evolution in educational theory, with new ideas and approaches emerging as our understanding of learning and teaching continues to evolve.

In recent years, Ethiopia has implemented language policy and curriculum reforms to improve English language teaching and learning. These reforms aim to enhance the communicative competence of learners by integrating active teaching methods and promoting learner-centered approaches (Hunde and Hika, 2023; Teshome, 2017). According to the General Education Curriculum Framework (2020), learning is understood as a process of change resulting from engagement in meaningful exploratory, investigative, and inquisitive activities by learners who take increasingly growing ownership of their learning.

The Ethiopian government invested so many budgets on education in general and to revise

English students' textbooks in particular. However, many scholars complain that most Ethiopian students are poor at using the English Language (Bishaw and Melesse, 2017). Teaching methods can be one of the factors behind the students' failure to use English in Ethiopia. According to Peng (2024), the use of various teaching methods, especially active learning methods, has a great impact on students' language learning. To this end, Kassa *et al*. (2024) found that the practice of active learning methods in Ethiopia is very low, where lecture methods are frequently used. Students' cognitive ability and problem-solving abilities and skills can be achieved through the implementation of active learning techniques (Mebratu and Woldemariam, 2018). While active learning approaches have gained recognition for their potential to enhance student engagement and learning outcomes, there is a need to examine their implementation and effectiveness in specific educational settings.

In international contexts, Lumpkin *et al*. (2015) conducted on the students' perceptions of active learning methods and found that students perceived active learning methods positively. Aga (2023) conducted a study on the challenges and motivation for teachers transitioning to active learning spaces in Norway. Aga found that poor handling of the challenges reduced the teachers' motivation to implement active learning methods. A study conducted by Liu and Ren (2024) in China looked at the challenges of implementing task-based language teaching (TBLT) in EFL classrooms. The study found that limited teacher training and large class sizes were major challenges in implementing TBLT effectively. These findings may be relevant to the Ethiopian context, where limited teacher training and large class sizes have also been identified as challenges in implementing active learning methods.

Current researches conducted in local and international contexts complain about Ethiopian students' English language proficiency (Yilkal, 2017). English is used as a foreign language in Ethiopia, and most students have very limited access to the English language. Therefore, active learning methods in the classroom are paramount (Özkan, 2016). On top of this, although the active learning method was introduced in Ethiopia about 20 years ago and has been implemented in primary and secondary schools, little change has been noticed in students' English language skills development (Haile, 2018; Ayalew, 2017). Tilahun (2023) also carried out a study on the practice and challenges of implementing active learning methods in the north, and almost all of the teachers have positively perceived active learning.

The researchers of this study also observed a lack of implementation of active learning methods while working as teachers and school principals in secondary schools, respectively, as well as the theoretical understanding gained through their doctoral and second-degree thesis studies, which made them interest in this area. Hence, there is a need to investigate opportunities and challenges in implementing active learning methods in EFL classrooms: The Case of Bole Secondary School in Bole Sub-City, Addis Ababa. Specifically, this study attempted to investigate the practices in implementing active learning methods in government secondary schools of Bole Sub-City; the relationship between the perceived challenges and the implementation of active learning and teaching methods. Finally, the study evaluated the extent to which the perceived challenges and opportunities affect the implementation of active learning and teaching methods in the selected secondary schools.

Significance of the Study

Studying practices, opportunities, and challenges in implementing active learning and teaching methods in secondary schools hold both theoretical and practical significance in this study. It contributes to educational theory, informs policy development, enhances student engagement and learning outcomes, supports professional teacher development, promotes educational equity, and prepares students for the demands of the future workforce. Active learning and teaching methods align with modern educational theories that emphasize

student engagement, critical thinking, and collaborative learning. Studying these methods can contribute to the development and refinement of educational theories and pedagogical practices. Answering the research questions of this study has important theoretical and practical ramifications, adding to the corpus of knowledge in education and offering useful advice for secondary school implementation.

Materials and methods

Research Design

The study is aimed at investigating the opportunities and challenges in implementing active learning methods in EFL classrooms. In order to achieve the objectives of this study, both descriptive and explanatory research designs were used. According to Creswell and Clark (2017), the descriptive survey research type is particularly used when one needs to understand some particular information and describe the characteristics of a particular individual, group or situation. In this study, EFL teachers' practice of active learning methods and challenges that affect the implementation of it were investigated. Explanatory research design was also employed to achieve the objectives of this study. An explanatory research design is a type of research design that aims to explore and explain the relationship between variables, uncover causal relationships, and provide a deeper understanding of the phenomena under investigation (Maxwell and Miller, 2018). The use of explanatory research design also provides a deeper understanding of the relationships between opportunities and challenges that contribute to the implementation of active learning and teaching methods.

Analysis Participants of the Study

The purpose of this study is to investigate the opportunities and challenges in implementing active learning and teaching methods in EFL Classrooms: The Case of Grade 11 Selected Government Secondary Schools in Bole Sub-city, Addis Ababa. The two selected government secondary schools were: Ayer Amba, and Lem secondary schools. The participants of the study were teachers, students, principals and supervisors of the sub-city. From these schools, 30 EFL teachers, 50 grade 11 students, 2 principals, and 2 supervisors were included in the study. The data were gathered from primary sources. Therefore, the primary sources for the study were teachers, students, principals and supervisors of the academic year 2024/25.

Descriptions of Study Area

This study was carried out in Addis Ababa City in Bole Sub-city. Bole Sub-city is one of the 11 sub-cities of Addis Ababa, Ethiopia. Bole Sub city is a busy, affluent sub city centred on Addis Ababa, reflecting the city's rich history, cultural heritage, and urban development. It serves as a commercial, educational, and administrative hub within the capital city. Bole sub-city is bordered in the north by Arada sub-city, in the east by Akaki Kality sub-city, in the west by Yeka sub-city, and the south by the Kirkos sub-city.

Sampling and Sampling Techniques

Different sampling techniques were used in this study for different subjects. For instance, secondary schools in Bole Sub-city Administration were included by using a convenience sampling technique. The convenience sampling technique was chosen because the researchers could easily select participants of this study based on their relative ease of access (Kumar, 2005). This means the secondary school's geographical nearness and accessibility to the researchers are considered in choosing the study area (Dornyei, 2007). The other sampling techniques that the researchers used were systematic random sampling and availability sampling. In systematic random sampling, 100 grade 11 EFL classroom students were selected, whereas availability sampling was used to get detailed information from teachers, principals, and supervisors. In availability sampling, 40 grade 11 English teachers, 2 principals and supervisor were included for this study. Among 30 English teachers, 3 of them were selected in order to

carry out classroom observation. Each classroom was observed three times. Two principals and two supervisors participated in the interview. The following formula was used to include 50 participants from 500 students.

$$K = \frac{N(500)}{n(50)} = 5$$

The researcher randomly selected number 5 and then 10, 15, 20 until 50 students were selected.

Instruments of Data Collection

To gather necessary data from the sample participants, three types of data-gathering instruments were used in this study. These are questionnaires, interviews, and classroom observation because the researchers believed that data gathering using these instruments are more important to obtain valid and reliable information and to cross and validate the instruments.

Questionnaire

The questionnaire is the heart of descriptive operation (Kothari, 2004). Questionnaires in this study were used to collect data about the practices, challenges, and opportunities in implementing active learning methods in the learning and teaching of English. Questionnaires were prepared by the researchers by reading previous literature. Questionnaires were also used to collect information about the extent to which the perceived challenges and opportunities affect the implementation of active learning and teaching methods. In this study, test-retest reliability was used to check test reliability. Test-retest reliability is used to gauge the consistency of scores in questionnaires over time for the same person. In addition to this, the validity of the instrument was ensured by using judgmental validation by a committee of experts that was made by the researchers.

Interview

Interviews were carried out to collect data about practice, challenges, and opportunities of active learning and teaching method implementation. A semi-structured interview type was used to collect necessary data and to triangulate data collected by questionnaires. In light of this, to supplement the data obtained through the questionnaire the researchers themselves conducted interviews with principals and supervisors using open-ended questions which were related to the practices and challenges in implementing active learning and teaching methods in the EFL classroom. Principals and supervisors were interviewed to collect data about challenges and opportunities existing in implementing active learning and teaching methods in the selected government secondary schools.

Classroom Observation

Observation is a purposeful, systematic and selective way of watching and listening to the interactions of a phenomenon as takes place (Kumar, 2005). The purpose of using classroom observation is to investigate teachers' practice of active learning and the challenges in the implementation of it. Creswell (2008) identified two types of observation, namely, participant and nonparticipant observation. In this study, the non-participant observation type was used because the researchers simply watched teachers and students; activities while teaching and learning English. Observation checklists were prepared and used during classroom observation. Three teachers were observed three times each for the practices and challenges in implementing active learning and teaching methods in EFL classrooms.

Methods of Data Analysis

Data were collected using both quantitative and qualitative methods. Hence, the data were analysed both quantitatively and qualitatively. The Statistical Package for Social Sciences (SPSS, 26.0 versions for windows) were employed for the analysis of quantitative data. Measures of central tendencies such as mean, standard deviations, and Pearson correlation

were used. The qualitative data were analyzed thematically.

Results and discussions

Table 1. Analysis of students' questionnaire on teachers' practice of active learning methods

No.	Items	Mean	Std. Dev.
1	Our English teacher encourage the students to participate actively in the classroom	3.80	1.29
2	Our English teacher follows students' engagement in the learning process	3.12	1.45
3	Our English teacher motivate students to do group activities with their peers	3.60	1.47
4	Our English teacher include experiential learning activities in the classroom	2.86	1.41
5	Our English teacher use technology to make teaching-learning process practical	3.34	1.30
6	Our English teacher give us problem-solving activities in the classrooms	3.88	1.28
7	Our English teacher provide opportunities for discussions and debates	2.98	1.62
8	Our English teacher give assignments that require students to demonstrate their knowledge in a creative way	2.62	1.24
9	Our English teacher provide opportunities for self-directed learning	3.00	1.26
10	Our English teacher use peer teaching methods in the classroom	3.28	1.35
11	Our English teacher make students to discuss in pairs and share their views to their classmates	4.28	1.14

Table 1 presents data about teachers' practice of active learning methods. The questionnaires were answered by using a likert scale from never to always, which were numbered as never (1), rarely (2), sometimes (3), often (4) and always (5). Depending on this, as it can be seen from the Table1 in item 5, the respondents responded that their teachers rarely used technology to make teaching-learning process practical, with a mean score of 3.34 and a 1.30 standard deviation score.

As it can be seen from Table 1, the teachers sometimes encourage students to participate

actively in the classroom (mean score of 3.80), follows students engagement (mean of 3.12 and 1.45 standard deviation), motivate students to do group activities (mean score of 3.60 and 1.47 standard deviation), include experiential learning activities in the classroom (mean of 2.86 and 1.41 standard deviation), problem-solving activities (mean score of 3.88 and 1.28 standard deviation), provided opportunities for discussions and debates that encourage active participation and critical thinking (2.98 and 1.62 mean and standard deviation scores (item 8), assigned assignments that require students to demonstrate their knowledge in a creative way mean and standard deviation 2.62 and 1.24 mean and standard deviation scores, respectively.

Table 2. Analysis of the challenges in the implementing active learning and teaching methods

No.	Items	Mean	Std. Deviation
1	There are students' resistance to implement active learning and teaching methods	3.90	1.21
2	Time constraints can limit opportunities for reflection, feedback, and revision	3.62	1.33
3	There are teachers lack of preparation to teach effectively in the classroom	3.64	1.24
4	Large class size affects the implementation of active learning and teaching methods	4.04	1.19
5	Students sitting arrangement affects the implementation of group activities	4.08	1.22
6	There is lack of parents' engagement in the implementation of active learning and teaching methods	3.52	1.47
7	There are teachers lack of classroom management	3.70	1.28
8	The lack of individual accountability in group work makes it difficult to assess students learning progress	3.88	1.28
9	There is lack of collaboration among students in the implementation of active learning and teaching methods	2.48	1.32
10	Cultural differences among students create challenges in group activities during active learning and teaching methods	2.46	1.44
11	Teachers ensure inconsistency in the implementation of active learning and teaching methods across classrooms	2.18	1.36
12	There are insufficient resources (e.g., materials, technology) available for active learning and teaching methods in classroom	4.02	1.23

Table 2 presents information about the challenges of implementing active learning methods. The teachers answered the questionnaires by using a likert from scale strongly agrees to strongly disagree. Based on this, strongly agree (5), agree (4), undecided (3), disagree (2) and 1 represents strongly disagree. As it can be seen from Table 2 in item 4, the teachers strongly agreed that large class size affects the implementation of active learning and teaching methods (with a mean score of 4.04 and a 1.19 standard deviation score). Most teachers agreed that time constraints are a common challenge when implementing active learning and teaching methods (3.62), there is students' resistance to active teaching and learning methods (3.90), there is insufficient resources in the implementation of active learning and teaching methods (4.02), teachers' lack of preparation to teach effectively in the classroom (3.64), there is lack of classroom management (3.70), lack of collaboration among students (2.48), and cultural differences among students (2.46) were some of the challenges that affect their implementation of active learning methods. In order to analyses the correlation between the perceived challenges and the implementation of active learning and teaching methods, a Pearson correlation coefficient was carried out. Papageorgiou (2022) states that the correlation coefficient ranges from negative 1 to positive 1. Negative 1 indicates that there is a negative relationship; zero indicates no relationship, and 1 indicates a strong positive relationship.

The result of the Pearson correlation coefficient of this study indicated that the Pearson correlation analysis between the perceived challenges and the implementation of active learning methods yielded a correlation coefficient of .830, with a p-value of .001, which indicates that there is a strong relationship between the perceived challenges and the implementation of active learning methods.

Table 3. Correlation analysis of the relationship between the perceived challenges and the implementation of active learning and teaching methods

		Perceived challenges	Implementation of active learning and teaching methods
Perceived challenges	Pearson Correlation	1	.516
	Sig (2-tailed)	.720	.720
Implementation of active learning and teaching methods	Pearson Correlation	.567	1
	Sig (2-tailed)	.830	.830

This means there is a statistically significant relationship between the variables. In other words, when the perceived challenges increase, the implementations of active learning methods decrease. The strength of the relationship between the two variables suggests that addressing the perceived challenges is an important factor in promoting active learning methods.

Analyses of the extent to which the perceived challenges and the opportunities affect the implementation of active learning and teaching methods

It is also important to run regression since it allows quantifying the influence of the perceived challenges and opportunities on the implementation of active learning. It can also help to understand how the perceived challenges and opportunities predict the implementation of active learning methods (Aiken *et al*., 2003). In regression analyses, R-squared and adjusted R-squared are important measurements to provide information about the goodness of the regression model. The R-squared ranges from zero to one, where zero indicates the model explains no variability in the dependent variable, and one shows that the model explains all variability in the dependent variable (Chicco *et al*., 2021).

Table 4. Analyses of the goodness fit of the model

Model	R	R-squared	Adjusted R-squared
1	0.780	0.608	0.580

In addition to this, multiple linear regression was calculated for both the perceived challenges and opportunities as well as the implementation of active learning methods, which were measured on a continuous scale (Aiken *et al*., 2003). In this study, the dependent variable is the implementation of active learning methods, while the independent variables are perceived challenges and opportunities. Multiple linear models were used to analyze the relationship between the dependent variable and independent variables. The identified challenges were lack of teaching training on active learning methods, limited resources, student resistance, lack of time, lack of administrative support, and large class size. The identified opportunities for implementing active learning methods were administrative support, availability of professional development, students' engagement, adaptability, teacher collaboration, curriculum flexibility, and using other existing opportunities.

Table 5. Analyses of the perceived challenges and the opportunities affect the implementation of active learning and teaching methods in the selected secondary schools

Variables	Coefficient	Std. Errors	t-value	p-value
Intercept	4. 250	0.350	17.14	0.001
Perceived challenges	-0.450	0.135	-4.33	-0.001
Perceived opportunities	0.356	0.080	4.56	0.001

As it can be seen in Table 4, the perceived challenges have a statistically significant negative effect on the implementation of active learning methods, with a coefficient of -0.450 (p-value of .001). However, the perceived opportunities have a statistically significant positive effect on the implementation of active learning methods, with a coefficient of 0.356 (p-value .001). In Table 4, the R-squared was .608, while the adjusted R-squared was .580. This study found that addressing the challenges such as lack of teaching training on active learning methods, limited resources, student resistance, lack of time, lack of administrative support, and large class size, while empowering the perceived opportunities, such as administrative support, availability of professional development, students' engagement, adaptability, teacher collaborative, curriculum flexibility, and using existing opportunities are effective strategies for promoting the implementation of active learning methods in secondary schools.

Analysis of Interview

In order to see how principals' concepts of active learning methods, the first interview question was: 'How would you describe the overall instructional approach in the school you manage? Describe the initiatives used in the learning and teaching of English? What do you think this approach is?' P1 said:

''*As a school principal, I can describe the overall instructional approach in the school I manage as focused on active, student-centered learning. Our goal is to engage students deeply in the learning process and help them develop critical thinking, problem-solving, and collaboration skills.*'' In a similar way, P2 said that '' In the learning and teaching of English, I encouraged English teachers to collaborate with teachers in other subject areas to create cross-curricular learning opportunities, which may help students engage in tasks that integrate English language skills with contents from other study areas''. According to Bane gass (2011), the integration of English language teaching and learning with other subjects helps learners to see the relevance and real-world applications of English language learning. Principals were also asked the opportunities to implement active learning and teaching methods. Both of the interviewed principals agreed upon providing comprehensive training and worship for their teachers on active learning strategies, instructional design and assessment in active learning approaches. They also reported that by allocating time and resources for teachers, it is possible to share the best experiences on active learning methods. They also said that ''the teachers' readiness and lack of confidence, skills and knowledge in order to design and facilitate active learning methods were one of the challenges''. One of the principals argues that teachers complain about the lack of time and large class sizes to implement active learning methods effectively. Both of the principals who participated in the interview agreed that lack of resources was one of the challenges they and their teachers face in implementing active learning methods. Cattaneo (2017) also found that the school may face limitations time and budget to invest high-quality instructional materials in implementing active learning methods.

The supervisor selected for the interview was coded as S1. The roles of supervisors in schools are very crucial in school management. For example, they provide guidance, give feedback, assess the learning goals, allocate resources, design and implement professional development programs, and deal with

challenges schools face in the teaching and learning process (Birkeli *et al*., 2023). In this study, the interview questions with the supervisor dealt with the existing opportunities to implement active learning and teaching methods, and the challenges in implementing active learning and teaching methods.

School supervisors should have a clear understanding of active learning methods, and their characteristics to help their implementation in the classroom (Al-Kiyumi and Hammad, 2020). The interview with the supervisor was concerned with checking their understanding of the fundamental principles of the active learning method or not. Accordingly, S1 reported that he knew well the difference between active learning methods and traditional teaching methods. When it comes to the benefits of active learning methods, S2 said: ‘*’I know the benefits of active learning methods, such as to enhance students’ engagement, retention of knowledge and lead to achieve well in academic*.’’ Supervisor had comprehensive knowledge of active learning strategies and techniques such as: collaborative learning, project-based learning, inquiry-based learning, etc. However, because of workloads, they could not able to guide effective implementation of active learning experiences.

Analysis of Classroom Observation

By using classroom observation, the researchers observed students; engagement, instructional strategies they used, their language practices, students’ collaboration and interactions, assessments and feedback they use, opportunities they had, and challenges they faced in implementing active learning methods in the EFL classroom. To begin with, in order to observe students’ engagement during the lessons, how they actively asked questions, shared ideas, and collaborated with their peers was observed. Accordingly, most of the students did not participate in many lessons. In addition to this, instructional techniques the teachers used were observed. Most of them used peer work, group work and whole class work. However, most of them did not use other active learning methods techniques such as role-paly, questioning and discussions, inquiry-based learning, hands-on activities and others. However, research supports that teachers can create dynamic, engaging, and successful learning experiences that improve students' language proficiency, communication skills, and overall academic and personal growth by incorporating active learning strategies into language instruction (Manzano *et al*., 2023).

In the observed classes, the teachers used only textbooks as instructional materials, but did not use digital tools and multimedia resources. These in turn enhance students’ engagement and language practice (Becirovic *et al*., 2021). How English teachers tried to adjust active learning activities in order to cater the diverse needs and levels of the students. In a similar way, how they assessed their students’ learning and provided timely feedback during English class was observed. As mentioned earlier, the teachers sometimes asked questions during the pre-teaching and after their lessons; only some teachers asked questions while teaching. Some of them asked their students to summarize lessons after the lessons, and home-take assignments. How those teachers assessed alignment between active learning techniques and the overall learning in the classrooms was not sufficient.

In English language teaching, different language practices and skills development techniques such as: interactive activities, integrated skills approach, focused group practices, use of authentic materials and scaffolding techniques were utilized by teachers.

In the classes observed, most of the teachers used the four languages skills such as: listening, speaking, reading and writing so as to help the students to improve their skills. On the other hand, some activities were given by the teacher in the classroom at the end of each topic to check the students’ understanding of the lessons. Moreover, the teacher guided and supported the students by moving in the classroom while they did their tasks. Hence, these activities helped the students to implement active learning and teaching methods and to build a sense of team spirit by

working cooperatively with each other.

Classrooms were observed to see what opportunities teachers had in implementing active learning methods. Accordingly, questioning techniques they used were observed, that is, the teachers frequently asked questions that encouraged their students to think critically and engage in discussion before and after their lessons. During the classroom observation, students are given the opportunities to do the activities in pairs and groups. The teacher encouraged them to work cooperatively to promote active participation in the effective implementation of active learning and teaching processes in the classrooms.

Why did you integrate the data you obtained through questionnaires, interviews and classroom observation into your conclusion here?

Upon gathering and evaluating data through a variety of instruments, it is recommended to present the key findings or conclusions in this section.

Recommendation

This study found several challenges that affect the implementation of active learning methods, and opportunities for implementing them. Therefore, teachers, principals, supervisors and all concerned bodies should work to minimize the challenges and maximize the opportunities to implement active learning methods.

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RESEARCH PAPER

Effects of Crop Management Practices on Selected Soil Physicochemical Properties in Bako Tibe District, Western Ethiopia

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Abstract

Indecorous land use and management systems have a negative effect on soil properties, which is related to the sustainability of agricultural production. With this in view, the study was conducted to investigate the effects of crop rotation on selected soil physicochemical properties in Bako Tibe district, Western Ethiopia. The composite soil samples were collected randomly from three cropping systems with similar slopes adjacent to each other. Selected soil physicochemical parameters were analysed by using standard procedures. The dominant textural classes of the soils under all crops were sand clay loam at 0-20 cm and sandy clay at 20-40 cm soil depth. The highest bulk density (1.29 gcm-3) and lowest bulk density (1.27 gcm-3) was observed under continuous maize and Maize Faba Bean -wheat. The highest (6.68) and lowest (5.66) soil pH values were observed in Maize-Faba Bean-Wheat and Continues Maize, respectively. The highest (3.85%) and lowest (3.10%) soil organic carbon was observed under Maize Faba Bean Wheat and Continues Maize, respectively. The highest (0.42%) and lowest (0.28%) mean of total nitrogen contents were observed under Maize- Faba Bean -Wheat and continuous maize, respectively. The mean values of cation exchange capacity range from 33.38 to 30.97meq100g-1 under the cropping system. The soil physicochemical parameters decreased from Maize- Faba Bean -Wheat to Maize- Faba Bean and Continues Maize. Therefore, selected soil physicochemical properties under continuous maize should be needed through educating and training farmers on integrated land management for sustainable crop production.

Keywords: Bako-Tibe, crop management, faba bean, maize and soil properties

Introduction

Soil is the base of nourishing life on earth and sustains the maintenance of all terrestrial ecosystems (Belay, 2003). Reducing soil resource degradation, increasing agricultural productivity, reducing poverty and achieving food security are major challenges of the countries in Africa. However, soil fertility decline has been one of the most challenging and limiting factors for food insecurity in the region. Land degradation through soil erosion and nutrient depletion is a major concern in Ethiopia, given the strong negative impacts on crop productivity, food security, the environment and quality of life (MoARD, 2010).

The causes of soil degradation in Ethiopia are cultivation on steep and fragile soils, erratic and erosive rainfall patterns, declining use of fallow and limited recycling of dung and crop residues to the soil, limited application of external sources of plant nutrients, overgrazing and deforestation (Belay, 2003). Management practices in the areas of intensive agriculture may affect soil properties as they vary

according to soil formation factors such as parent material, topography and climate (Celik *et al*., 2011). The overall productivity and sustainability of a given agricultural sector is highly dependent on the fertility and physicochemical characteristics of soil resources (Mohammed *et. al*., 2005).

Depletion of soil nutrients is a reversible constraint as long as soil test-based fertilizer application is in place (Fassil and Charles, 2009). However, assessing soil fertility status is difficult because most soil chemical properties either change very slowly or have large seasonal fluctuations; in both cases, it requires long-term research commitment (Taye and Yifru, 2010). Soil and water conservation practices are influential tools that enable the productive potential of the soil. Management practices to sustain crop yields are necessary to conserve or enhance soil quality (Aziz *et al*., 2009).

The periodic assessment of important soil properties and their responses to changes in land management are necessary in order to improve and maintain the fertility and productivity of soils (Wakene and Heluf, 2003). Although knowledge of soil quality status plays a vital role in enhancing production and productivity of the agricultural sector on a sustainable basis, currently only a little scientific information is available on the magnitude of soil quality changes under different land uses and crop production systems. In addition, the information on the management system of soil quality is pertinent to sustainable crop production in the country in general and in the study area in particular.

The expansion of agriculture to meet the demands of the growing population such as food and fiber at the expense of vegetated lands is the most significant historical change in all parts of the world (Liebman *et al*., 2003). Poor soil management practices, including the removal of crop residues and burning, intensive tillage, and mono-cropping farming practices that expose the soil to leaching and erosion lead to a decline in soil fertility. One of the main challenges in Western Oromia generally and particularly in Bako district, where maize is the main staple and major producing crop, is continuous mono-cropping with residue removal through burning and/or used for other purposes (Wakene, 2001). In the study area, the losses of soil physicochemical properties were because of different anthropogenic factors such as mono-cropping, land degradation, removal of crop residue and animals' manure for different purposes. Therefore, the objective was to evaluate the effects of crop management practices on soil physicochemical properties in Bako Tibe District, Western Ethiopia.

Materials and methods

Description of Study Areas

The study was conducted in Bako Tibe District, West Shewa Zone, Oromia Regional National State Ethiopia. It is 250 km away from Finfinnee and 125 km away from Ambo town (Figure 1). This District has a longitude and latitude of 9°08′N 37°03′E with an altitude ranging from 1727 to 1778 meters above sea level (masl) (CSA, 2007). The study area was covered by natural forest 20 years back. But today almost all of them have disappeared due to rapid increase in population and high deforestation in order to obtain more land for cultivation, grazing, timber, charcoal and settlement. The total area of the BakoTibe District is 63,988.17 ha of land, out of the total area 42,916.28 ha (67.07%) cultivable land, 980.2 ha (1.53%), grazing land, 1891.85ha (2.96%) Built up (covered in buildings, roads etc), 5207.97 ha (8.14%) forest land, 9581.04 ha (14.97%) bush and shrubs land, 3410.83 ha (5.33%) Wetland (Figure 2).

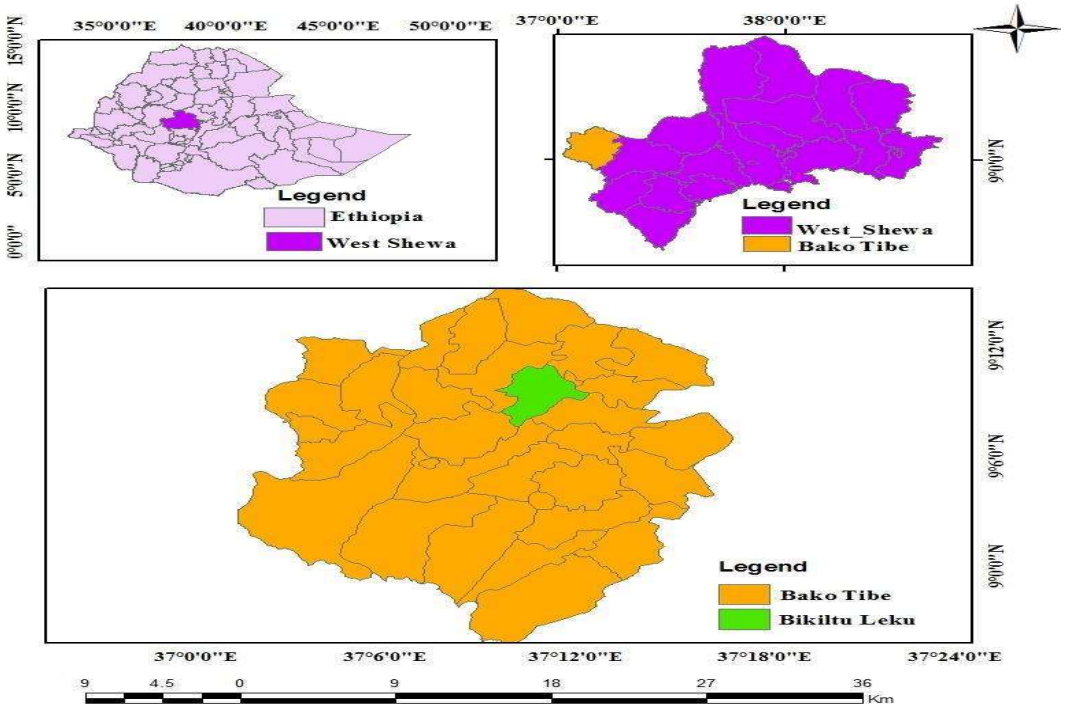

Figure 1.Map of the Study Area

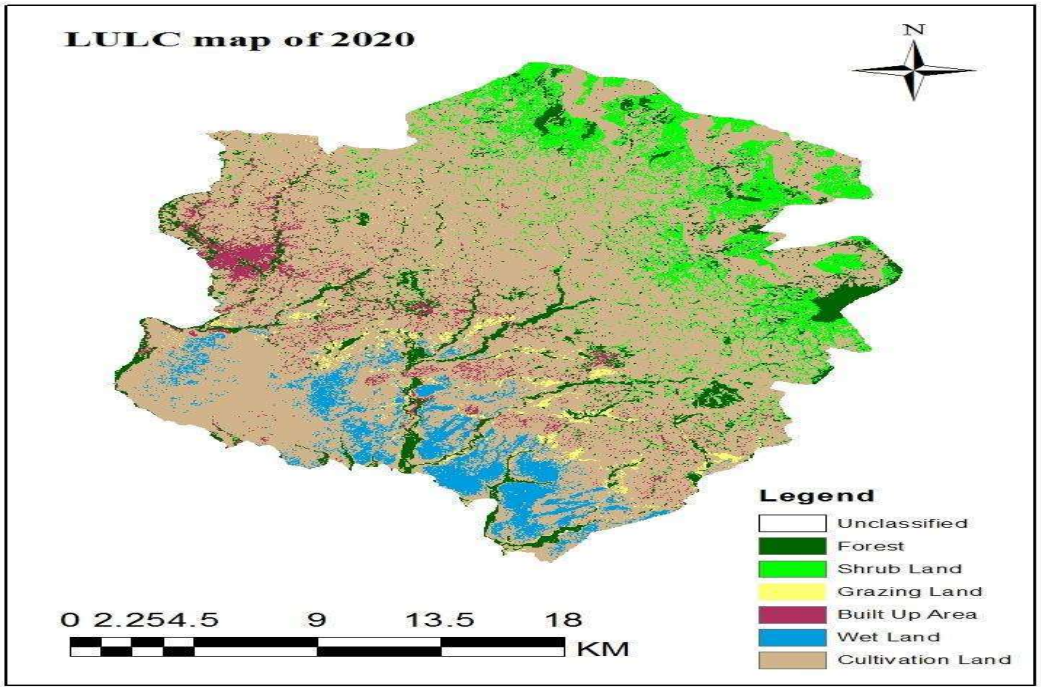

Figure. 2. Land Use Land Cover Map of the Study Area

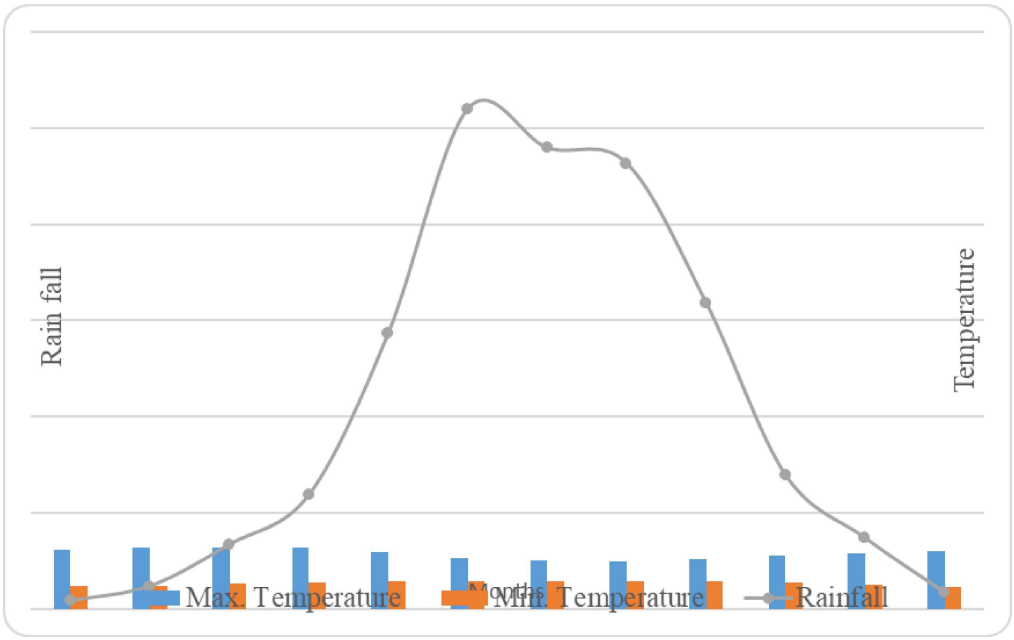

Figure 3.Mean annual rainfall and Temperature for fifteen years (2005-2019), (BARCMS, 2020)

Climatic condition of the study area

The major Agro-ecological zones of the study area are semi-arid, sub-humid and humid with unimodal rainfall characteristics. The area receives an average rainfall annually of 1257.98 mm and the temperature (^{0}C) ranges from 13.42^{0}C to 28. 73^{0}C. The rainy season extends from May to September and maximum rain is received in the months of June to August (BARCMS, 2020).

Major soil types and vegetation

The major soil types of the area were 55% red soil (Biyyoo Diimaa), 15% black cotton soil Vertisols (Biyyoo Gurraacha) and 25 % brown soil (Biyyoo Magaala) (BARC, 2014). The most dominant soil in the area is reddish brown Nitisols. The textural class of soil in the study area was dominated by clay and loam. The area is endowed with diverse vegetation species ranging from little dense and old natural forests in pocket areas at the tips of both up and downstream sides, to the patch of sparse shrub-grass complex in various areas. Dominant tree species in the area include Cordia africana (Waddeessa), Ficus vista (Qilxuu), Croton mycrostachyus (Bakkanniisa), and the exotic tree species Eucalyptus camalduleses (Baargamoo Diimaa (BARDO, 2019).

Farming System

The area is known for the mixed crop-livestock farming system in which cultivation of Maize (Zea mays L), Niger seed (Guizota abyssinicaL.), Potato (Solanum tuberosumL.), Sweet potato (IpomoeabatatasL.), Hot pepper(Capsicum frutescence L.) and Mango (Mangifera indicaL.), Banana (Musaspp.), Sugarcane (Saccharum officinarumL.), teff (Eragrostis tef (zucc.) and Haricot bean (Phaseolus vulgaris L.) are the major cropping activities. Maize and pepper were the dominant crops grown in the area (BARDO, 2015). Mixed farming is the major economic activity that involves crop and livestock production systems. Livestock production is an essential part of the farming system as nearly most of the land preparation is done with ox-drawn ploughs.

Site selection

During site selection, the general geography of the area was identified, purposively. The criteria used to select the kebele where three selected different crop cultivation systems for more than 5 years, continuous maize cultivation, maize_faba bean cultivation and maize - faba bean - wheat cultivation dominantly and Biqiltu laku kebele was considered as the representative of the district.

Soil Sample Collection

The soil samples were taken from different crop management systems using the transect sampling method. Samples were taken from each cropping system (continuous Maize cultivation, Maize- Faba bean rotation and Maize -Faba bean–wheat rotation) from two soil depths (0-20 cm and 20-40 cm) by transecting (X) method. The investigation was made on 1ha of each crop rotation system and mono-cropping practices.

A one ha plot (1 ha) for each cropping system or practice was (100 x100 m) for continuous Maize cultivation, maize-faba bean cultivation and maize–faba bean–wheat rotation for soil sample collection. Accordingly, three adjacent sites under different land use types (continuous maize, continuous maize-faba- bean and continuous maize-faba-bean-wheat cultivated) were selected for this study, with similar slope, elevation, fertilization, liming and erosion and aspect in each crop management practice. Then representative soil sampling sites were selected based on the above criteria and crop management history.

In each study site continuous maize cultivation, maize_ faba bean cultivation and maize–faba bean-wheat cultivation of about one ha is randomly outlined from which representative soil samples were taken. For the determination of bulk density (BD), undisturbed soil samples were taken from each cultivated land by core sampler. A total of 18 composites (3 land use types* 2 depth *3 replication) disturbed soil samples were air-dried, grinded with mortar and pestle and passed through 0.5 mm mesh sieve for OC and TN and 2 mm for the other parameters.

Air-dried samples were stored in polythene bags to prevent contamination and minimize soil moisture loss, to obtain fine air-dried soil in which the particle size analyses were performed using the pipette method (Day, 1965). From both soil depths and different crop management practices, soil samples were prepared and packed in fresh polythene bags and transported to the soil testing center for further analysis at Bako Agricultural Research Center for the analysis of soil physicochemical properties.

Soil Sample Analysis

Soil texture was determined by the Bouyoucos hydrometer method (Bouyoucos, 1951).

Soil bulk density was measured from the undisturbed soil samples as per the procedure described by Jamison *et al.* (1950), while particle density (Pd) was measured using the pycnometer method at the Bako research center.

Soil pH was measured in 1:2.5 soils: H_2O and soils: KCl solutions using a combined glass electrode pH meter (Chopra and Kanwar, 1976). Exchangeable basic cations (Ca^{2+}, Mg^{2+} and K^{+}) were determined by saturating the soil samples with 1M NH_4OAc solution at pH 7.0. Exchangeable Ca and Mg were determined by using atomic absorption spectroscopy (AAS), while exchangeable Na and K were measured by flame photometers from the same extract (Chapman, 1965). The cation exchange capacity (CEC) of the soil was determined at pH 7 from the NH4+ saturated samples that were subsequently replaced by K from a percolated KCl solution (Chapman, 1965). Soil organic matter was determined by using rapid titration methods and then its contents were estimated from the organic carbon content by multiplying with 1.724 (Walkley and Black 1934). OM = OC x 1.724. The total N contents of the soil were determined by the wet-oxidation procedure of the Kjeldahl method (Bremner and Mulvaney, 1982). Available P was extracted by the Bray II Method (Bray and

Kurt, 1965). The percent base saturation (PBS) of the soil samples was calculated from the sum of the base exchangeable cations (Ca, Mg and K) as a percentage of CEC.

Statistical Analysis

Crop management practices and soil depth were used as independent variables and the soil physicochemical parameters as dependent variables and the significant difference of soil physicochemical were tested using analysis of variance (ANOVA) following the general linear model (GLM) procedure at ($P < 0.01$ and 0.05) significant levels. The least significant difference (LSD) test and correlation analysis were employed to assess the mean difference and the association between soil variables and crop rotation types. Correlations among the soil properties were checked by Pearson product-moment correlation test (two-tailed) at $P < 0.05$.

Results and discussion

Soil Physical Properties

Soil texture

The highest mean values of the particle size distribution (51%) and lowest (45.70%) sand content were observed under continuous maize and Maize -Faba bean-wheat crop management practices, respectively (Table 1).

The silt fraction was highly significantly ($P<0.05$) different under the cropping system and soil depth (Table 1). The highest (16.5%) and lowest (12.3%) silt content was observed under maize-faba bean-wheat and continuous maize cropping systems, respectively (Table 1). The silt content of the soil increases from continuous maize to maize-faba bean and maize-faba bean-wheat cropping system. As soil depth increased from 0-20 cm to 20-40 cm silt content of the soil decreased due to the OM content of topsoil than subsoil.

The sand percentage and silt content at 0-20 cm soil depth were greater than 20-40 cm soil depth. Under the cropping system from continuous maize, maize-faba bean and maize-faba bean-wheat silt content of the soil was increased but the sand content was decreased this showed that the cropping system enhanced the silt contents of the soil. Sand particles were not significantly and negatively correlated with clay at correlation coefficients ($r = -0.840^{**}$). Silt particles were significantly and positively correlated with pH, OM, TN, Ca, Mg and CEC at ($r=0.892^{**}$, 0.769^{*}, 0.757^{**}, 0.643^{**}, 0.759^{**} and 0.684^{*}), respectively (Table 4). Sand was negatively correlated with clay ($r = -0.840^{*}$) (Table 4).

This is in agreement with Rao and Mathuva (2000) found that maize following annual legumes was 32 - 49% more profitable than continuous maize. Also, Brady and Weil, (2002) reported that pedologic processes such as erosion, deposition, illuviation and weathering which are shaped by management practices can alter the texture of soils.

Bulk density

The mean values of the bulk density of the selected cropping system were presented (Table 1). The bulk densities ranged from 1.27 to 1.29 gcm^{-3} among cropping systems (Table 1). The highest (1.29 gcm^{-3}) and lowest (1.27 gcm-3) bulk density values of soils were observed under continuous maize and maize-faba bean-wheat, while the highest (1.28 gcm^{-3}) and lowest (1.27 gcm^{-3}) bulk density values of soils were observed at 0 -20 cm and 20 - 40 cm depth, respectively (Table 2).

The lowest (1.27 gcm^{-3}) bulk density value in maize-faba-bean-wheat cropping system soils is due to its relatively higher SOM, total porosity and low clay particle compared with maize-faba bean and continuous maize. Lower bulk density is good for agricultural soil because low bulk density encourages plant root penetration and allows easy movement of water and air in the soil.

Table 1. Mean comparison of soil physical properties under cropping system and soil depth

Cropping system									
	Sand(%)	Silt (%)	Clay(%)	TC	BD (gcm^{-3})	TP(%)	AWHC(%)	FC (%)	PWP(%)
M-FB-W	45.70	16.5[a]	38.3	SC	1.27	47.28	14.64	37.3[a]	26.4
M-FB	47.17	14.7[ab]	38.7	SC	1.28	45.24	13.49	36.4[ab]	25.2
CM	51.00	12.3[b]	36.7	SC	1.29	45.79	12.88	35.1[b]	25.5
LSD (5%)	NS	**	NS		NS	NS	NS	*	NS
Soil depth (cm)									
0 -20	48.2	15.78[a]	36.22	SCL	1.27	51.6[a]	13.43	33.44[b]	24.2[b]
20 -40	47.3	13.22[b]	39.56	SC	1.28	40.6[b]	13.90	39.07[a]	27.2[a]
LSD (5%)	NS	*	NS		NS	**	NS	*	*

LSD = least significant difference NS=Not significant; * = significantly different; ** = highly significantly different; BD= Bulky density; TP = Total Porosity; CM = continuous Maize; M-FB = Maize Faba bean; M-FB-W = Maize –Faba bean –Wheat, AWHC=Available water holding capacity, FC= Field Capacity, PWP=Permanent wilting point

This is in agreement with Shirani *et al*. (2002) reported that continuous ploughing at the same depth leads to the formation of a hard pan in the lower layers over a period of time which hinders the deeper penetration of roots into soil and results in a temporary water logging situation during irrigations. Similarly, Mulugeta (2004) reported that soil BD increased in the 0-20 and 20-40 cm layers relative to the length of time the soils were subjected to cultivation.

The bulk density and total porosity are inversely proportional to each other. As bulk density increases, total porosity decreases and vice versa. The bulk densities of the study area increased from maize-faba bean-wheat to maize-faba bean and continuous maize-cultivated land. As compared to maize-faba bean-wheat, the bulk density of the soils of maize-faba bean and continuous maize was increased on both depth and cropping system land (Table 1). As bulk density increases above its range, the physicochemical quality of the soil of the area lowers. This is in agreement with Fu *et al*. (2004) reported that soil quality levels can be reduced due to bulk density applied to different land use types.

Total porosity

The total porosity was highly significantly ($P < 0.05$) affected by soil depth but non-significantly affected by cropping system affected (Table 1). The total porosity of the soil can be used as an indication of the degree of compaction in soil in the same way as bulky density. Accordingly, the mean porosity of selected crop rotation (continuous maize, maize-faba bean and maize-faba bean-wheat) ranges between 45.24 to 47.28 % under the cropping system. The highest (47.28 %) mean total porosity was observed in the soils of the maize-faba bean-wheat, and the lowest (45.79%) was observed under the soils of continuous maize cultivation. At 0-20 cm soil depth higher TP was recorded.

Total porosity decreases as bulk density increases from 0-20 cm to 20-40 cm depth due to the decrease of OM and OC from surface to sub-surface. The lowest total porosity in continuous maize was due to lower SOM, bulk density and is the result of higher removal of crop residue for fuel, method of harvesting, and slow decomposition of maize residues removing crop residues for cleaning land for the next season. The higher values of total

porosity corresponded to the higher amount of OM and lower bulk density values.

A decline in total porosity in the soils of continuous maize and maize-faba bean and cropping system as compared to soils of maize-faba bean-wheat were attributed to a reduction in pore size distribution and it is also closely related to the magnitude of SOM loss which depending on the intensity of soil management practices. Thus, increased soil bulk density and decreased total porosity in continuous maize and maize-faba bean soils of the studied area indicate a trend towards lower soil quality compared with maize-faba bean-wheat which has low Bulk density and higher total porosity. The highest total porosity was due to the higher low Bulk density. Likewise, Mulugeta *et al*. (2005) found an increase in the 0-10 cm and 10-20 cm layers relative to the length of time the soils were subjected to cultivation after deforestation.

Soil moisture content

The available water holding capacity of the soil was non-significantly ($P \leq 0.05$) different under the cropping system and soil depth (Table 1). Field capacity and permeant wilting point were highly significantly ($P \leq 0.05$) different by soil depth (Table 1). While field capacity was significantly ($P \leq 0.05$) different under the cropping system (Table 1). The highest (14.64 %) mean available water holding capacity was observed under MFBW, and the lowest (12.88%) was observed under the soils of CM cultivation. As soil depth increases from 0-20 cm to 20-40 cm soil SMC (available water holding capacity, field capacity and permanent wilting point) also increases (Table 1). Soil moisture content (field capacity, permanent wilting point and available water holding capacity) increased from 0-20 cm to 20-40 cm soil depth. The result agrees with Wakene (2001); and Ahmed (2002) reported that soil water contents at field capacity, permanent wilting point and available water holding capacity increased with depth for the soils under different management practices.

Available water holding capacity was significantly and negatively correlated with silt content of soil (-0.553) (Table 5). The field capacity of the soil was positively and highly correlated with a permeant wilting point at (0.65) (Table 4)

Soil chemical properties

Soil pH

The soil pH-H_2O value was highly significantly ($P < 0.05$) affected under different cropping systems and soil depths (Table 2). Under all cropping systems soil pH-H_2O values were found to be acidic (Table 2). The soil pH (H_2O) values ranged from 6.68 to 5.66 among cropping systems of land. The highest pH-H_2O (6.68) and the lowest pH-H_2O (5.66) of soil were observed under the maize-Faba bean-Wheat and Continuous Maize, respectively (Table 2).

The lowest pH-H_2O (5.66) value of soil pH-H_2O was observed under the Continuous Maize cultivated land due to the leaching of exchangeable basic cations (Ca Mg, K and Na) from the surface of soils, intensive cultivation, continuous removal of basic cations by harvested crops and continuous use of fertilizer such as ammonium base fertilizer. Soil pH was decreased under the cropping system from maize-Faba bean-Wheat to maize-Faba bean and Continuous Maize. The soil under maize-Faba bean-Wheat and maize-Faba bean was slightly acidic but the soil under Continuous Maize cultivation was moderately acidic (Table 2). The lowest soil pH-H_2O (5.66) under continuous maize cultivated land might be due to leaching and erosion problems, and low availability of nutrients.

The highest pH -H_2O (6.68) value of soil was recorded in maize-faba bean-wheat due to higher accumulation of OM and higher exchange of basic cations. Similarly, Gebeyaw (2015) reported that higher mean values of pH were observed within the surface soils (0-20 cm soil depth). It is also in line with Wakene and Heluf (2003) who reported that the use of acidifying mineral fertilizers and intensive cultivation enhanced the leaching of basic cations and oxidation of organic matter reduced soil pH. The pH (H_2O) was significant and positively correlated with SOM (0.738) and it

was negatively correlated with bulk density (-0.477) (Table 4).

Table 2. Mean comparison of selected soil chemical properties under cropping system and soil depth

Cropping system				
	pH (H_2O)	OM (%)	TN (%)	Av. P (ppm)
M-FB-W	6.68[a]	6.64[a]	0.42[a]	6.01
M-FB	6.13[b]	6.29[a]	0.31[bc]	5.88
CM	5.66[c]	5.34[b]	0.28[c]	5.69
LSD (%)	**	**	**	NS
Soil depth (cm)				
0 -20	6.43[a]	6.53[a]	0.36[a]	6.16
20 - 40	5.88[b]	5.65[b]	0.32[b]	6.15
LSD (%)	**	**	*	NS

LSD = least significant difference NS=Not significant; * = significantly different; ** = highly significantly different; OM = Organic Matter; TN = Total Nitrogen; Av. P = Available phosphorus; CM = continuous Maize; M-FB = Maize Faba bean; M-FB-W = Maize –Faba bean –Wheat

Soil organic matter

The mean values of the SOM of the study area under maize-faba bean, maize-faba bean-wheat and continuous maize were presented in Table 2. Soil OM content was significantly ($P < 0.05$) affected by crop management practices and soil depth (Table 2). The SOM ranged from 5.34 to 6.64% under cropping management practices (Table 2). As per the rating of Landon (1991) the soil OM contents of the study area rated as high under the maize-faba bean-wheat, maize-faba-bean, and continuous maize cropping system at 0-20 cm soil depth and medium at 20-40 cm depth, respectively (Table 2).

The highest (6.64%) soil OM content was observed in the maize-faba bean-wheat followed by maize-faba bean (6.29%), and the lowest (5.34 %) was observed under continuous maize. At 0-20 cm soil depth 6.53% mean soil OM content was observed followed by 5.65% at 20-40 cm soil depth (Table 2). The average content of soil OM decreased from maize-faba bean-wheat to maize-faba bean and continuous maize due to difference in source OM added or removed from each cropping system. As soil depth increased soil OM decreased because of decomposition of crop residues on the topsoil (Table 2).

The soil OM is directly proportional to the presence of soil OC obtained by multiplying by 1.724. The highest OM under the maize-faba bean-wheat cropping system is mainly due to the accumulation and decomposition of legume crop residues on upper surfaces and reduced plant residues as compared to the subsurface soil. The lowest content of SOM under continuous maize computed to maize-faba bean and maize-faba bean-wheat may be due to poor soil conservation such as continuous cultivation, method of harvesting, unbalanced amount of OM removed or added to soil and removal of crop residue for fuel and feed from continuous maize cultivated land of study area.

Total nitrogen and Available phosphorus

The total nitrogen was significantly ($P < 0.05$) affected by the cropping system and it was

significantly (P <0.05) by soil depth (Table 2). The mean of the total nitrogen ranges from 0.28 to 0.42% among cropping systems of the study area. The highest (0.42) mean total nitrogen was observed in the MFBW cropping system and the lowest (0.28) was observed under CM, at 0-20 cm while the highest (0.36%) was in maize-faba bean-wheat, the lowest total nitrogen (0.32%) under continuous maize cropping system at 20-40 cm depth, respectively (Table 2).

An addition of a relatively higher plant green manure and residues might have contributed to the highest (0.42%) amount of continuous maize under maize-faba bean-wheat rotation, while a minimal rate of decomposition under continuous maize (0.28%) may result in the lowest TN, respectively. The decline of total nitrogen from maize-faba bean-wheat to maize-faba bean and continuous maize cultivated lands might be due to the susceptibility of nitrogen to leaching problems, high rainfall, erosion and poor soil conservation practice were reasons for the reduction of total nitrogen in the study area. Similarly, Nega (2006); and Teshome *et al*. (2013) reported that average total N declined with increasing depth from surface to subsurface soils. Also, Sanginga *et al*. (2002) reported the availability of extra nitrogen through biological nitrogen fixation and other rotation effects. Gugino *et al*. (2009) reported that including legumes in crop rotation is a useful strategy for increasing microbial biomass responsible for nitrogen mineralization. Soil conservation and management practices such as cropping systems are important to maintain and increase the total nitrogen of continuous maize cultivated land.

The highest available phosphorus (6.16 ppm) observed at 0-20 cm soil depth might be due to higher organic matter on the surface soil than under subsurface soil (20-40 cm). This finding is in agreement with Wakene and Heluf (2003) who described that the lowest available phosphorus content both in the surface soil layer and throughout the depth was recorded under cultivated land due to continuous intensive cultivation for soils of the Bako area acidic Alfisols. Also, Achalu *et al*. (2013) reported that more than optimum (highest) available P concentration could be observed from a lower concentration of Al-Fe and higher fertilization of inorganic fertilizers and maximum values of organic matter.

Exchangeable base

The mean values of the exchangeable Mg of selected cropping systems (continuous maize, maize-faba bean and maize-faba bean-wheat) are presented in Table 3. The exchangeable Mg was significantly ($P \leq 0.05$) influenced by the cropping systems (Table 3). The mean of exchangeable Mg ranges from 4.70 to 6.42 (cmolckg-1) among cropping systems (Table 3). At 0-20 cm depth soil mean value of Mg was 5.49 cmolckg-1and at 20-40 cm soil depth 4.81 cmolckg-1 (Table 3). As per the ratings of FAO (2006), the mean exchangeable Mg is high for all cropping system types at both depths (Table 3). The highest exchangeable Mg (6.42 $cmolckg^{-1}$) was observed under the maize-faba bean-wheat, the lowest (4.70 $cmolckg^{-1}$) exchangeable Mg was observed under continuous maize (Table 3). The highest exchangeable Mg observed in the surface soils might be due to the higher accumulation of OM and plant residue cover on the upper surface of the soil. The lowest exchangeable Mg is due to lower pH, SOC, continuous removal with crop harvest, continuous cultivation and poor conservation practices of land which result in the leaching of basic cations from the top soils of cultivated land. Likewise, Huluf and Wakene (2006) reported that continuous cultivation enhances the depletion of $Ca^{2+}$and Mg^{2+}, especially in acidic tropical soils.

The exchangeable Ca was highly significant ($P < 0.05$) and influenced by crop rotation (Table 3).

Table 3. Mean comparison of exchangeable bases and CEC under cropping system and soil depth

Cropping system	Exch K	Exch Ca	Exch Mg	CEC
		$cmol_c kg^{-1}$		
M-FB-W	0.91	10.58[a]	6.42[a]	33.38
M-FB	0.86	8.98[b]	6.53[a]	31.57
CM	0.83	8,08[b]	4.70[b]	31.97
LSD (5%)	NS	**	*	NS
Soil depth (cm)				
0 - 20	0.89	9.72	5.49	33.43[a]
20 – 40	0.84	8.71	5.81	30.52[b]
LSD (5%)	NS	NS	NS	**

LSD = least significant difference NS = Not significant; Exch K =Exchangeable potassium; Exch Ca =Exchangeable Calcium; Exch Mg = Exchangeable Magnesium; CEC =cation Exchangeable Capacity; CM=Continuous maize; M-FB = maize- faba bean and M-FB- W= Maize- faba bean – wheat, = significant; ** =highly significant.

The mean exchangeable Ca ranges from 8.08 to 10.58 ($cmolckg^{-1}$) among cropping systems and exchangeable Ca ranges from 8.71 to 9.72 $cmolckg^{-1}$ at 0-20 cm to 20 cm - 40 cm soil depth, respectively (Table 3).

The highest (10.58 $cmolckg^{-1}$) exchangeable Ca was observed under maize-faba bean-wheat followed by maize-faba bean (8.98 $cmolckg^{-1}$). This may be due to the higher SOM and plant material. The lowest exchangeable Ca (8.08 $cmolckg^{-1}$) in the soils of continuous maize cultivation might be due to the relatively lower soil pH, SOM, continuous cultivation and method of harvesting and removal of crop residues for fuel. This is in agreement with Abera and Kefyalew (2017) reported lower exchangeable Ca^{2+} in the surface horizon of the cultivated field due to the removal of Ca with crop harvest. The exchangeable Ca increased from continuous maize cultivated land to maize-faba bean and maize-faba bean-wheat in both soil depths. As per the ratings of FAO (2006), the mean exchangeable Ca contents were high under maize-faba bean-wheat and medium for maize-faba bean and continuous maize at both soil depths (Table 3).

The mean of exchangeable K ranges from (0.83 to 0.91 $cmolckg^{-1}$) among cropping systems (Table 3). The highest (0.91 $cmolckg^{-1}$) mean exchangeable K was observed under the maize-faba bean-wheat followed by maize-faba bean (0.86 $cmolckg^{-1}$), the lowest (0.83 $cmolckg^{-1}$) exchangeable K in continuous maize; while the lowest (0.84 $cmolckg^{-1}$) exchangeable K in CM at 0-20cm and 20-40cm soil depth, respectively (Table 3).

The higher exchangeable K content in the soils of the maize-faba bean-wheat and maize-faba bean than that of the continuous maize could be due to the high OM content. The lowest exchangeable K in continuous maize compared with maize-faba bean-wheat and maize-faba bean may be due to lower pH, intensive cultivation and removal with crop harvest and other poor management practices that enhance its losses. This is in agreement with Berhanu (2016) high intensity of weathering, intensive cultivation and use of acid-forming inorganic

fertilizers has been reported to affect the distribution of K in soils and enhance its depletion. This might be the possible reason for the relatively low exchangeable K in soils of continuous maize cultivated soil. As per the ratings (FAO, 2006), the mean exchangeable K contents were high under the cropping system at both soil depths.

Cation exchange capacity

The cation exchange capacity of the soil was highly significantly affected by soil depth (Table 3). The means of cation exchange capacity range from 30.97 to 33.38 $cmolckg^{-1}$ under the cropping system (Table 3). The CEC of soil was increased from continuous maize, maize-faba bean and maize-faba bean-wheat due to higher soil OM in maize-faba bean-wheat compared with maize-faba bean and continuous maize cultivated land, but when two soil depths are compared higher CEC was observed at 0-20 cm due to higher SOM and clay content which resulted in lower CEC observed at 20-40 cm due to lower clay soil particles compared with 0-20 cm soil depth. This result indicated that the cation exchangeable capacity of soil is directly related to soil OM and clay particles of soil.

The highest CEC (33.38 $cmolckg^{-1}$) was observed under the soils of maize-faba bean-wheat followed by maize-faba bean (31.57 $cmolckg^{-1}$), whereas the lowest (30.97 $meq100g^{-1}$) was observed under continuous maize. At 0-20 cm and 20-40 cm of soil depth mean value of CEC were (33.43 $cmolckg^{-1}$) followed by maize-faba bean (30.52 $cmolckg^{-1}$), respectively (Table 3). Similarly, Lechisa *et al*. (2014) reported that the highest CEC was observed in forest land (16.53 $cmolckg^{-1}$) while the lowest was observed in cultivated land (7.63 $cmolckg^{-1}$). Also, Haile (2007) reported that the low level of clay and humus in soil is low in CEC, whereas soil high in clay and humus has a higher in CEC. As per the rating of (FAO, 2006) CEC of the study area was rated as high under all cropping system land (maize-faba bean, continuous maze and maize-faba bean-wheat) at both depths..

Table 4. Pearson`s Correlation coefficient (r) among selected soil physicochemical quality.

SQI	PH	OC	OM	TN	av.p	ex.Ca	ex.Mg	ex.K	CEC	Cly	Slt	Snd	Bd	TP	AWHC	FC	PWP
PH	1																
OC	.657**	1															
OM	.738**	.741**	1														
TN	.738**	.724**	.714**	1													
av.p	.362	.307	.331	.208	1												
ex.Ca	.629**	.538*	.688**	.756**	.111	1											
ex.Mg	.690**	.712**	.643**	.749**	.112	.550*	1										
ex.K	.408	.082	.323	.324	.519*	.507*	.196	1									
CEC	.420	.442	.323	.737**	.174	.608**	.336	.202	1								
Cly	-.038	-.295	.045	.027	-.117	.020	-.077	-.089	.106	1							
Slt	.892**	.778**	.769**	.757**	.369	.643**	.759**	.418	.395	-.153	1						
Snd	-.440	-.150	-.434	-.460	-.117	-.400	-.341	-.166	-.374	-.84**	-397	1					
Bd	-.477*	-.539*	-.421	-.458	-.67**	-.248	-.312	-.206	-.396	-.098	-.57*	.428	1				
TP	.342	.401	.384	.324	.329	.215	.078	.226	.039	-.126	.250	-013	-.16	1			
AWHC	-.336	-.445	-.429	-.385	-.165	-.309	-.307	-.338	-.139	-.096	-.55*	.376	.364	-.412	1		
FC	-.209	-.356	-.300	-.006	-.270	-.077	.096	-.034	.149	.477*	-.24	-.33	.124	-62**	.406	1	
PWP	-.211	-.442	-.296	-.108	-.307	-.078	-.303	-.030	-.029	.397	-.35	-.17	.137	-.369	.443	.65**	1

*= significant at p<0.05 and**= significant at p<0.01; BD = Bulk Density, TP= Total porosity, Av. P = Available Phosphorous, CEC = Cation Exchange Capacity,(Exch. Mg, Ca, K = Exchangeable Magnesium, Calcium ,Potassium, respectively) TN = Total Nitrogen, OM = Organic Matter, AWHC = Available water holding capacity, FC= Field capacity ,PWP = Permanent wilting point ,OC= organic Carbon,

Conclusion

Continuous crop system has a negative effect on soil physicochemical properties, which is related to the sustainability of agricultural production. The most important problem for soil physicochemical properties was intensive cultivation, the wide practice of mono-cropping systems, erosion and leaching problems, deforestation and the continuous use of acid-forming inorganic fertilizers rather than organic fertilizers for production used agriculturally.

As the maize-faba bean-wheat cropping system changed to other continuous cultivation caused a significant decline in soil physicochemical properties which contributed to low agricultural production and productivity. The soil quality decreased from maize-faba bean-wheat rotation to maize-faba bean and continuous maize cultivated land, respectively. Soil physicochemical properties were maintained relatively under the maize faba-bean-wheat rotation, compared with maize-faba-bean and continuous maize cultivated. Therefore, from three cropping systems soil management under continuous maize should be needed. Thus, in order to change the current situation of improper cropping system and its management to proper cropping system and management, this study recommended detailed and periodic research work, educating and training of farmers on proper rotation and techniques of soil and water conservation, adopting integrated soil managements such as organic fertilizers, reducing intensive cultivation and liming to decrease soil acidity for replenish the degraded soil physicochemical properties and sustainable agricultural production in the study.

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RESEARCH PAPER

Bridging the Gaps: Incongruences and challenges in Academic English skills and Professional English skills

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Abstract

Mastery of English language skills is essential for academic success and professional development, particularly in non-native English-speaking contexts such as Ethiopia. This study investigated English language skill difficulties faced by undergraduate agriculture students at Ambo University and former graduates in their workplaces. It focused on their proficiency in the four macro-skills (listening, speaking, reading, and writing), the challenges encountered in academic contexts, and the language barriers experienced in professional settings. A mixed-methods approach was adopted, combining quantitative and qualitative data collection techniques. A survey was administered to 13 former graduates and 121 undergraduate agriculture students across different academic programs, assessing their self-reported proficiency and their areas of difficulty in English language skills. Furthermore, semi-structured interviews were conducted with four English language instructors and four employers working in various sectors of the agriculture industry. In addition, an evaluation of course materials assessed their alignment with students' English proficiency levels. The quantitative data were analyzed using descriptive statistics, while thematic analysis was applied to the qualitative data. Findings revealed significant difficulties in writing and speaking, particularly in academic reporting, presentations, and discussions. Former graduates reported that these challenges persist in professional settings, hindering effective communication, access to resources, and career advancement. Contributing factors included inadequate language support and insufficient focus on English within the curriculum. This research highlights the need for tailored language instruction aligned with the academic and professional demands of agriculture students. By addressing these needs, universities can better prepare graduates to meet the challenges of global and national agricultural development. The findings provide actionable insights for higher education institutions in Ethiopia and similar contexts, underscoring the importance of specialized English education in fostering academic and professional competence in agriculture.

Keywords: Academic needs, English for Specific Purpose, English language skills, needs analysis

Introduction

English for Specific Purposes (ESP) has emerged as a critical area in language education, especially in non-native English-speaking contexts where English serves as the primary medium of instruction in higher education and the working language in many professional fields. Hutchinson and Waters (2020) emphasize the importance of tailoring ESP to meet specific academic and professional needs. For agriculture students and former graduates at Ambo University, proficiency in English is essential for academic success and professional competence. Mesfin (2020) highlights similar challenges faced by students in Ethiopia. However, these students face significant challenges in acquiring the specific language skills necessary for their academic coursework and professional careers. This study investigates the English language skills difficulties encountered by undergraduate agriculture students and former graduates, emphasizing the need for ESP interventions to enhance their linguistic proficiency and

performance in academic and professional settings (Hyland, K. 2018).

The concept of ESP is grounded in tailoring language instruction to meet specific learner needs in particular disciplines, such as agriculture. Hutchinson and Waters (2020) and Abuklaish (2014) highlight that ESP differs from general English by focusing on practical applications in professional and academic contexts, requiring specific vocabulary, discourse, and communicative skills. In agriculture, these skills include reading and interpreting scientific articles, writing research reports, engaging in technical discussions, and delivering presentations on specialized topics. However, existing research indicates that many students, especially in developing countries like Ethiopia, struggle with these demands due to limited prior exposure to English for academic purposes (Mesfin, 2020; Bedilu, 2020).

Needs analysis is central to any ESP curriculum, identifying gaps between students' current language abilities and the skills required in their field. Basturkmen (2010) emphasizes that a thorough needs analysis involves understanding target language use situations, required competencies, and learners' perceptions of their needs. For agriculture students, this analysis evaluates their abilities in reading technical documents, scientific writing, and spoken communication in academic and professional settings. Studies suggest needs analysis is crucial in fields like agriculture, where language requirements are highly specialized and distinct (Chostelidou, 2011; Abuklaish *et al*., 2014).

At Ambo University, where English is the medium of instruction, agriculture students often encounter linguistic challenges hindering academic performance and limiting professional participation. Their difficulties span reading comprehension, writing proficiency, oral communication, and listening skills. Kagwesage (2013) and Shibeshi (2017) note that for students in technical fields, understanding and producing specialized texts is particularly difficult when their general English skills are weak. Flowerdew (2013) adds that agriculture students must navigate complex scientific literature and produce research reports requiring precise language use, yet many lack even basic English proficiency, let alone mastery of discipline-specific language.

In a similar vein, agriculture former graduates face challenges in their professional careers. They must communicate effectively with peers, supervisors, and international partners, write reports, deliver presentations, and engage in negotiations, all of which demand high English proficiency. Deveci (2017) and Bantalem (2017) argue that limited English skills can negatively impact employability and professional advancement, especially in fields requiring international collaboration. For agriculture graduates, insufficient ESP training leaves them unprepared for professional demands, limiting career opportunities in both national and international contexts.

Another significant concern is the inadequacy of instructional materials. A study by Tadesse (2022) notes that most CES course books used in Ethiopian universities lack contextual relevance, failing to address the specific communicative needs of agriculture students. These materials often emphasize general language skills rather than integrating agricultural themes, technical terminologies, or real-world scenarios. This misalignment between course content and practical requirements exacerbates the language proficiency challenges faced by agriculture students and graduates.

Additionally, pedagogical approaches in CES instruction are criticized for being overly theoretical and teacher-centered, offering limited opportunities for practical language use (Demissew, 2020). Studies from similar contexts, such as Al-Issa and Al-Bulushi (2019) in Oman, suggest that interactive and task-based methods are more effective in equipping students with functional language skills. Adopting such approaches in Ethiopia could bridge the gap between academic preparation and professional application, particularly for agriculture students requiring context-specific communication abilities.

Despite these findings, limited research in Ethiopia focuses on the English language needs of agriculture students and graduates. Most studies address general English language teaching, neglecting the unique requirements of agriculture majors, whose academic and professional success relies heavily on their ability to communicate technical knowledge effectively. This study addresses this research gap by investigating the proficiency levels of agriculture students and graduates, identifying their major challenges, and offering practical recommendations to enhance English language instruction in Ethiopian higher education.

The persistent challenges faced by agriculture students and graduates necessitate a clear articulation of the problem. Despite courses like CES in Ethiopian higher education institutions, many students and graduates lack the proficiency to navigate academic and professional environments effectively. This gap affects their performance and undermines national efforts to produce globally competent agricultural professionals. Addressing this issue requires aligning undergraduate English programs with the professional language needs of graduates, as emphasized in ESP literature (Hutchinson and Waters, 2020; Belcher, 2006). For agriculture professionals, language skills are essential for tasks such as technical report writing, stakeholder engagement, and participation in international forums. A lack of congruence between pre-service English training and professional demands limits graduates' ability to apply language skills effectively (Basturkmen, 2010).

Needs analysis provides a framework to identify and integrate workplace linguistic and communicative demands into the curriculum. For agriculture students at Ambo University, this involves embedding agricultural themes, workplace simulations, and interdisciplinary collaboration into the CES course. The adoption of Communicative Language Teaching (CLT), emphasizing practical language use through authentic tasks, ensures students develop functional language proficiency (Richards and Rodgers, 2001). Aligning academic English programs with workplace needs enhances employability and equips graduates with critical thinking and communication skills for success in both academic and professional domains (Dudley-Evans and John, 1998).

This study investigated the English language difficulties of agriculture students and former graduates, focusing on their proficiency levels and challenges in academic and professional contexts. Specifically, it examines the effectiveness of the CES course in addressing these challenges and suggests solutions to bridge the gaps. The study addresses the following research questions: 1) What are the English language proficiency levels of agriculture students and graduates? 2) What specific English language difficulties do students and graduates face in academic and professional settings? The study includes undergraduate agriculture students and graduates from Ambo University, emphasizing their experiences and perspectives regarding English language use.

The significance of this study lies in its potential to inform curriculum designers, educators, and policymakers about the specific English language needs of agriculture students and graduates. By addressing these needs, the study contributes to improved language instruction practices, enhanced employability of graduates, and supports the agricultural sector's development in Ethiopia. Furthermore, the findings serve as a model for similar contexts where English is used as a medium of instruction in specific fields.

Materials and Methods

The study was conducted at Ambo University, located in the Oromia region of Ethiopia, with a focus on undergraduate agriculture students and former graduates. The research employed a descriptive case study design to investigate the English language skills difficulties faced by these students. A total of 154 participants were selected through probabilistic and purposive sampling methods. The sample included 121 current undergraduate agriculture students from the third academic year, 13 former graduates, 16 instructors (12 MCIs and four ELIs) and

four employers. This sample size was chosen to ensure the representativeness of the findings.

Data collection was carried out using a combination of methods. A structured questionnaire was designed to gather quantitative data on the participants' self-assessed proficiency in four major English language skills: listening, speaking, reading, and writing. The questionnaire consisted of both closed-ended questions (using a Likert scale) and open-ended questions to capture more in-depth responses. In addition, semi-structured interviews were conducted with eight participants (four instructors and four employers) to gain deeper insights into the specific challenges they encountered in developing their English language skills during their studies. The questionnaire was piloted with 10 students to test for clarity and reliability, and necessary adjustments were made before the full distribution. The study adhered to ethical research practices, including obtaining informed consent from all participants. Participants were provided with detailed information about the study's objectives, procedures, and confidentiality measures. Data were anonymized to protect participants' identities, and all research activities were conducted in accordance with the university's ethics review board guidelines. The data collection process took place over a period of two weeks, the second and the third weeks of April 2022.

The collected data were analyzed using both qualitative and quantitative methods. Quantitative data from the questionnaires were processed using SPSS software version 25 to generate descriptive statistics, including frequencies, means, and standard deviations, which were used to identify the most common language difficulties. The qualitative data from interviews document analysis and open-ended questionnaire responses were analyzed thematically. The responses were coded and categorized into themes to identify recurring patterns related to challenges in speaking, writing, listening, and reading skills. These findings were then cross-referenced with the quantitative data to ensure a comprehensive understanding of the language difficulties experienced by the participants..

Results and discussions

This section presents the results of the study in the following order: students' and former graduates' perceived ability in the English language and students' and former graduates' English language lacks.

English Language proficiency of the students and former graduates

The study used three items (Items 2, 3, and 4) to assess students' English language proficiency in studying major courses. Item 3 focused on students' ability in the four macro-skills, while Items 2 and 4 focused on their abilities in studying major courses. The questionnaires were given to both instructors and students. Below are the summaries of the results:.

Table 1. Students' English language proficiency to follow major courses as indicated by major course instructors (MCI) and students (STS)

No	Item	Respondents	Responses										Grand Mean
			VW		W		A		G		VG		
			N	%	N	%	N	%	N	%	N	%	
1	To what extent do you/your students follow major courses taught in English	STS			35	28.9	16	13.2	58	47.9	12	9.9	3.38
		MCI	1	8.3	7	58.3	3	25	1	8.3			2.2

VW= very weak, W=weak, A= average, G=good, VG= very good

As shown in Table 1, regarding students' overall English language ability to follow major courses, 47.9% of the students rated their ability as "good," while 9.9% described it as "very good." In contrast, none of the instructors considered the students' ability to follow major courses as "very good," and only 8.3% rated it as "good." Conversely, 28.9% of the students

described their English ability as "weak," whereas 13.2% rated it as "moderate" in understanding major courses taught in English.

Table 1 also depicts that almost a quarter of the instructors, 25% claimed that the students had average English language ability in following major courses in the university under consideration, and above a tenth, 13.2% of the students shared the perception of the instructors. More than half of the instructors, 58.3% responded that students have weak performances in accomplishing tasks in major courses, while only 28.9% of the students felt the same. Based on the given information, there is a disparity between the instructors' and the students' responses. Thus, students felt that they were following the courses well in English while the instructors perceived that the students were weak in following the major courses given in English.

Both the students and English language instructors, during their interviews, supported the majority view expressed by major course instructors in the questionnaire data. The students' interview results revealed that many students face challenges in attending major course classes due to their low level of English proficiency. For example, AUST1 responded to an interview question about the extent to which students can follow major courses taught in English, stating:

"I have several language problems when I attend the major course classes. My English language ability in almost all the skills is weak, and I face difficulties in listening to lectures to take notes, speaking to communicate with classmates and instructors, reading and understanding handouts and references, and writing answers to essay-type assignments and exams.

Similarly, another respondent (AUST3) shared,

"I believe that my ability in using English for major course study is below the demand of the academic level I am pursuing. I am not good at performing speaking, writing, reading, and listening activities, and even my ability to grasp vocabulary and using appropriate and acceptable grammar for communicating ideas in major courses is worse."

In contrast, some participants expressed confidence in their English skills. For instance, AUST4 stated, "I am good at following major courses, all of which are given in English, as I have a good command of English language skills except the writing skills."

These varied responses reveal a disparity in students' self-assessed English language proficiency, with some perceiving their skills as inadequate to meet academic demands, while others report fewer difficulties. This suggests that while some students struggle significantly with language barriers, others may face only specific challenges, such as writing. Addressing these individual skill gaps could enhance overall academic performance and participation.

The English language instructors too, confirmed that the students have poor language performances to attend their major courses. One of the instructors (MCI3) said that most of the students failed to communicate their academics using English. For instance, asking and answering questions, writing term papers, reports, presentations, reading academic notes, and understanding lectures and so on were areas where students lacked abilities.

Moreover, other instructors (MCI1 and MCI5) on their part said that having a good command of English is customary for the students since major course lessons are delivered in English. The instructors added that the students are weak when they deliver academic speeches, listen to lectures, read academic notes, take notes from lectures; and write answers to essay-type questions using the English language. They further suggested that students have to be proficient enough in all the language skills so that they can easily communicate in academic contexts. It seems from the data that there was a disparity between the students and the instructors' views regarding the students' ability in performing academic activities in English. The students felt that they had average English language abilities when the instructors seemed to rate students' English language

ability to perform different academic tasks as weak.

Thus, it seems from the above data that both the student and instructor respondents were aware of the view that having good language ability is critical for students to be successful in their academics and professional settings. On the other hand, the responses reveal the students were below average (weak) in their English language ability in using English for their academic studies.

The findings of the study align with Bantalem (2017), who observed a slight difference in the perceptions held by students and teachers regarding students' English language abilities for following major courses. Specifically, a greater number of teachers believed that students possessed poor language abilities compared to the students themselves, who were more optimistic or held differing views about their proficiency. This discrepancy highlights a significant issue: the language ability students are expected to have for effectively engaging with major courses taught in English is higher than their current ability. As a result, students face considerable challenges in comprehending and learning their major courses, which may adversely affect their academic performance and overall learning experience.

Moreover, Shibeshi (2017) corroborates this by finding that his participants recognized the critical role English plays in following health and related courses, despite their poor performance in using the language. He further emphasizes that the Communicative English Skills course was not designed with the academic and professional needs of health science students in mind, resulting in its failure to address their academic and career requirements. Additionally, the study highlighted that speaking, writing, and reading about food science topics, as well as understanding instructions, lectures, meetings, and discussions, are crucial for BSc food science students.

From the discussion so far, it can be inferred that the language competence and readiness of agriculture students to follow their major courses, where English serves as the medium of instruction, were found to be inadequate. This conclusion is supported by evidence showing that the students under study struggled with several key academic tasks. These included taking effective notes, composing answers for essay-type assignments, comprehending lectures, reading and understanding academic handouts, and actively engaging in classroom activities such as asking and answering questions.

Students' and Former Graduates' Ability in the Four Macro-skills

Students' Ability in the Four Macro-skills

Item 3 of the questionnaire required MCIs to reveal their perspectives on the students' ability in the four-macro skills to study major courses: Listening, speaking, reading and writing. The participants were asked to rate students' abilities with 'very weak, 'weak, 'average', 'good' and 'very good'. The students were also asked the same item regarding their abilities in the given skills. Table 2 presents the results in mean scores and percentages.

As indicated in Table 2, the students put their ability in speaking and listening below average. The calculated mean score for the two items (Item 1 and 3) which read 2.80 and 2.76 respectively could be rounded to 3.0, the average mean score, indicating that the students had some ability of listening and the reading skills in pursuing their major courses. The instructors however, felt that the students' ability in these mentioned skills is average, 3.00 and. 3.08 respectively. The instructors also said that the students are weak in both writing (2.33) and speaking (2.58) skills though they claimed that the students are a little better in speaking than writing. The students on their part, however, believe writing (2.01) and speaking (2.46) are by far below average though speaking is better than writing.

Table 2. Students' ability in the four macro-skills as indicated by the students and major course instructors

No	Macro Skills	Respondents	Responses										Grand Mean
			VW		W		A		G		VG		
			N	%	N	%	N	%	N	%	N	%	
1	Listening	STS			5	4.1	46	38.0	43	35.5	27	22.3	2.76
		MCI				2		8		2			3.00
2	Speaking	STS			2	1.7	40	33.1	58	47.9	21	17.4	2.46
		MCI			5	417	7	58.3					2.58
3	Reading	STS			15	12.4	50	41.3	41	33.9	15	12.4	2.80
		MCI			2	16.7	7	58.3	3	25.0			3.08
4	Writing	STS			23	19.0	76	62.8	19	15.7	3	2.5	2.01
		MCI			7	58.3	5	41.7					2.33

VW= very weak, W=weak, A= average, G=good, VG= very good

From the data, we can infer that both the instructors and students believe that students are relatively better in their receptive skills (reading and listening) than the productive skills (speaking and writing). The only disparity between the instructors and the students' perception on the students' abilities in the four macro-skills is a matter of ranking. The instructors put the ranking of their students' abilities from average (in reading and listening) to weak (in writing and speaking) while the students rated their abilities from good (in listening and reading) to average (in speaking and writing).

Data obtained from interviews attest the responses of the majority of the major course instructors. The interview conducted with English language instructors regarding agriculture students' ability of using the macro skills, confirmed almost the same result except some disparities given on the receptive skills. One instructor (MCI3), for example, rated reading as average and the other skills as poor. The other instructor (MCI2) said that students are very poor in speaking and writing skills while they are average in reading and listening when they study their major courses. Besides, an interview with the students and the open ended question on the students questionnaire indicated that Writing is the major problematic area that they failed to jot down what they intended to do.

The former graduates were asked to rate their English language abilities of listening, speaking, reading and writing. They rated their abilities using Likert scale which was worded as 'very good', 'good', 'average', 'weak' and 'very weak.

Former graduates' Ability in the Four Macro-skills

According to the data in the Table 3 above, the former graduates are relatively better in their reading followed by listening, speaking and writing. The mean scores of reading and listening skills are 3.38 and 3.07 respectively and these show that they are nearer to good in both skills. When we see the speaking skills, they are below average with a mean score indicating 2.76. The mean score of writing skills is 2.61, and this indicates that the former graduates are weak in writing. Moreover, it was indicated in the table that out of 13 former graduates, 12(92.4%) of them rated their reading skills as average and good when only one respondent rated she/he was of weak performance in reading.

When it comes to speaking and writing skills, the former graduates evaluated their proficiency as average in speaking and weak in writing. This self-assessment suggests a significant disparity in their command over different language skill domains. Notably, these

graduates appear to be stronger in receptive skills—such as reading and listening—compared to productive skills, which involve speaking and writing. This trend is consistent with the challenges often observed in language learners, where the ability to understand and process information (receptive skills) develops faster than the ability to articulate thoughts effectively (productive skills). The findings highlight the need for targeted interventions in teaching methodologies to bridge this gap and enhance graduates' performance in productive skills, particularly writing, which is essential for their academic and professional success.

Table 3. Former graduates' self-assessment of language skills competence in target situations

No.	Language Skills	Respondents	Responses										Grand Mean
			VW		W		A		G		VG		
			N	%	N	%	N	%	N	%	N	%	
1	Listening	13			2	15.4	8	61.5	3	23.1			3.07
2	Speaking	13			3	23.1	10	76.9					2.76
3	Reading	13			1	7.7	6	46.2	6	46.2			3.38
4	Writing	13			5	38.5	8	61.5					2.61

VW= very weak, W=weak, A= average, G=good, VG= very good

In general, the former graduates had average performance in almost all the four language skills when the percentage reads 76.9, 61.5, 61.5 and 46.2 for speaking, listening, writing and reading skills respectively. Thus, they ranked their language ability as reading first, listening second, speaking third and writing the least. Hence, it is possible to understand from the questionnaire data that former graduates have some problems in productive skills particularly in writing and speaking.

An interview was held with employers to disclose their views on former graduates' English language ability of the four macro skills (listening, speaking, reading and writing) when performing different activities in occupational settings. The data obtained with this regard are presented as follows.

The results of the interview with employers also support the former graduates' view for the same item. For instance, EMP1 and EMP3 said that the former graduates (employees) were of weak performance in communicating their activities that require the skills of writing and speaking. They added that some employees failed to organize and write lab and official reports in English. They ordered former graduates' English language ability in a decreasing order (from good to weak) as listening, reading, speaking and writing for the major skills.

On the contrary, EMP1 mentioned that former graduates are good at almost using all the English language skills to accomplish activities (listening, speaking, reading and writing) in the occupational settings. He (EMP1) said that despite some disparities across former graduates, reading, speaking, listening and writing are ranked in the decreasing order of ability the former graduates had to the interviewee's perception.

Thus, it is evident from both the questionnaire and the interview data that former graduates had average performance in productive and receptive skills which attributed to their in efficient communication in the professional/occupational areas.

The results of this study agrees With Bedilu's (2020) work when he found that language skills

have significant value for students' academic performance and professional competence. For instance, he found that having good language command in all language skills is very important in former graduates work situations. The importance of English language skills for future profession, were rated in decreasing order as reading, listening, speaking, and writing respectively. This result is also consistent with Bantalem (2017), Abuklaish, (2014) and Chostelidou (2011) who found out that the English language abilities are very important for agriculture students in their current studies and future careers.

Nevertheless, the findings in this category of the current study contradicts with Dagmawit (2011) as the overall degree of difficulty for each language skills were rated by almost all of the participants as writing, reading speaking and listening in decreasing order for students' professional life. As a result, it is possible to deduce that all language skills are almost equally important for undergraduate agriculture students to be proficient enough in the professional domains.

In conclusion, it is appropriate to consider that agriculture former graduates were found good at the receptive skills when they exhibit less than average proficiency in the productive ones

Students' and Former Graduates English Language Challenges in Academic and Professional Contexts

Students' Difficulties in Learning and Using English for Academic Purposes

Identifying areas of difficulty and gaps students experience is essential when conducting a needs analysis in academic settings. In this context, a questionnaire (Item 1) was specifically designed to explore the challenges students face concerning various micro-skills. Participants were given five response options: "very great difficulty," "great difficulty," "some difficulty," "little difficulty," and "no difficulty." The data collected on this aspect are presented below:

Table 4 indicates that student respondents viewed most of the speaking sub skills as they confront it with 'great difficulty' in the academic endeavors. The grand mean value computed for this skill reads 2.004 which could be rounded to 2, the value assigned to represent 'great difficulty.' With regard to the speaking sub-skills, majority of the student respondents responded that presenting term papers or reports, asking and answering questions in the class and participating in class discussions were considered as activities students engage in with great difficulty with the computed mean scores of 2.31, 2.39 and 2.41 respectively. Similarly, Speaking to continue daily conversations with mean score 2.91 became the oral language sub skill learners perform with average difficulty in their academic arena. As it is evident from the table above, both the students and the Major course instructors (MCI) agreed that presenting projects /term papers is the most difficult oral language activity. The computed mean value for this item is 2.31 for the students and 1.91 for the instructor respondents. Besides, the MCI respondents perceived that undergraduate agriculture students felt great difficulty in undertaking speaking activities in their classrooms.

They rated the degree of difficulty the students faced in the academic setting in decreasing order as asking and answering questions, participating in class discussions, speaking to continue daily conversations, and speaking to request or give comments with respective mean scores of 1.99, 2.05, 2.56 and 2.78.

With regard to listening sub-skills, the students considered themselves as moderately competent enough in performing listening activities. They rated their difficulties in listening average including their skills to follow question and answer sessions in class, instructions and explanations in labs, follow seminars, course lectures, and spoken presentations in their academic study (mean scores were between 2.50 and 3.49). Similarly, the MCIs viewed their students' difficulties to be average in listening to instructions and explanations in labs, follow seminars, course lectures, and spoken presentations with

computed mean scores of 2.86, 2.91, 2.99, 3.25 and 3.34 respectively.

Table 4. Students' difficulties in some sub-skills as rated by the students (STS) and the MCIs

No.	Items	Mean scores		Rank	
		STS	MCI	STS	MCI
	Listening activities in English	3.06	2.96		
1	Listening to instructions and explanations in labs	2.86	2.72	4	5
2	Listening to follow question/ answer sessions in class	2.99	2.91	3	4
3	Listening to spoken presentations in class	3.25	3.16	2	1
4	Listening to follow course lectures	3.34	2.99	1	3
5	Listening to follow seminars	2.86	3.02	4	2
	Reading activities in English	2.57	2.37		
6	Reading exam questions	2.78	1.81	1	5
7	Reading instructions for lab/assignments	2.34	2.32	5	4
8	understanding study notes/ lecture handouts	2.59	2.59	3	2
9	Reading text books and references	2.64	2.64	2	1
10	understanding appropriate terms in the course	2.51	2.51	4	3
	Speaking activities in English	2.004	2.258		
11	Speaking to continue daily conversations	2.91	2.56	1	2
12	asking and answering questions in the class	2.39	2.05	3	3
13	presenting term papers or reports	2.31	1.91	4	5
14	Participating in class discussion	2.41	1.99	2	4
15	Speaking to give comments	2.31	2.78	4	1
	Writing activities in English	1.99	2.29		
16	Writing to take notes from books/lecture	2.85	2.71	1	1
17	Writing field and lab reports	2.01	2.13	2	4
18	Writing term papers	1.83	2.13	4	4
19	organizing ideas appropriately	1.71	2.31	5	3
20	writing answers to essay type exams	1.85	2.05	3	5
21	Summarizing something read	1.71	2.43	5	2

Both the students and MCIs were asked 5 (Items 6-10) questions on the reading sub skills, and the questionnaires were provided to seek information about learners' difficulties in academic settings. In this regard, the computed mean of 2.56 indicated that reading and understanding academic texts is the most difficult reading event agriculture students were facing in their academic setting. The mean score of 2.34 which falls with the scale of a bit above 2, the value assigned to great difficulty, also proved that the majority of the students were understanding appropriate terms in the major course with great difficulty.

Likewise, understanding lectures is the second most difficult activity followed by understanding appropriate terms with respective mean scores of 2.51 and 2.59. The student respondents found it relatively easier to read and understand books and references and exam questions with mean score of 2.64 and 2.78 respectively than those mentioned above. On the contrary, MCIs responded to the same question as understanding exam questions is the most difficult (1.81) reading event followed by understanding appropriate terms (1.96) in the academic setting. Like the students, the respondent instructors believed understanding lectures, books and references are activities their students accomplish with some difficulty when the respective mean scores read 2.84 and 2.87.

It is designated in Table 4, that of all the language skills, the students rated the writing

skills activities as the most difficult ones. Likewise, the student respondents put organizing ideas appropriately (1.71), summarizing something read (1.71), writing essay/term papers (1.83), writing answers to essay type exams (1.85), writing field and lab reports (2.01), making notes from books (2.85) in decreasing order of difficulty. In sum, the grand mean value for the writing skills is 1.99, which could be rounded to 2, the value assigned to great difficulty indicates that students face serious challenges when they are required to perform different writing activities in the academic setting.

Although MCIs mostly agreed with the students' order of ranking and level of difficulty, there were slight disparities between the two respondents when the instructors ordered from the most difficult writing activities to those performed at moderate difficulty as writing answers to essay type exams, writing field and lab reports, organizing ideas appropriately, summarizing something read, making notes from books when the computed mean score read 2.05, 2.13, 2.31, 2.43, and 2.74 respectively.

Semi-structured interview was held with MCIs to reveal their perspectives of students' difficulties when using English for their academic purposes. The instructors were interviewed on the extent to which the students face difficulties to accomplish different academic activities in English (understanding lectures, taking lecture notes, participating in class discussions, understanding text/reference books, and etc.). Besides, they were interviewed on their evaluation of the English proficiency level of the students by considering the students' listening, speaking, reading and writing skills. The data obtained with this regard are presented as follows.

In this response, three different views were reflected. Specifically, two teachers (MCI1 and MCI4) said that their students had very great difficulty in using English for academic concerns. For instance, MCI1 said:

"*Majority of the students in my class encounter much difficulty when they use English to listen to lectures, participate in class discussions, ask and answer questions, read and understand lecture notes, write term papers, write answers to essay type assignments or exams*."

MCI4 on his part responded to the same question when he said:

…the students had poor language proficiency in all the language skills and they were unable to express their ideas through speaking (oral presentations, asking and answering questions in the classroom) and writing skills (summarizing something read, writing answers to essay questions) when they were better at receptive skills, they rarely use English."

The other two MCIs (MCI2 and MCI3) mentioned that even though the students had difficulties in learning and using English for studying their major courses, they believed that the degree of difficulty was somewhat average. MCI2, for example, said:

"*I believe that having good command of English language skills is imperative for students to gain knowledge in their respective field of study at universities, where the medium of instruction is English. As such my students are of average proficiency in almost all the four language skills that they experience moderate difficulty when performing different activities in their studies*."

On the contrary to the above two views, MCI5 said that except for the writing skills, students are performing almost better at reading, listening and speaking skills activities respectively. However, she (MCI5) emphasized the challenges the students had in the writing sub skills when communicating their academics. From the above responses, it is noted that students have great difficulties in writing essays/term papers, writing answers to essay type exams, participating in class discussions, asking questions in class, understanding lectures, taking notes and expressing themselves in English. Comparatively, the students have less difficulty in understanding lectures, answering questions in class and making notes from books.

The majority of the students in their part reported that they encountered great difficulties in summarizing something read, asking and answering questions, understanding lectures, understanding appropriate terminologies, writing essay type exams, writing field and lab reports and participating in class discussions. On the other hand, they reported that they are in good position in taking lecture notes, understanding manuals and understanding textbooks and reference books.

In general, it is very important to learn from data that students encountered challenges of using different academic English language skills when they use and learn it for academic accomplishments/ study major courses. Thus, as issues the researcher dealt with under this theme has tried to address each and every function and genre to be dealt with; data generated from this study suggest that students have a lot of gaps to be intervened so as to make them capable in their academic and professional environments

Former Graduates' Difficulties in Some Sub-skills in Occupational Setting

Moreover, former graduates were also asked (Item 2) to reveal their awareness of their own difficulties with English language sub-skills when performing in workplaces. In addition, semi-structured interview was held with employers. Hence, below is the summary of students' responses on the issue

Table 5 depicts that the mean values for the former graduates on the given listening skills show, the former graduates are relatively best in listening to presentations, instructions, etc., and listening to lectures with respective mean scores of 3.23 and 3.00, which are near to the numerical value given the ability level 'average. These are followed by meetings, seminars, conferences with respective mean scores of 2.86, 2.86, 2.76, which are near to the average varyingly.

Listening to foreigners was the listening activity area where the former graduates were found to be weak with a mean score of 2.61, far below average. In practice, Table 6 also shows that the former graduates were average in their ability at listening in performing different purposes in professional/occupational areas.

The former graduates were relatively best at reading researches, lab reports with a mean score of 3.38, which refers to the ability level as 'good'. The former graduates are exactly average at reading manuals and reading business or personal letters with the mean score of 3.00 and 3.00 respectively. In a very similar fashion, reading professional books, journals, newspapers were reading areas the former graduates themselves average with the respective mean score of 2.85 and 2.85.

Among the given speaking skills, the former graduates are relatively best in giving instructions with the mean score of 2.92, which is very close to the average (3). The former graduates were below 'average' in their ability in giving instructions with the mean score of 2.85, which could be rounded to 3, the value assigned to average. Moreover, in delivering speeches at meetings, conferences and seminars, giving presentations, reports and speaking to colleagues and agriculture experts with their respective mean scores of 2.42, 2.61, 2.28 and 2.90 former graduates were found weak.

Regarding the writing activities, the former graduates are relatively best in writing specific work programs and schedules and writing notes from different sources with respective mean scores of 3.23 and 3.15. They were above average in writing curriculum vitae and writing job application letters or personal letters with respective mean scores of 3.07 and 2.85. In writing reports (research, lab, journal articles), former graduates were 'weak' with respective mean scores of 2.30.

Moreover, the interview data from the employers as well as the former graduates themselves support the findings of the questionnaire data. Most of the employers believed that the former graduates were not proficient enough in communicating through writing and speaking.

Table 5. Former graduates' difficulties in some sub-skills as given by the former graduates themselves

Items	Mean	St. D	Ranks
Listening activities in English			
a) Listening at meetings, seminars, conferences	2.8462	.37553	3rd
b) Listening to lectures	2.7692	.43853	4th
c) Listening to instructions	3.0000	.81650	2nd
d) Listening to foreigners	2.6154	.50637	5th
e) Listening to presentations/seminars	3.2308	.43853	1st
Reading activities in English			
a) Reading professional books	2.8462	.68874	4th
b) Reading researches, lab reports	3.3846	.50637	1st
c) Reading Manuals	3.0000	.57735	2nd
d) Reading professional journals, Newspapers	2.8462	.68874	4th
e) Reading business or personal letters	3.0000	.81650	2nd
Speaking activities in English			
a) Giving presentations, reports, papers	2.2308	.43853	5th
b) Giving workshops	2.6154	.50637	3rd
c) Delivering speech at meetings conferences and seminars	2.6154	.50637	3rd
d) Giving instructions	2.8462	.37553	2nd
e) Speaking to English-speaking colleagues/ agri-experts	2.9231	.27735	1st
Writing activities in English			
a) Writing reports (research, lab, journal articles)	2.3077	.75107	5th
b) Writing specific work programs and schedules	3.2308	.72501	1st
c) Writing notes from different sources	3.1538	.55470	2nd
d) Writing Curriculum Vitae	3.0769	.86232	3rd
e) Writing job application letters or personal letters.	2.8462	.37553	4th

For instance, two of the employers (EMP2 and EMP3) said, employees face great difficulty when they write research reports, lab/field reports, personal and official letters. They added that the employees were of not good proficiency in giving presentations, papers, workshops and delivering speeches at meetings, conferences and seminars.

On the other hand the respondents agreed that the former graduates under study were better at reading and listening when communicating in their occupational/professional settings. The former graduates had relatively better performance when reading professional books, manuals, business or personal letters and the employers added that the same is true when the former graduates were listening at meetings, oral presentations and instructions given by the employers.

Based on the information given in the table, it seems that the former graduates are better in their ability in receptive sub-skills (reading and listening) than productive sub-skills (speaking and writing). This shows that former graduates lack ability in some sub-skills that hampered communication for professional purposes.

The findings of the current study is in harmony with Bedilu (2020) and Hyland, K. (2018) who have found that students and former graduates seem to have various language, linguistic, lexical, and etc., difficulties that hampered their effective communication within academic and professional contexts. The study showed that former graduates had more difficulties in the receptive skills than in the productive skills. Similarly, Abuklaish's (2014) study identifies several difficulties that his subjects faced in learning and using English in the two domains. Delivering speeches at meetings and conferences; writing reports, reading magazines, articles, listening at meetings were some of the communication challenges that Thai food science workers encountered.

Hence, it is possible to infer that undergraduate agriculture students and former graduates faced different challenges that hindered the effective communication in their academic and professional settings. The students were found better at speaking and reading followed by listening when writing was the most difficult but very important skill for their academic performances. Regarding the former graduates, the most problematic area that challenged their professional communication in a decreasing order of difficulty could be reading, speaking, listening and writing sub skills.

Thus, it can be deduced from the data that the undergraduate agriculture students and former graduates encountered various difficulties in using English for both academic and professional duties which is due to a mismatch between agricultural students' purposes for which they are using English and the contents of current communicative English skill course. Thus, to solve the problem, it is essential to clearly identify the specific purposes for which agricultural students and former graduates need English for academics and professional settings.

Conclusions

The findings of this study underscore the significant challenges undergraduate agriculture students and former graduates face in mastering the English language for both academic and professional purposes. The analysis revealed that these students struggle particularly with technical reading, academic writing, and oral communication, skills crucial for their success in higher education and the global agricultural workforce. The gap between their current English proficiency and the demands of their academic and professional tasks highlights the inadequacy of general English instruction, pointing to the urgent need for a tailored English for Specific Purposes (ESP) curriculum. By addressing these specific language needs, such a curriculum would empower students to perform better academically and professionally, enhancing their readiness for career opportunities that require effective communication and technical expertise. This study's findings offer valuable guidance for universities like Ambo University to develop targeted language programs that equip agriculture students with the essential skills for thriving in both local and international contexts.

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RESEARCH PAPER

Family Characteristic Variables and Their Relationships with Family Cohesion, Adaptability, and Communications among Families in Mettu Town, Southwest Ethiopia: From Adolescents' Viewpoint

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Abstract

This study aimed to investigate the existing family characteristic variables and variations they made in family cohesion, flexibility, and communication among families in Mettu town, Southwest Ethiopia. It must be noted that research-based knowledge of family characteristics and functioning has substantial implications for family interventions. Despite this, evidence shows a dearth of studies in these areas in Ethiopia. Considering this gap, a quantitative study with a cross-sectional design was conducted. For this purpose, questionnaires were administered to a sample of 192 adolescents selected from three high schools based on stratified random sampling. Descriptive statistics, Pearson correlation, MANOVA, and follow-up univariate ANOVAs were computed with SPSS. The finding showed that there were significant variations in cohesion ($F(2,189) = 5.835$, $P<0.01$, $\eta^2 = 0.058$), flexibility ($F(2,189) = 4.87$, $p<0.01$, $\eta^2 = 0.049$), and communication ($F(2,189) = 10.157$, $p<0.01$, $\eta^2 = 0.097$) as a function of family structure. There were also significant variations in cohesion ($F(4,187) = 2.99$, $P<0.05$, $\eta^2 = 0.047$), flexibility ($F(4, 187) = 3.08$, $p < 0.05$, $\eta = 0.1742$), and communication ($F(4, 187) = 19.356$, $p<0.01$, $\eta^2 = 0.293$) as a function of family size. However, differences were not observed in the composite of the dependent variables related to economic status ($P > 0.01$). Overall, while nuclear family structure, reasonable family size, and optimum economic status promote health functionality, single parenting, economic stressors, and large family sizes that dilute family resources result in unhealthy functionality. Therefore, policymakers and scholars should further examine family issues and design family interventions.

Keywords: Family, adaptability, cohesion, communication, structure, functioning

Introduction

Throughout historical times, the family as a system has been studied from various perspectives (Zahra and Saleem, 2021) because it is a basic unit of a society that is important for the development of its members (Dai and Wang, 2015). On the other hand, family system scholars posit that the family as a whole or as a system consists of different sub-systems that dynamically affect each other (Olson, 2011). Regarding the within-family-level variables, it is good to scrutinize family characteristic variables, specifically family structure, economic status and size, as they are always dynamic. For instance, with the transformation of social values, family structure became highly varied (Bianchi and Casper, 2000). So, it is important to scrutinize how families are structured in a variety of ways including nuclear, single-parent families, child-headed families, or blended families (i.e., those consisting of previously divorced but now remarried parent couples) (Lin *et al*., 2019). In a study conducted by Wakgari and Belay (2021), it was observed that the common category of families in terms of structure consists of nuclear, single-parent and extended

families. They also confirm that families vary in terms of economic status and size too.

Family in terms of its functionality is a system representing a condition where communication, interactions, family rules, and ways of sharing roles that are conducive to positive development (Olson *et al*., 2007). This functionality is seen in terms of various dimensions: cohesion, adaptability, and communication. While cohesion refers to the emotional connection, adaptability or flexibility represents the amount of change in family leadership and relationship roles and rules (Olson, 2010). Adaptability represents the quality of leadership and organization within a family as well as the distribution of roles and rules of relationships (Olson and Gorall, 2006). Family communication represents the expression of thoughts and feelings in an assertive way among the family members while carefully receiving other members' thoughts and feelings (Dursic, 2018).

So, although the functionality of a family in terms of cohesion, adaptability, and communication may depend on several factors, family characteristic variables mainly structure, economic status, and size are considered here. Here, it has been confirmed that there are variations in family functioning across family structures favoring nuclear over non-nuclear families (Villarreal-Zegarra and Paz-Jesus, 2017). Similarly, it was observed in a study that two-parent families (i.e., nuclear) had higher mean scores on family cohesion compared to single-parent families whose mean score on cohesion was relatively lower (Bello *et al*., 2017). Hence, family structure influences the functionality of a family in the dimensions of cohesion, adaptability, and communication. Family structure had an impact on the adaptability and communication dimensions of family functioning. When it comes to a family's relative economic status, a study conducted by Wakgari and Belay (2021) shows that it had relationships with family functioning mainly cohesion and adaptability. The scholars suggested that there were significant differences in cohesion and adaptability favoring medium economic status over the lower and higher ones.

Scholars believe that poor socio-economic situations negatively impact family functioning and its dimensions. Banovcinova *et al*. (2014), for instance, suggested that a low economic situation disrupts the functioning of the family system. The family economic stress model also outlines that low family income creates economic stresses and pressures that affect parental and within-family relationships (Mistry *et al*. 2008) and the family's functionality.

Nevertheless, the roles that family size has in family cohesion, adaptability and communication have not been studied as far as the researcher's reviews are concerned. Yet one thing that must be noted is that family functioning has something to do with family's resources that have further association with family size. Downey (1995), for instance, suggested that the effect of family size is well explained by the Confluence model justifying that there is a reverse relationship between family size and child outcomes.

Thus, based on the preceding background research gaps have been observed in creating a suitable family atmosphere and ensuring the well-being of family members particularly in Ethiopia as stated in the Child Right Policy (Federal Democratic Republic of Ethiopia, 2017) tracing need for family studies and interventions. This gap in creating a suitable atmosphere represents existing problems in creating a healthy family (Matejevic *et al*., 2014) that includes family cohesion, adaptability and communication. Despite the policy statements, empirical evidence that shows the status of family functioning as well as relevant interventions designed to ensure the family's wellbeing seems to be nonexistent on the ground in Ethiopia. To alleviate these problems, the role of empirical evidence on cohesion, adaptability, and communication would have been traced in the policy. Family assessment is also rarely considered by researchers in Ethiopia, despite its importance (Taye, 2021).

On the other hand, family characteristics that have been in constant change become a very important area requiring empirical

examinations. There exists dynamism in family structure because of changing familial and societal arrangements (Sharma, 2013). Because of the prevalence of divorce, there is more single-parent structure today than ever. Hence, it is important to determine the nature of the families in terms of the existing structures in the study contexts. When it comes to family characteristics pertinent to economic status, it was outlined that the economic condition of the family generally influences family functioning (Dai and Wang, 2015). There is also a dearth of studies examining the impacts of family size on family functioning.

So, while the family characteristic variables themselves were matters of study, their roles as factors influencing the cohesion, adaptability and communication dimensions of family functioning became important. Regarding this, studies are showing the role of family structure and family functioning in influencing the well-being of family members (Lang, 2018). However, there is a dearth of studies on whether structure has an impact explicitly on cohesiveness, adaptability, and communication. Empirical work focusing on the impact of a family's economic status and size on patterns of family functioning was also nonexistent in our case. As far as the researcher's reviews and experiences were concerned, the impact of family characteristic variables on cohesion, adaptability, and communication has not been considered by researchers in Ethiopian contexts.

The study has, therefore, been designed to determine the existing family characteristic variables (i.e., family structure, relative economic status, and family size) and the statistical differences they made in the patterns of family functioning among families in Mettu town, Southwest Ethiopia.

Based on the study gaps, this study addressed three leading questions:

1. What were the nature or patterns of family functioning, mainly family cohesion, adaptability/flexibility, and communication in the study contexts?

2. What kinds of relationships were there between family characteristic variables and patterns of family functioning, i.e., cohesion, adaptability/flexibility and communication?

3. Was there a statistically significant difference in patterns of family functioning, i.e., family cohesion, adaptability/flexibility, and communication as the function of family characteristic variables mainly family structure, family's relative economic status, and family sizes?

Materials and methods

Research design

To extract the required data that would address the stated leading questions and to effectively deal with the general objective, the study employed a quantitative approach with a particular design known to be cross-sectional. The design was employed for its appropriateness to examine statistical differences enabling us to measure several variables at one point in time. The design was chosen for it addresses the study goal to statistically determine whether there were variations in family cohesion, adaptability and communication across family characteristic variables. It has to be noted that one of the factors that determines the choice of a research design over the others is the goal of the research (Coolican, 2014).

Study site

The study site is Mettu town, i.e., the main town of Illu Aba Bor Zone of Oromia Regional National State, Southwest Ethiopia, which is nearly 600 km away from Addis Ababa. In Mettu, there are interesting social relationships between the families and the cultural environment. Also, as people of different ethnicities live together, the number of ethnically mixed marriages and interethnic families is high. Thus, the ethnic composition of the population is more diversified, leaving big implications for research in the areas of family functioning. Moreover, as far as the researcher's experiences are concerned, families with different structures and

relationships exist in Mettu. Afan Oromo is a widely spoken language followed by Amharic. Regarding religious composition, many different religions exist in Mettu including Orthodox Christian, Muslim, Protestant, and Waaqeffataa. More importantly, it is not uncommon to find a family member with different religions that might contribute to the complexity of the family which has big implications for family study and interventions, indeed.

In Mettu, there were four high schools (9–12 grade level), three of which were targeted, while the remaining one was omitted for a reason. While this study was conducted, the excluded school (i.e., Mettu University Special High School) was newly established and didn't have all class levels. And, the site was selected for some reasons, including accessibility and the researcher's familiarity with the actual contexts.

Population and sampling

The study population was all students enrolled in high schools (i.e., grades 9–12) in Mettu town whose ages were between 15 to 20 years old. Participants were adolescents attending their education in the 2023 academic year. It was thought that adolescents are the proper participants for some reasons. First, it is thought that they can understand and properly fill out the questionnaire compared to young children. Secondly, because they were in schools, it was not very demanding to get them in person. On the other hand, because it is difficult to visit each family, the researchers decided to study the theme from adolescents' viewpoints.

Regarding sampling, combined procedures were used. In the first place, while Mettu town was selected based on accessibility, three senior high schools (i.e., Mettu High School, Abdi Bori Secondary School, and Hachalu Memorial Secondary School) were considered purposively. The total number of students in the schools was 3728 (i.e., 1250 in Mettu High School, 1643 in Abdi Bori Secondary School, and 835 in Hachalu Memorial Secondary School).

Sample size varies depending on different factors including the purpose of the study and the nature of the population under scrutiny. Yet, the general truth that must be considered is that the larger the sample size, the better the representation will be (Cohen *et al*., 2000).

When it comes to sampling, therefore, about 210 students were elected with the help of stratified random sampling. The selection was made based on the stratification of various types. With the help of proportional stratified random sampling (i.e., a sample of adolescents in proportion to the number of students in each school), a sample of 91 adolescents (M = 45, F = 46) from Abdi Bori High School, 71 adolescents (M = 35, F = 36) from Mettu High School, and 48 adolescents (i.e., M = 24, F = 24) from Hacalu Memorial High School were selected. Gender-based stratification was made based on an equal allocation approach in that the number of boys and girls was nearly equal. So, from the sample, while only 192 students (i.e., F = 98, M = 96) were considered for the final analysis, the remaining ones were omitted for not filling out the questionnaire properly.

Tools of data collection

Measures of demographic and family characteristic variables

Here personal variables mainly age, gender and family characteristic variables mainly a family structure, relative economic status, and size were assessed. These family characteristic variables were assessed with close-ended demographic variable questions prepared by the researcher based on various literatures. Of course, measuring a family's socioeconomic status is not an easy job. Were *et al*. (2022) stated that for there is an association between SES and family's well-being, there is a need to assess methods of classification of families into SES strata as low, middle and high. To measure these variables, Howe *et al*. (2010) who used a subjective measure of a family's socioeconomic status in an African country was based. Indicators were condensed to have three key measures of family's SES: perceived adequacy of income, perceived adequacy of basic needs and services and perceived relative

economic positions. Then respondents were made to rate the key indicators as low/less than adequate, medium/adequate, and high/more than adequate).

The measure of family cohesion, adaptability/flexibility and communication

To measure family cohesion, a self-report scale that was originally developed as part of the Family Adaptability and Cohesion Evaluation Scale (FACES) in the Circumplex Model of Marital and Family Systems (Olson, 2010) and later validated and adapted to the local contexts by Wakgari and Belay (2021) was used. The scale has three sub-constructs: one balanced (i.e., "balanced cohesion") and two unbalanced (i.e., "enmeshed "and "disengaged". The Family Cohesion Scale has a total of 19 items, i.e., 7 items for "enmeshed," 7 items for "balanced cohesion," and 5 items for "disengaged" dimensions (Wakgari and Belay, 2021). Concerning the psychometric features of these scales, Wakgari and Belay (2021) found that the alpha reliability was 0.841 for "enmeshed," 0.923 for "balanced cohesion," and 0.934 for the "disengaged" one.

In measuring family adaptability, the self-report scale that was developed as part of FACES-IV in the Circumplex Model of Marital and Family System (Olson *et al.*, 1979) and later validated and adopted to the local contexts by Wakgari and Belay (2021) was used. The scale has also three sub-constructs: one balanced (i.e., balanced flexibility/adaptability) and two unbalanced (i.e., "chaotic" and "rigid") sub-scales. The family flexibility scale also has a total of 19 items, i.e., 7 items for "chaotic",7 items for "balanced flexibility" and 5 items for the "rigid" (Wakgari and Belay, 2021). Regarding the psychometric features of the scales, Alpha reliability was examined to be 0.95 for the "chaotic," 0.918 for the "balanced flexibility," and 0.665 for the "rigid" scale (Wakgari and Belay, 2021).

Family communication was measured by the Family Communication Scale which was originally developed as part of FACES-IV of the Circumplex Model of Marital and Family Systems as a validation scale by Olson *et al*. (2007) with 10 items. Its initial alpha reliability was 0.93. However, the newly validated FCS had an alpha reliability of 0.97 (Wakgari and Belay, 2021).

Data analysis

For the analysis, first, descriptive statistics (mean and standard deviations) were used to determine the portion of families that fall into different family characteristic variables and to identify the pattern and nature of family cohesion, adaptability and communication. Descriptive statistics were employed to address the research question that says, "What was the nature or patterns of family functioning mainly family cohesion, adaptability, and communication in the study contexts?". Secondly, Pearson's correlation was used to compute whether there were statistically significant relationships between family characteristic variables and family cohesion, adaptability, and communication to address the question stated as "What kinds of relationships were there between family characteristic variables and patterns of family functioning, i.e., cohesion, adaptability and communication?". Lastly, as the research design was cross-sectional, a one-way ANOVA was believed to be appropriate to determine whether there were statistically significant differences in family cohesion and adaptability as a function of family characteristic variables. Therefore, because all the family characteristic variables treated in the study had more than two levels and because there was a need to test several outcome variables at a time, MANOVA along with follow-up univariate ANOVA was computed to address the research question stated as "Was there a statistically significant difference in patterns of family functioning, i.e., family cohesion, adaptability, and communication as the function of family characteristic variables mainly family structure, family's relative economic status, and family sizes?". Conducting separate ANOVA for each dependent variable may result in the loss of important information regarding any relationship between the variables. Hence, by including all dependent variables in MANOVA in the same analysis, we can determine further

relationships between several variables at a time (Fields, 2013). In this case, since we have three independent variables (i.e., family size, SES, and structure) and three dependent variables (i.e., family cohesion, adaptability and communication), it was believed that MANOVA along with follow-up ANOVA is appropriate. Generally, all the statistical analysis were carried out with SPSS-25.

Ethical considerations

Ethical concerns in research are something that addresses the required standards of professional conduct in research works that are under the control of the researcher (Neuman, 2007). With this understanding, different ethical issues were considered throughout this study. Thus, obtaining informed consent, administering the questionnaire at times that were convenient to the respondents, respecting confidentiality and participants' rights to privacy, and enshrining anonymity were few among many ethics.

Results

Personal and family characteristic variables

Descriptive statistics show that the age range of the respondents was 15-20, with a mean age of 17.5. In terms of gender, while girls account for 51%, boys account for about 49%. When it comes to family structure, most of the respondents were from nuclear families (n = 122, 63.5%). This proportion was followed by those adolescents from extended families (n = 52, 27.1%) and those from single-parent families (n = 18, 9.4%) appearing last. Regarding the relative economic status, most of the respondents were reported to be from families with a medium economic level (n = 112, 58.3%), followed by those from lower economic levels (n = 60, 31.3%). And only a few (n = 20, 10.4%) of them were from families with higher economic status. Regarding family size, there were families with a minimum of three to those with a maximum of eight members.

Nature and patterns of family functioning (i.e., cohesion, adaptability and communication)

Table 1 as follows presents descriptive statistics showing the mean, standard deviation, and percentile scores on the cohesion, adaptability, and communication.

As observed in Table 1, in the cohesion dimension a higher proportion of families fall into enmeshed (40.1%), followed by disengaged (33.9%), and balanced cohesion (26.0%). It was also observed that the mean score on cohesion which was 62.96 fall in the percentile range of 25 to 50 implying that the families had a generally moderate level of family cohesion. This interpretation was given based on Olson's (2010) guideline presented in the Family Adaptability and Cohesion Evaluation Scale manual, whereby a percentile rank for the cohesion dimension that falls between 36 and 65 represents a connected (moderately cohesive) family, while the one that falls between 65 and 85 represents a well-cohesive family.

In adaptability dimension, although majority of the families fall into the rigid dimension followed by balanced flexibility, it was generally determined that the mean score (M = 60.69) and the percentile rank show that the families fall into a moderately flexible level. The mean score for communication (M = 32.32) falls in the 50th percentile rank implying that the families had a good (moderately high) level of communication.

Table 1: Descriptive statistics showing the nature of family cohesion, adaptability/flexibility and communication

	Dimensions	Descriptive statistics					Percentile and corresponding scores						
		N (%)	Min.	Max.	Mean	Std. Deviation	5	10	25	50	75	90	95
Cohesion	Disengaged	65(33.9)	43.00	51.00	46.446	1.750	45.00	45.00	47.25	70.00	72.00	74.00	75.00
	Enmeshed	77(40.1)	67.00	78.00	72.052	2.175							
	Balanced	50(26.0)	68.00	75.00	70.440	1.579							
	Total	192(100)	43.00	78.00	62.963	12.013							
Adaptability/ Flexibility	Rigid	83(43.2)	41.00	72.00	50.156	7.873	44.00	45.00	47.25	68.00	70.00	71.00	72.00
	Chaotic	54(28.1)	65.00	74.00	70.074	2.036							
	Balanced	55(28.6)	44.00	73.00	67.381	6.355							
	Total	192(100)	41.00	74.00	60.692	11.188							
Communication	Comm.	192(100)	23.00	47.00	32.322	6.115	24.00	25.00	28.00	31.00	36.75	42.00	44.00

Correlation between family characteristic variables and family cohesion, adaptability and communication

The following correlation shows the degree and direction of relationships that existed between family characteristic variables and family cohesion, adaptability and communication.

Table 2. Correlation matrix showing the relationships between family characteristic variables and family cohesion, adaptability and communication

	FS	FSTR	FEcon	FCoh	FFLX	FCOM
Family Size (FS)	1					
Family Structure (FSTR)	-0.253**	1				
Family Econ Status (FEcon)	-0.292**	0.064	1			
Family Cohesion (FCoh)	-0.279**	0.322**	0.176*	1		
Family adaptability (FFLX)	-0.258**	0.276**	0.132	0.789**	1	
Family Communication (FCOM)	-0.406**	0.286**	0.127	0.703**	0.587**	1

Table 2 shows that there were significant negative correlations between family characteristics pertaining to size and cohesion, adaptability and communication ($p<0.01$) implying that the larger the family size the lower the cohesion, adaptability and communication would be. However, family characteristics variable pertinent to structure had statistically positive correlation with cohesion, adaptability and communication ($p<0.01$). Concerning the relationships that SES had with the patterns of family functioning mixed results were observed. Thus, while family characteristic variable pertaining to SES had significant positive correlation with cohesion ($r=0.176$, $p<0.05$), it showed positive but not significant relations with adaptability and communication.

Patterns of family functioning in families with different characteristics

In this sub-section, different statistical analyses were used to determine whether the patterns of family functioning differ by family characteristic variables (size, structure, and relative economic status). Hence, whether there were variations in cohesion, adaptability and communication aspects of functioning across family structure, economic status and size were checked using MANOVA coupled by follow-up univariate ANOVA.

Patterns of family functioning (cohesion, adaptability and communication) across family structure

The study used preliminary test statistic on variations in cohesion, adaptability and communications across family structure. Then, ANOVA and MANOVA were employed to examine differences across family structure. As shown in Table 3, the preliminary test statistics in MANOVA showed that there were variations on the composite of the three dependent variables in association to the independent variable.

Table 3. Preliminary test on variations in patterns of family functioning across family structure

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	0.964	1656.259[b]	3.000	187.000	0.000
	Wilks' Lambda	0.036	1656.259[b]	3.000	187.000	0.000
	Hotelling's Trace	26.571	1656.259[b]	3.000	187.000	0.000
	Roy's Largest Root	26.571	1656.259[b]	3.000	187.000	0.000
Family structure	Pillai's Trace	0.119	3.952	6.000	376.000	0.001
	Wilks' Lambda	0.881	4.058[b]	6.000	374.000	0.001
	Hotelling's Trace	0.134	4.163	6.000	372.000	0.000
	Roy's Largest Root	0.133	8.340[c]	3.000	188.000	0.000

Thus, Table 3 indicates that all the possible test statistics were significant (Pillai's Trace F (6, 376) =3.952, $p<0.01$; Wilks' Lambda F (6, 374) =4.058, $p<0.01$; Hotelling's Trace F (6, 372)=4.163, $p<0.01$; and Roy's Largest Root F (3, 188) =8.340, $p<0.01$), indicating that the individual independent variables should be subjected to follow-up univariate ANOVA presented below.

Table 4. Tests of between-subject effects of family structure on family cohesion, adaptability and communication

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	Cohesion	402522.499	1	402522.499	2930.13	.000	.939
	Flexibility	377725.047	1	377725.047	3139.629	.000	.943
	Comm.	105050.325	1	105050.325	3077.904	.000	.942
Family structure	Cohesion	1603.206	2	801.603	5.835	.003	.058
	Flexibility	1172.502	2	586.251	4.87	.009	.049
	Comm.	693.319	2	346.660	10.157	.000	.097
Error	Cohesion	25963.538	189	137.373			
	Flexibility	22738.368	189	120.309			
	Comm.	6450.660	189	34.130			
Total	Cohesion	788733.000	192				
	Flexibility	731163.000	192				
	Comm.	207740.000	192				
Corrected Total	Cohesion	27566.745	191				
	Flexibility	23910.870	191				
	Comm.	7143.979	191				

Note: R Squared =0 .105 (Adjusted R Squared = 0.096); R Squared =0 .078 (Adjusted R Squared = 0.068); R Squared = 0.097 (Adjusted R Squared = .087)

There were significant variations in cohesion ($F(2,189) = 5.835$, $P<0.01$, $\eta^2 = 0.058$), flexibility ($F(2,189) = 4.87$, $p<0.01$, $\eta^2 = 0.049$), and communication ($F(2,189) = 10.157$, $p<0.01$, $\eta^2 = 0.097$) across family structure. Proportion of multivariate variance of dependent variables (q^2) related to structure were 5.8%, 4.9%, and 9.7% whereby communication and cohesion took precedence (See Table 4). Positive communication, cohesion, and flexibility were features of nuclear families.

Table 5. Post-hoc test of multiple mean comparisons on the role of family structure on family cohesion, adaptability and communication

Dep. Variable	(I) Family structure.	(J) Family structure.	Mean Diff. (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Cohesion	Single	Extended	-1.52	3.20	.883	-9.09	6.05
		Nuclear	-7.07*	2.96	.037	-14.06	-.08
	Extended	Single	1.52	3.20	.883	-6.05	9.09
		Nuclear	-5.55*	1.94	.013	-10.13	-.97
	Nuclear	Single	7.07*	2.96	.047	.085	14.06
		Extended	5.55*	1.94	.013	.97	10.14
Adaptability /Flexibility	Single	Extended	-.82	2.99	.960	-7.91	6.26
		Nuclear	-5.72	2.77	.100	-12.26	.82
	Extended	Single	.82	2.99	.960	-6.26	7.91
		Nuclear	-4.90*	1.82	.021	-9.19	-.61
	Nuclear	Single	5.72	2.77	.100	-.82	12.26
		Extended	4.91*	1.82	.021	.61	9.19
Comm.	Single	Extended	-.05	1.59	.999	-3.82	3.7
		Nuclear	-3.98*	1.47	.021	-7.45	-.49
	Extended	Single	.05	1.59	.999	-3.73	3.82
		Nuclear	-3.94*	.97	.000	-6.2	-1.65
	Nuclear	Single	3.98*	1.47	.021	.49	7.47
		Extended	3.94*	.97	.000	1.65	6.22

With Table 5 it was observed through a post-hoc test of multiple mean comparisons that, in cohesion dimension, when nuclear families were compared to single-parent homes and extended families, the mean differences were positive and statistically significant ($p<0.05$). When single-parent families were compared to nuclear, the difference was negative and statistically significant ($P<0.05$) implying that better cohesion was associated more with nuclear structure followed by extended and single-parent homes. In flexibility dimension, when a single-parent family was compared to an extended family, the mean difference was negative but not statistically significant ($P > 0.05$). When compared to the nuclear family, the difference was also negative and not significant ($P > 0.05$). But when nuclear families were compared to single-parent and extended families, the mean differences were positive in both cases implying that nuclear families had a higher mean score in flexibility, whereas extended families or single-parent homes did not. Also in communication, when

nuclear families were compared to single-parent and extended, the differences were positive and significant ($p<0.05$) that positive communication characterizes nuclear families than it does for the remaining ones.

Patterns of family functioning (cohesion, adaptability/flexibility and communication) across the family's economic status

To determine patterns of family functioning: cohesion, adaptability and communication, preliminary test statistics (MANOVA) were computed as shown in Table 6.

Table 6: Preliminary test statistics (MANOVA) on variations in patterns of family functioning across family's economic status

	Effect	Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.965	1717.864[b]	3.000	187.000	0.000
	Wilks' Lambda	.035	1717.864[b]	3.000	187.000	0.000
	Hotelling's Trace	27.559	1717.864[b]	3.000	187.000	0.000
	Roy's Largest Root	27.559	1717.864[b]	3.000	187.000	0.000
Economic status	Pillai's Trace	.055	1.770	6.000	376.000	0.104
	Wilks' Lambda	.945	1.783[b]	6.000	374.000	0.101
	Hotelling's Trace	.058	1.796	6.000	372.000	0.099
	Roy's Largest Root	.056	3.523[c]	3.000	188.000	0.016

It was observed from the preliminary analysis of MANOVA that a family's economic status had no significant impacts on dimensions of family functioning with no significant F-ratio on the possible test statistics including Pillai's Trace ($F (6, 376) =1.770$, $p = 0.104$), Wilks' Lambda ($F (6, 374) =1.783$, $p = 0.101$), and Hotelling's Trace ($F (6.372) =1.796$, $p = 0.099$) (see Table 6). This implies that there were no differences in the composite of the dependent variables related to economic status indicating that there was no need to perform a follow-up univariate ANOVA. Despite this, computing a follow-up ANOVA was necessary to have a picture of the actual trends in variation of dependent variable across the independent variable. Hence, the follow-up univariate ANOVA drawn out of MANOVA has been presented in Table 7 as follows.

Table 7. Tests of between-subject effects (i.e., of family economic status on family cohesion, flexibility, and communications)

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	Family cohesion	461975.600	1	461975.600	3186.435	.000	.944
	Family flexibility	428476.544	1	428476.544	3409.021	.000	.947
	Family comm.	116912.316	1	116912.316	3265.849	.000	.945
Family economic status	Family cohesion	165.154	2	82.577	.570	.567	.006
	Family flexibility	155.645	2	77.823	.619	.539	.007
	Family comm.	378.072	2	189.036	5.281	.006	.053
Error	Family cohesion	27401.590	189	144.982			
	Family flexibility	23755.224	189	125.689			
	Family comm.	6765.907	189	35.798			
Total	Family cohesion	788733.000	192				
	Family flexibility	731163.000	192				
	Family comm.	207740.000	192				
Corrected Total	Family cohesion	27566.745	191				
	Family flexibility	23910.870	191				
	Family comm.	7143.979	191				

Note: a. R Squared = .021 (Adjusted R Squared = .010), b. R Squared = .014 (Adjusted R Squared = .003), c. R Squared = .053 (Adjusted R Squared = .043)

So, Table 7 above shows that while there were no statistically significant variations in family cohesion ($F(2,189) = 0.57$, $p = 0.567$, $\eta^2 = 0.006$) and flexibility ($F(2,189) = 0.619$, $p = 0.539$, $\eta^2 = 0.007$) as the function of family's economic status, significant differences in communication were observed as the function of family's economic status ($F(2,189) = 5.281$, $p < 0.05$, $\eta^2 = 0.053$). The proportion of multivariate variance (η^2) of family cohesion, flexibility, and communication that were associated with the family's economic status were 0.6%, 0.7%, and 5.3% respectively.

It was generally observed, however, that higher mean scores in cohesion, flexibility, and communication were observed in families with medium economic status than they were in families with lower or higher economic status

Family functioning patterns (cohesion, adaptability and communication) across family size

The follow-up univariate ANOVA was drawn to present whether there were significant variations in cohesion, flexibility, and communication across family size. See MANOVA showing effect of family size on cohesion, flexibility, and communication as follows:

MANOVA in Table 8 shows that family size had significant impacts on all dimensions of family functioning with a significant F-ratio on all the possible test statistics (Pillai's Trace $F(12,561) = 5.69$, $p < 0.01$; Wilks' Lambda $F(12,489) = 6.37$, $p < 0.01$; Hotelling's Trace $F(12,551) = 7.00$, $p < 0.01$; and Roy's Largest Root $F(4, 187) = 20.29$, $p < 0.01$). The result generally showed that there were differences in the composite of the dependent variables related to family size. This result led the individual dependent variables to be subjected to follow-up univariate ANOVA to assess whether the dependent variables: cohesion, flexibility, and communication showed similar trends in their variations across family size

Table 8: Preliminary test statistics (MANOVA) on variations in patterns of family functioning across family size

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.975	2432.805[b]	3.000	185.000	.000
	Wilks' Lambda	.025	2432.805[b]	3.000	185.000	.000
	Hotelling's Trace	39.451	2432.805[b]	3.000	185.000	.000
	Roy's Largest Root	39.451	2432.805[b]	3.000	185.000	.000
Family size	Pillai's Trace	.326	5.693	12.000	561.000	.000
	Wilks' Lambda	.681	6.371	12.000	489.755	.000
	Hotelling's Trace	.458	7.004	12.000	551.000	.000
	Roy's Largest Root	.434	20.299[c]	4.000	187.000	.000

Table 9. Tests of between-subject effects of family size on cohesion, flexibility, and communications

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	Cohesion	511891.977	1	511891.977	3643.158	.000	.951
	Flexibility	483998.411	1	483998.411	4034.960	.000	.956
	Comm.	132935.336	1	132935.336	4920.385	.000	.963
Family size	Cohesion	1291.793	4	322.948	2.998	.041	.047
	Flexibility	1479.989	4	369.997	3.085	.017	.062
	Comm.	2091.750	4	522.938	19.356	.000	.293
Error	Cohesion	26274.952	187	140.508			
	Flexibility	22430.881	187	119.951			
	Comm.	5052.229	187	27.017			
Total	Cohesion	788733.000	192				
	Flexibility	731163.000	192				
	Comm.	207740.000	192				
Corrected Total	Cohesion	27566.745	191				
	Flexibility	23910.870	191				
	Comm.	7143.979	191				

Note: a. R Squared = .199 (Adjusted R Squared = .182), b. R Squared = .174 (Adjusted R Squared = .156), c. R Squared = .293 (Adjusted R Squared = .278)

The follow-up univariate ANOVAs shown in Table 9 indicated that all the dependent variables were significantly different for families with different sizes: F (4,187) = 2.99, P<0.05, Η2=0.047; F (4, 187) = 3.08, p < 0.05, Η2 =0.174; and F (4, 187) = 19.356, p<0.01, Η2= 0.293, respectively. The multivariate eta-squared ($Η^2$) values showed that the proportion of multivariate variance of family cohesion, flexibility, and communication that were associated with family size was 4.7%, 6.2%, and 29.3% respectively whereby communication took precedence followed by cohesion and adaptability. This implies that family size is an important determinant of the functionality of a family in different dimensions.

Discussions

It is generally believed that family functioning is all about how a family functions, communicates and interacts in a goal-directed and dynamic manner (Garst *et al*., 2013). For this reason, as suggested by Wakgari *et al*. (2023) it has long been believed that family functioning, including the nature of cohesion and communication, has paramount importance in many respects. Hence, the writers believe that to achieve a family's wellbeing, researchers should shift their attention to dealing with the family characteristics and functioning: cohesion, adaptability and communication. For this reason, it has been recognized that healthy family functioning: cohesion, adaptability and communication varies across several factors. Among those factors that determine the health of the family's functionality, this study emphasized on family characteristic variables pertaining to structure, size and relative economic status. The study therefore had a goal of determining whether there were significant variations in family functioning: cohesion, adaptability and communication across family characteristic variables.

To this end, it was observed that in all patterns of family functioning, families had a moderate level of functionality. The mean scores in cohesion, flexibility, and communication fall in percentile ranks that show a moderate level of functionality in almost all aspects. This interpretation was given based on a guideline (Olson, 2011).

The study showed that while family characteristic variables pertaining to size had a reverse relationship with cohesion, adaptability and communication, family's economic status showed a mixed result. Relationships among the major variables of the study were also examined. Hence, all the patterns of family functioning had significantly positive relationships with each other implying that the more cohesive a family was the more flexible it would be and the more positive communication it had. Of course, positive communication plays a mainstay role in bringing about a cohesive-flexible home environment (Olson, 2011). The study showed that there were variations in the composite of patterns of family functioning in association with family structures. There were significant variations in family cohesion, adaptability, and communication as a function of family structure. Thus, family structure plays a prominent role in cohesion and communication. It was generally determined that high family cohesion, positive communication, and a higher level of flexibility were the features of nuclear families than they were for single-parent and extended families in Mettu. It can be concluded that this finding goes in line with other empirical evidence that nuclear families are associated with relatively healthy functioning mainly in terms of cohesion and communication than single parents or extended families (Bello *et al*., 2017).

It has also been confirmed in the relevant literature that there are variations in family functioning across family structures, favoring nuclear over non-nuclear families (Villarreal-Zegarra and Paz-Jesus, 2017). It was observed, for example, in an empirical study that nuclear families had higher mean scores on family functioning like cohesion compared to single-parent families whose mean score on this functioning pattern was relatively lower (Bello et al., 2017). So family structure influences functionality of a family (Dai and Wang, 2015).

Regarding the roles of economic status, while no substantial differences in cohesion and flexibility were observed, differences were observed in communication whereby better communication was associated with medium economic status than it was for the lower and higher ones implying that while SES had no significant role in cohesion and flexibility, it showed significant effects on family communication. Nevertheless, it was observed that families with a medium economic level had a better level of functionality in all aspects. Meaning, those families whose economic status was medium had relatively healthier kinds of cohesion, flexibility, and communication relative to those families whose economic levels were reported to be lower or higher.

In line with this, a study conducted by Wakgari and Belay (2021) revealed that there were significant differences in scores on healthy dimensions of cohesion and flexibility (i.e., balanced cohesion and flexibility) and family communication across families' relative economic status favoring medium economic status over lower or higher ones. On the other hand, a study conducted by Booysen et al. (2021) revealed that poor or unhealthy family function was associated with lower economic status. So, tracing that there is a need for further empirical examinations to explain the nature of association that exists between patterns of family functioning and the family's relative economic status, Wakgari and Belay (2021) enlightened that while the healthy or functional aspects of cohesion and adaptability were associated with optimum economic status, the unhealthy or dysfunctional ones characterized families with low or high SES. These authors justify that this happens just because families with lower economic status have lots of worries and stresses that spoil the functionality of the family. On the other hand, families with high economic levels might have quite different kinds of factors like spending time and effort on other matters and businesses at the expense of family time that deterring functionality of the family. The scholars therefore pointed out that while the economic stresses seem to have ruined cohesiveness and adaptability in families with low economic status, it can be assumed that priorities might have been given to other issues than they did to the family issues in families with high economic status affecting the functionality of the family. The other assumption can be the fact that those families who fall into the medium economic status and whose children label their families as medium ones may be government employees who are educated. As a result, these families have better cohesion, flexibility, and positive communication than the rest portion of the community.

As far as patterns of family functioning across family size were concerned, it was observed that family size had substantial roles in regulating the functionality of a family. Thus, it was recognized that there were differences in the composite of patterns of family functioning related to family size implying that patterns of family functioning, i.e., cohesion, adaptability, and communication were significantly different for families with different numbers of members. More importantly, the impact of family size on family communication was much more substantial.

Limitations of the study

This study had various limitations, for example, data was collected from adolescents in that they filled out the questionnaire representing their families. Although they are mature enough to report the family characteristic variables accurately, their perceived responses on family functioning may not be accurate as such. There was also a challenge like reluctance and lack of interest among the respondents. Finally, though there are many factors associated with family functioning, this study was limited to selected variables; hence, a comprehensive family studies that include some more factors must be designed by future researchers.

Conclusions

Evidence reveals that family characteristic variables such as family structure, size, and economic status are some of the within-family-level variables affecting functionality of family. Here, it was observed that family characteristics pertinent to structure and size had substantial impacts on cohesiveness,

flexibility, and communication in that they had strong association with nuclear family arrangements than single-parent homes. On the other hand, dysfunctional patterns of functionality were associated with single-parent and extended families. Regarding a family's economic status, health functionality was more associated with a medium economic status than with a lower or higher economic status. While economic stress that results in the dilution of resources affects the functionality of a family in the case of families with lower economic status, it was assumed that priorities might be given to various issues than family issues affecting the health of the family in families with higher economic status.

It was determined that family size was an important determinant for the functionality of a family. Above all, the impact of family characteristic variables on family communication surpasses the impacts they had on cohesion and flexibility. This conclusively implies that nuclear family structure, optimum economic status, and reasonable family size promote positive family communication that further improves cohesiveness and flexibility.

On the other hand, it must be noted that with the transformation of social values and with the changing technology, these family characteristic variables become varied thus affecting the functionality of the family. For example, there have been variations in family structure and economic situations in the last few decades. For this reason, there are more single-parent homes today than ever before. Economic situations have also put families under stress. Nevertheless, there has been a dearth of studies dealing with family characteristic variables and the impacts they have on family functioning in Ethiopia. Moreover, there has been a dearth of family support programs leaving big implications for policies and strategies, research, and family interventions.

Recommendations

Today many factors determine the functionality of a family as understood by this and other studies. Family characteristic variables are some of the factors determining the health of a family's functionality in terms of cohesion, adaptability and communication. On the other hand, it must be noted that these family characteristic variables become highly varied thus affecting the state of functionality of the family. For example, there have been variations in family structure and economic situations in the last few decades. There are more single-parent homes today than ever before. The economic situation has also put many families under stress. Therefore, to build a healthy family, efforts must be made to deal with the governing factors like family characteristic variables from the sides of professionals and relevant bodies. Responsible bodies should mainstream the family issues in their project plans in one way or the other. Evidence also reveals that family characteristic variables pertinent to family size is one of the within-family-level variables affecting family cohesion, adaptability, and communication tracing that managing family size needs to be reconsidered via different means among family planners, and family policy makers. On the other hand, family cohesion, adaptability and communication not only determine the wellbeing of the family but also have further impacts on the individual family members, relevantly children and adolescents. Thus, practitioners must move with the understanding that the goal of family-related intervention is the wellbeing of the family members relevantly children and adolescents. Moreover, there has been a dearth of studies dealing with family characteristic variables and their impacts on family functioning that future researchers should shift their attention towards these areas in Ethiopia. There has also been a dearth of family support programs in our context leaving big implications to family therapy. Finally, as this study has some alerting parts for policymakers, family policy makers should re-examine the existing documents and make efforts for their effective implementations.

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