ETHIOPIAN JOURNAL
OF
AGRICULTURAL SCIENCES

ISSN 0257-2605 (Print)
ISSN 2415-2382 (Online)
Vol. 32 No. 4
October 2022

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Ethiopian Institute of Agricultural Research

ETHIOPIAN JOURNAL
OF
AGRICULTURAL SCIENCES

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www.eiar.gov.et
P.O.Box 2003
Addis Ababa, Ethiopia
Abbreviated title: Ethiop. J. Agric. Sci. (Online)
URL: http://www.eiar.gov.et/index.php/journals

Ethiop. J. Agric. Sci. 32(4) 1-29 (2022)

Assessment of Genetic Variability and Acid Soil Tolerance in Ethiopian Barley Landraces

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Abstract

Barley is an important food security and industrial crop in Ethiopia and its production is constrained by several factors including soil acidity stress. Thus, an experiment was conducted using 320 barley genotypes in alpha lattice design with two replications at Holeta, Jeldu and Midakegn testing sites during 2017 and 2018 to assess genetic variability among barley genotypes, to identify barley genotypes tolerant to acid soils using stress indices and to assess the association among stress indices as well as grain yield. Data analysis showed significant ($P\leq 0.01$) differences between the genotypes and the interactions. Estimates of heritability and genetic advance of the studied traits also revealed potential prospects for genetic improvement of traits of interest. Moreover, the overall mean grain yield under non-stress was 3212.42 kg ha^{-1} (1797 to 5936 kg ha^{-1}) compared to 2347.83 kg ha^{-1} (1797 to 5936 kg ha^{-1}) under acid soil stress indicating a yield reduction of 26.92%. Assessment of acid soil stress indices was also found to be promising in identifying tolerant genotypes with good yield potential. Yield under stress showed a strong positive correlation ($r = 0.89^{**}$) with yield under non-stress indicating that some genotypes which performed well under non-stress also showed good performance under acid soil stress. Moreover, STI, GMP, MP, AAI and ATA revealed the existence of a strong positive correlation between themselves and yield performance under both sets. Therefore, high yielding and tolerant barley genotypes were identified for further adaptation studies and simultaneous breeding line identification for subsequent crossing and variety development.

Keywords: Acid soil; Barley accession; Stress indices; *Hordeum vulgare*

Introduction

Barley (*Hordeum vulgare* L.) is the most important staple crop with an area coverage of close to one million hectares and a total annual grain production of about 2.34 million tons in Ethiopia (CSA, 2021). It is grown by smallholder farmers in Oromia, Amhara, Tigray and part of South Nations Nationalities and Peoples (SNNP) regional states with an altitude ranging from 1400 to 4000 meters above sea level (masl). Compared to malt barley production the share of food barley production is more than eighty percent in Ethiopia. Thus, barley grain accounts for more than half of the food requirement in the highland of the country for which it serves as the main source of calories and the food value of barley as source of energy is highly recognized by the farmers in Ethiopia (Ceccarelli *et al.*, 1999; Zemede, 2000). Besides the grain value of barley, its straw and grain by-products from breweries constitute an indispensable component of animal feed in the highland where feed shortage is prevalent (Aemiro *et al.,* 2011).

Generally, barley production is hampered by several biotic and abiotic constraints among which soil acidity is now a serious threat in most central, western and southwestern highlands of Ethiopia where barley production is the most important (Getachew *et al.,* 2017). The dominant agricultural areas of the highlands which are characterized by high rainfall distribution with an altitude greater than 1500 masl are located in almost all regions of Ethiopia are affected by soil acidity (Getachew *et al.,* 2019; Hailu and Getachew, 2011). In these highland areas, crop cultivation has occurred for many years with continued removal of reserve nutrients in the harvested products. The lack of proper cultural practices which cause nutrient loss through erosion and leaching has also aggravated the problem. Moreover, it is estimated that more than 40% of the total arable land of the country has soil acidity problems (Mesfin, 2007). About 28.1% of areas are affected by soil acidity (Fig. 2) and these soils are dominated by strongly acidic to moderately acidic soils (Ermias *et al.,* 2013; Hirpa *et al.,* 2013; ATA, 2014). Under acid soil stress conditions plant growth inhibition may result from a combination of factors including Aluminum (Al), Manganese (Mn), H-ion toxicities and deficiency of essential elements (Bona *et al.,* 1993). Al toxicity is the primary limitation to agricultural production in acid soils affected areas (Rao *et al.,* 1993) and at low pH value (pH < 5.0), Al is solubilized into toxic ionic forms (Al^{3+}) which can rapidly inhibit root growth, affecting nutrient uptake, and ultimately reducing productivity (Chuan *et al.,* 1996; Soto-Cerda *et al.,* 2013). Among cereal crop species, barley is regarded as the most sensitive crop to soil acidity (Bona, 1993; Wang *et al.,* 2006) and substantial barley yield reduction due to soil acidity was also reported by various researchers in Ethiopia (Hailu and Getachew, 2011; Getachew *et al.,* 2017; Getachew *et al.,* 2019).

From a plant breeding perspective, the extension of yield potential and reduction of susceptibility to abiotic and biotic stresses are genetic forces as a foundation for crop improvement (Garvin and Carver, 2003). Generally, the basic intention of germplasm resource programs is to assure the continued availability of genetically diverse genotypes with the traits required for developing stable and productive varieties with desirable quality standards (Bockelman and Valkoun, 2011; Brown *et al.,* 2014; Tandzi *et al.,* 2019). Accordingly, the country has a wealth of genetic resources of more than fifteen thousand barley accessions which were collected across the country and preserved *ex-situ* and *in-situ* by the Ethiopian Biodiversity Institute (Adugna, 2011; Bockelman and Valkoun, 2011). Ethiopian barley landraces were known for great gene diversity especially in harboring resistance genes (Qualset, 1975; Yitbarek *et al.,* 1998) and exploited worldwide by modern plant breeding endeavors (Firdissa and Heinrich, 2009).

Genetic variation allows different plant species and different varieties of the same species, to exhibit differing abilities to grow in acidic soils (Garvin and Carver, 2003). As an intervention strategy, genetic improvement is the best solution for developing barley varieties that are tolerant to soil acidity/aluminum toxicity. Studies revealed that a range of soil acidity tolerance have been identified and selective barley breeding programs have produced varieties with increased aluminum tolerance (Miao *et al.,* 2013). Hence, utilization of the conserved crop germplasm resource to develop acid soil tolerant varieties is an economically feasible and environmentally friendly management option that can complement other non-genetic approaches under acid soil environments (Getachew *et al.,* 2019; Tandzi *et al.,* 2019).

Genotype evaluation for acid soil tolerance assessment in Ethiopia is limited except for the studies in tef which were conducted by Ermias *et al.* (2013) and Misgana *et al.* (2019). In this respect, stress indices are the most useful tools for the evaluation of plant response under stress as they are the reflector of crop plant behavior under stress by relating yield under non-stress and stress conditions (Jamshid and Javnmard, 2018). Generally, several yield-based stress indices have been widely used to identify acid soil stress-tolerant genotypes based on yield loss under stress versus normal conditions (Kasno *et al.,* 2013; Dewi-Hayati *et al.,* 2014; Tandzi *et al.,* 2015). Acid soil or Aluminum Tolerance Index (ATI) and Aluminum Adaptation Index (AAI) according to Howeler (1991); Stress Tolerance Index (STI) and Geometric Mean Index (GMP) as per Fernandez (1992); Stress Susceptibility Index (SSI) according to Fischer and Maurer (1978) and Mean Productivity (MP) and Tolerance Index (TOL) according to Rosielle and Hambling (1981) are among the most utilized stress indices. Although these stress indices have been used for the evaluation of various crops under stress environments, there is limited information regarding barley genotypes assessment under soil acidity stress conditions in Ethiopia. Accordingly, a field screening experiment was executed to generate data and evaluate barley genotypes for acid soil stress tolerance. Therefore, this study was initiated to assess genetic variability among barley genotypes under acid soil stress and non-stress conditions, identify barley genotypes tolerant to acid soils using stress indices and evaluate the association among stress indices as well as grain yield.

Materials and Methods

The experiments were conducted using 320 barley genotypes comprising 294 accessions obtained from the Ethiopian Biodiversity Institute (EBI, http://www.ebi.gov.et) and twenty-six nationally released barley varieties. Among the prominent released varieties which were known for their wide adaptation and good yield potential are; HB-1307, HB-1966, IAR/H/485, Ardu-1260B, Shege, EH-1493. Representative barley accessions of national collection across the country with full passport data were identified and purified or homogenized at Holeta Research Center. The accessions were collected from acid soil affected areas of the country were represented by; Agaw Awi and East Gojam zone in Amahara; East Shewa, North Shewa and East Wollega in Oromia; Gurage, Hadiya and North Omo in SNNP regional states. Collection areas of these barley accessions called hereafter “genotypes for experimental purposes are described in Fig. 1. The genotypes considered were from the collections made in 16 administrative zones in the four regional states of Ethiopia (Amhara, Oromia, Tigray and SNNP). Likewise, germplasm collection points across the country are indicated on the Ethiopian map with triangular symbols marked with blue color (Fig. 1).

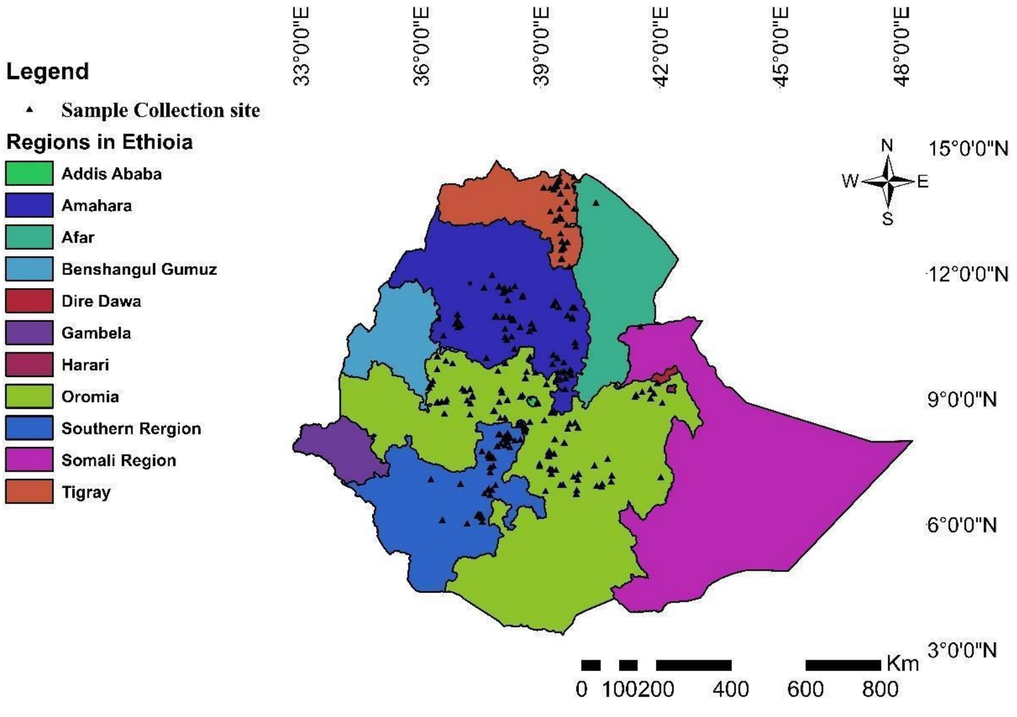
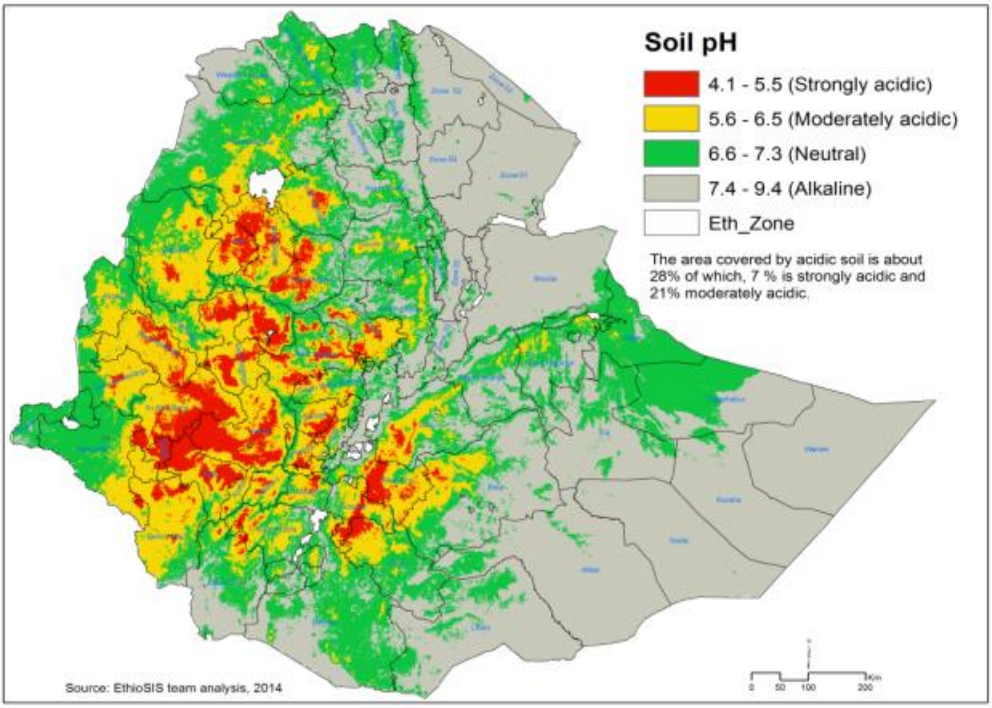


Figure 1. Map of Ethiopia showing the approximate areas of origin of barley accession and inter-regional boundaries, whereas different colors designate regional states of the country. The triangular points were developed from the geographic coordinate (latitude and longitude) position of barley collection points.

Test Environment and Experimental Design

Based on various reports from the soil research team at Holeta Agricultural Research Center, soil samples were collected and analyzed at the Holeta soil laboratory to determine the appropriate acid soil test environment. Accordingly, soil parameters such as pH (1:1.25 H_2O) exchangeable acidity and exchangeable aluminum were quantified. Based on the result of soil samples, experimental fields were identified at Holeta, Jeldu and Midakegn sites depending on the level of soil acidity. Description of the study locations for geographical position and soil physico-chemical properties are shown in Table 1.



The area covered by acidic soil is about 28% of which, 7 % is strongly acidic and 21% moderately acidic.

Source: EthioSIS team analysis, 2014

Figure 2. Extent and distribution of soil acidity in Ethiopia; (adopted from ATA, 2014).

Accordingly, the selected experimental field was divided into two equal parts side by side at the respective site. Then the fields were assigned to lime treated (non-stress) and without lime treatment (acid soil stress) experimental sets respectively. In stress breeding, researchers recommend that genotype evaluation and selection needs to be done under both stress and non-stress conditions (Fischer and Maurer, 1978; Fernandez, 1992). For the non-stress field, $CaCO_3$ or lime requirement was determined based on exchangeable acidity which was estimated through extraction and titration as described by Kamprath (1984).

$$LR\ CaCO3\ kg/ha = EA\ cmol\ kg\ soil \times DS\ (m) \times A\ m2 \times bgcm32 \times LF$$

Where: LR= Lime Rate; EA= Exchangeable Acidity; DS= Depth of Soil (0.15m); A= Area of experimental land; b= Soil bulk density; LF= Liming Factor or adjustment factor (LF= 1.5) is determined based on crop response.

Fifteen cm plow depth, bulk density of the soil and area (m^2) of the experimental field were used for lime rate (LR) determination. Subsequently, the required amount of fine lime was incorporated into the soil thirty days before planting to get sufficient incubation time.

Table 1. Description of the test locations for geographical position and physico-chemical properties of the soils

SN	Experimental Site	pH	Ex A	ExAl	*ρd*	Altitude	Longitude	Latitude
1	Holeta Research Center	4.86	1.55	1.05	1.13	2400	38^{0}30'17E	9^{0}03'28N
2	Jeldu (Kolu)	4.08	2.58	1.74	1.26	2800	38^{0}03'54E	9^{0}17'50N
3	Midakegn (Baro Bidaru)	4.07	3.74	2.62	1.15	2900	37^{0}28'25E	9^{0}08'35N

Ex A= Exchangeable acidity; Ex Al= exchangeable aluminum; b= Soil bulk density;

Accordingly, each set of experiments was conducted separately under acidic soil and lime treated optimum conditions at three locations for two consecutive years. The experiments were conducted in an alpha lattice design replicated twice, with 20 incomplete blocks, each containing 16 genotypes. Plot area of 2.0 m^2 consisting of four rows 2.5 m long spaced 0.2 m apart between rows, 0.4 m between plots and 1.5 m between blocks was considered. Seeds were sown on rows with manual drilling at a rate of 85 kg ha^{-1}. Likewise, fertilizers were applied at the rate of 46 kg ha^{-1} P_2O_5 and 41 kg ha^{-1} Nitrogen from NPS (Nitrogen, Phosphorus, Sulphur) formulation and Urea source respectively once at planting based on the research recommendation in the study area. The ratio of N:P:S is 19: 38: 7 for Nitrogen, P_2O_5 and Sulphure respectively. Generally, both experimental sets received similar management except for lime treatment.

Data Collection

Data were collected at all locations from both sets of experiments either from the whole plot or from ten randomly sampled plant bases in each plot. Mean values of the 10 randomly sampled plants and plot basis were used to estimate the performance of each genotype for the traits considered (Table 2).

Table 2. Descriptions of morpho-agronomic traits of barley genotypes on plot and plant basis

Traits	Description of data collection
Days for Heading	Recorded as the number of days from sowing to the date on which 50% of the plants in a plot have produced their first flower.
Days to Maturity	Recorded as the number of days from sowing to the stage when 75% of the plants in a plot have reached maturity.
Grain Filling Period	Number of days between days to flowering and days to physiological maturity
1000-Kernel Weight	Weight in grams of random samples of thousand kernels per plot.
Hectoliter Weight	Hectoliter weight (kg/hl) is flour density produced in a hectoliter of the seed and it was determined using moisture and hectoliter analyzer.
Biological Yield	Biomass yield was determined by weighing the total air-dried above-ground biomass harvested from the plot and expressed in kg ha^{-1}.
Grain Yield	Grain yield was determined by weighing grain samples from a plot adjusted to 12% moisture content and expressed in kg ha^{-1}. Grain yield adjustment or correction factor; CF= (100-Actulal Moisture 100-Standrd Moisture)
Stress Score	Acid soil stress score was recorded based on (1-9) scale, in which 1 is when there is very low sign of stress and 9 is high stress susceptibility (IPGRI, 1994).
Plant Height	Measured as a height in cm from the soil surface to the tip of the spike excluding the awns at maturity and expressed as an average of ten plants.
Fertile tillers /Plant	Number of fertile tillers per plant excluding the main plant was recorded at maturity and expressed as an average of ten plants in a plot.
Spike Length	Spike length of main tiller measured in cm from base to tip excluding the awns and expressed as an average of ten plants in a plot.
Kernel Number Per Spike	Determined by counting the number of kernels produced on the main tiller of each plant and expressed as an average of ten plants in a plot.
Kernel Weight Per Spike	Determined by weighing the kernels in grams in each spike of the main tiller of each plant and expressed as an average of ten plants in a plot.
Spike Weight	Determined by weighing the spike of the main plant as an average of ten plants in plot.

Statistical Analysis of Phenotypic Traits

All quantitative traits data were subjected to analysis of variance (ANOVA) using META-R version 6.0 developed by CIMMYT (Alvarado *et al.,* 2016; Alvarado *et al.,* 2020) and Minitab software version 17 statistical software packages (Minitab, 2007). Traits with count and scale data were log and square root transformed before analysis according to Gomez and Gomez (1984). Analysis of variance was done first separately for each environment under respective management. For the combined analysis of variance, the homogeneity of error variance was tested using the F-max method from a separate analysis, which is the ratio of the larger variance to the smaller variance (Hartley, 1950; Gomez and Gomez, 1984).

The total variability for the traits of days to heading, days to maturity, grain filling period, plant height, number of fertile tillers, spike length, spike weight, number of kernels per spike, thousand kernel weight, hectoliter weight, grain yield, and biomass yield were quantified and individual as well as combined analyses of variance over test environments using the following models:

The linear models were implemented in *lmer* from package *lme4* of R using REML to calculate BLUPs and estimate the variance components for individual and combined analysis. For individual trial; $Y_{ijk} = \mu + Rep_i + Block_j\ (Rep_i) + Gen_k + \varepsilon_{ijk}$ and for the combined analysis across all environments for the lattice design, is based on the model; $Y_{ijkl} = \mu + Env_i + Rep_j(Env_i) + Block_k(Env_i\ Rep_j) + Gen_l + Env_i \times Gen_l + \varepsilon_{ijkl;}$ where Y_{ijkl} is the trait of interest, μ is the mean effect, Rep_j is the effect of the j^{th} replicate within i^{th} environment, $Block_k$ (Rep_i) is the effect of the k^{th} incomplete block within the i^{th} environment and j^{th} replicate, Gen_l is the effect of the l^{th} genotype, and $Env_i \times Gen_l$ are the effects of the i^{th} environment and the environment × genotype interaction, ε_{ijkl} is the error associated with the i^{th} environment, j^{th} replication, k^{th} incomplete block and the l^{th} genotype, which is assumed to be normally and independently distributed, with mean zero and homocedastic variance σ^2. When using META-R for calculating the BLUPs, all effects (including environment) were considered random (Alvarado *et al.*, 2016; Alvarado *et al.*, 2020).

In the current study, seven grain yield based stress indices were used to evaluate acid soil stress tolerance and susceptible barley genotypes. Description of all the stress indices with their respective formula are shown in Table 3. Moreover, the reduction in overall trait mean values due to acid soil stress was calculated as percent mean reduction; PMR (%) = (Yns-Yst)Yns×100; Where; Yns and Yst are yields of a given genotype under non-stress and stressed soil conditions respectively.

The broad-sense heritability for the combined analyses was calculated as;
$h^2 = [\ 2g\ \ 2g + 2g\ e\ /n\ env + 2e/\ n\ env\ \ n\ reps] \times 100$; where σ^2g, σ^2ge, σ^2e, n env, and n reps are; genotype, genotype by environment interaction variance, error variance components, number of environments and number of replications respectively. Phenotype variance was computed from the summation of $\sigma^2g + (\sigma^2ge/n\ env) + (\sigma^2e/\ n\ env \times n\ reps)$.

Genetic advance in an absolute unit (GA) and percent of the mean (GAM), assuming selection of the superior 5% of the genotypes, was estimated following the methods illustrated in Johnson *et al.* (1955) and Brown *et al.* (2014) as:
$GA = K \times \sigma Ph \times h\ 2$ $\quad$ $GAM = [GAX\ ] \times 100$
Where σ_{Ph}= phenotypic standard deviation, h^2 = broad sense heritability and X = Grand mean, K= the standardized selection differential at 5% selection intensity (k = 2.063).

Pearson correlation coefficient and principal component analysis were carried out using those indices along with grain yield under stress and non-stress. The correlation coefficient is useful in finding out the overall degree of linear association between two traits. Even, a better approach than a correlation analysis such as biplot analysis is needed to identify superior genotypes for both stress and non-stress environment for assessing relationships among all attributes at once

(Talebi *et al.,* 2009; Nazari and Pakniyat, 2010; Teklay *et al.,* 2020). Principal component analyses for yield-based stress indices and grain yield was carried out using R software and the values of various indices and yield under both conditions were pre-standardized to means of zero and variances of unity before principal component analysis to avoid bias due to differences in values or measurement scales (Manly, 1986).

Table 3. Description of the selected acid soil stress indices

Tolerance Index	Formula	Reference	Remark
Stress Susceptibility Index (SSI)	SSI = (Yns-Yst)(Yns*(1-μYstμYns))	Fischer and Maurer (1978)	Values of SSI < 1 denote high yield stability and values > 1 indicate high stress susceptibility
Tolerance Index (TOL)	TOL= Yns-Yst	Rosielle and Hambling (1981)	Highest values for TOL indicate greater yield reduction due to stress, whereas low values show tolerance
Stress Tolerance Index (STI)	STI = Yns(Yst)(μYns)2	Fernandez (1992)	Highest values STI indicates stress tolerant genotype
Aluminum Adaption Index (AAI)	AAI = Yns(Yst)μYns(μYst)	Howeler (1991)	Highest values of AAI designate stress tolerant genotype
Mean Productivity (MP)	MP = (Yns+Yst)2	Rosielle and Hambling (1981)	Highest values of MP means higher stress tolerance and yield potential for genotype
Geometric Mean Index (GMP)	GMP = Yns ×Yst	Fernandez (1992)	Highest values of GMP designate high yield potential of genotype under stress and non-stress
Yield stability Index or Aluminum Tolerance Index (ATI)	ATI = YstYns	Bouslama and Schapaugh (1984); Howeler (1991)	Genotype with high values of ATI designate stable under stress and non-stress

Where; Yns and Yst are yields of a given genotype under non-stress and under stress soil conditions respectively. μYst is mean yield of all test genotypes under stress conditions whereas μYns is mean yield of all genotypes under non-stress soil conditions.

Result and Discussion

Analysis of Variance

Individual analysis of variance for each environment revealed significant ($P \leq 0.01$) differences among genotypes for the trait studied. Overall mean grain yield at Holeta-17, Holeta-18, Jeldu-17, Jeldu-18 and Midakegn-18 were 2387, 2568, 1195, 2092 and 839 kg ha^{-1} under stress; whereas 2777, 2897, 2835, 3870 and 3705 kg ha^{-1} under non-stress respectively. After checking for homogeneity of variance, combined analysis of variance revealed highly significant ($P \leq 0.01$) differences among the genotypes under both trials sets indicating adequate variability for the trait studied. Likewise, environment and genotypes by environment interaction also showed significant differences for most of the characters except biomass yield, spike weight, number of kernels per spike and plant height. Combined analysis of variance for the lime treated experiments at Holeta, Jeldu and Midakegn locations over two years showed highly significant ($P \leq 0.01$) differences among genotypes for grain yield, biological yield, days to heading and maturity, grain filling period, hectoliter weight, thousand kernel weight, number of fertile tillers, spike length, plant height, spike weight, number of kernels per spike and kernel weight per spike (Table 4a).

Similarly, the result of the experiment under acid soil stress is presented in Table 4b. In this experiment combined analysis was based on three environments excluding Jeldu-17 and Midakegn-18 owing to variance heterogeneity and transformation couldn’t stabilize the variance heterogeneity. Analysis of variance for the experiments combined over Holeta-17, Holeta-18 and Jeldu-18 showed significant ($P \leq 0.01$) differences among genotypes and genotypes by environment interaction for most of the morpho-agronomic traits studied. Moreover, the heritability of the traits ranging from 58% to 97% and 58% to 94%; genetic advance from 6.3% to 67.3% and 7.04% to 76.8% under non-stress and stress conditions respectively, indicating potential prospect for genetic improvement in traits of interest (Table 3a and 3b). Heritability of all traits showed a similar trend under both sets of experiments though relatively low under acid stress compared to non-stress conditions.

Table 4a. Variance components for some agronomic traits of barley genotypes under lime treated environments at Holeta, Jeldu and Midakegn testing locations.

Statistics	[1]DTH	DTM	GFP	PHT	FT	SPL	HLW	TKW	GY	BMY	SPW	NKPS	SWPS
Genotype	46.02**	70.02**	5.06**	65.89**	0.12**	0.655**	5.50**	26.77**	762671.66**	6814001.11**	0.387**	140.11**	0.25**
Env	11.46**	401.41**	255.2**	62.88**	1.48**	0.187^{ns}	5.05**	33.21**	173480.58^{ns}	0.0001^{ns}	0.0001^{ns}	1.08^{ns}	0.004^{ns}
G x E	3.52**	9.67**	7.88**	12.36**	0.066**	0.091**	4.19**	5.41**	421435.21**	1669250.65**	0.001ns	4.79**	0.012**
Residual	6.488	16.535	20.288	33.985	0.392	0.528	14.81	6.771	586011.94	3692073.94	0.118	26.503	0.094
Mean	64.48	119.40	56.69	103.31	2.96	6.97	63.70	44.51	3212.42	8748.77	2.11	35.65	1.792
CV (%)	3.95	3.41	7.95	5.64	21.14	10.43	6.04	5.85	23.83	21.96	16.31	14.44	17.086
h^2	0.96	0.94	0.58	0.92	0.69	0.90	0.65	0.94	0.84	0.91	0.93	0.97	0.927
GA (%)	21.28	13.99	6.25	15.51	20.0	22.74	6.05	23.19	51.36	58.52	58.53	67.33	54.91

Note: **, * Significant difference at ($P \leq 0.01$), ($P \leq 0.05$) respectively and ns: non significant difference.

Table 4b. Variance components for agronomic traits of barley genotypes under acidic soil environments at Holeta, and Jeldu locations.

Statistics	[1]DTH	DTM	GFP	PHT	FT	SPL	HLW	TKW	GY	BMY	SPW	NKPS	SWPS
Genotype	50.475**	90.80**	13.95**	71.76**	0.136**	0.75**	7.62**	25.01**	860231.78**	8476170.42**	0.222**	110.38**	0.166**
Env	14.88*	222.47**	129.62**	38.77^{ns}	0.857*	0.696*	5.60**	26.29**	0.001^{ns}	1790928.82^{ns}	0.0001^{ns}	8.14^{ns}	0.001^{ns}
G x E	5.62**	6.39**	3.24**	4.81^{ns}	0.075**	0.026**	6.96**	5.85**	293443.61**	0.0001$^{\mathbf{ns}}$	0.056**	7.81**	0.05**
Residual	8.281	29.72	31.25	78.911	0.432	0.725	11.37	15.381	714631.52	5431824.92	0.187	37.854	0.148
Mean	66.15	120.09	53.95	93.84	2.17	6.80	61.69	41.26	2347.83	7420.54	1.77	32.13	1.54
CV (%)	4.35	4.54	10.36	9.47	30.27	12.52	5.47	9.50	36.00	31.41	24.32	19.15	25.08
h^2	0.94	0.93	0.69	0.83	0.58	0.85	0.64	0.85	0.80	0.90	0.75	0.93	0.73
GA (%)	21.44	15.74	11.84	16.94	26.70	24.24	7.40	22.98	72.75	76.83	47.24	64.79	46.60
PMR (%)	-2.52	-0.58	4.83	9.16	26.69	2.44	3.16	7.30	26.91	15.18	16.11	9.87	13.96

Note: **, * Significant difference at ($P \leq 0.01$), ($P \leq 0.05$) respectively and ns: non significant difference.

[1]DTH= days to 50%heading, DTM= days to 50% maturity, GFP= number of days from heading to maturity, PHT=plant height(cm), NFT=number of fertile tillers, SPL=spike length(cm), HLW= hectoliter weight(kg/hl), TKW=thousand kernel weight(g), GY=grain yield (kg/ha), BY=biological yield(kg/ha), SPW=spike weight(g), NKPS= number of kernels per spike, KWPS=kernel weight per spike(g), PMR(%) = Percent Mean Reduction

The overall mean grain yield under non-stress was 3212.42 kg ha^{-1} compared to 2347.83 kg ha^{-1} in the stress condition, indicating a grain yield reduction of 26.92%. Moreover, the maximum and minimum yield performance under acid stress and non-stress soil conditions were 4722.8 kg ha^{-1}, 1142.8 kg ha^{-1} and 5932.8 kg ha^{-1}, 1791.5 kg ha^{-1} respectively. On the other hand, the relative overall mean performance of all traits except days to heading and days to maturity showed reduction under acid soil stress with varying magnitude in which the highest reduction was indicated in grain yield followed by fertile tillers per plant, spike weight, and biological yield (Table 4b). The test of mean comparison of the top ten percent of barley genotypes for their morpho-agronomic traits was presented in Table 6. Out of the total barley genotypes evaluated, twenty genotypes were among the top 10 percent showing high yield performance with varying magnitude under stress and non-stress soil conditions (Table 7a and Table 7b).

Generally, the current study disclosed the possibility of identifying lines with better grain yield, acid soil stress tolerance and other desirable attributes for further evaluation and subsequent breeding lines development to address the acid soil problem. According to Brown *et al.* (2014) observable phenotypic variation among or within the crop population and the requirement for phenotypic variation to have a genetic basis are the prerequisites in selective breeding. Then, selection will only be successful if there is sufficient phenotypic variation and if at least some of this variation has a genetic in origin. To this end, these barley genotypes would be valuable as a source of breeding materials for future variety improvement. Accordingly, Sintayehu and Tesfahun (2011) described genetic diversity and character association in barley genotypes evaluated in Arsi area indicated significant variation for various traits.

In a similar study conducted on genetic variability, heritability and genetic advance in seed yield and yield related traits in Ethiopian barley genotypes, Zerihun *et al.* (2011) reported significant genotypic variation in some important traits. Ceccarelli and Stefania (2000) also noted that in the barley landrace study, the heritability estimates under stress are even higher than in non-stress sites and high genetic variability is expressed within the landraces under stress. A similar observation of genetic variability was reported in the study of acid soil stress tolerance in maize (Tandzi *et al.*, 2015). In general, researchers reported varying ranges of genetic variability and heritability in several crop breeding and evaluation which is attributed to the type of genetic materials, a trait to be measured and environmental condition to which the individuals are subjected (Falconer and Mackay, 1989; Dabholkar, 1992; Ceccarelli and Grando, 1996).

Exploration of Barley Genotypes for Acid Soil Tolerance using Stress Indices

Barley productivity is hampered by several production constraints among which soil acidity is now becoming a serious threat to crop production in most central, western and southwestern highlands of Ethiopia (Getachew *et al.,* 2017; Getachew *et al.,* 2019). Preliminary observation of soil samples in the central highland of west Shewa indicates the extent of severity of soil acidity in the current scenario (Table 1). Several screening methods for acid soil tolerance have been employed from genotype screening in the laboratory to soil bioassay and field evaluation (Hede *et al.,* 2001). Field screening techniques is the most direct way of acid soil tolerance study for both grain and total biomass performance under field conditions which facilitates evaluation of large populations and allows estimation of yield under natural soil and climatic conditions in which resistant varieties are ultimately grown (Howeler, 1991; Singh, 2007). Consequently, analysis of variance for grain yield and related agronomic traits in this study revealed the presence of a considerable genotypic variation under non-stress and stress conditions (Table 4a and Table 4b) thereby suggesting the possibility of selecting better-performing genotypes.

The variation in yield reduction under low soil pH is based on the level of exchangeable acidity and exchangeable Aluminum in the soil, the agro-climatic conditions of the environment, and the genetic potential of crop genotypes (Tandzi *et al.,* 2019). As indicated in soil analysis results in Table 1, the extent of soil acidity at Jeldu and Midakegn districts was very intense which caused substantial yield reduction. Accordingly, the severity of stress in some of the environments caused varying magnitude of substantial grain yield reduction of 14%, 11%, 58%, 46% and 77% at Holeta-17, Holeta-18, Jeldu-17, Jeldu-18 and Midakegn-18 test environments respectively (data not shown).

Based on stress tolerance index (STI), stress susceptibility index (SSI) and geometric mean productivity (GMP) indices; 22% of the barley genotypes were categorized to be tolerant, as indicated with high values of STI, AAI, and GMP and low values of TOL and SSI. Accordingly, mean values of STI, AAI, GMP, TOL and SSI were 1.57, 2.15, 4008.3, 367.4 and 0.42 respectively. However, 48% of the genotypes were susceptible based on stress index characteristics of low STI, AAI and GMP, high TOL and SSI values. The mean values of these indices were 0.43, 0.59, 2098, 1169.9 and 1.41 respectively. Likewise, 30% of the evaluated barley genotypes showed STI, AAI, GMP, TOL, SSI values of 0.79, 1.08, 2837.6, 745.5, and 0.89 respectively indicating intermediate type. Some prominent improved varieties known for their good yield potential and wide adaptation were grouped under tolerant and intermediate types as elaborated in principal component analysis (Fig. 5). In the current study STI, AAI, GMP and MP were identified as good indices in identifying tolerant and high yielding genotypes in a similar trend. Those genotypes in the top ten percent also showed top values in these indices. Moreover, SSI and TOL were similar in identifying genotypes. Thus, promising breeding lines with good acid soil stress tolerance and yield potential can be extracted from those genotypes for subsequent crossing works. According to Fernandez (1992) stress assessment based on STI and GMP helps in the selection of genotypes with higher stress tolerance and yield potential. Likewise, SSI estimates the rate of change for each genotype in yield between the stress and non-stress conditions relative to the mean change for all genotypes. Values of SSI higher than one indicate high-stress susceptibility or poor yield stability and values lower than unity denotes low susceptibility or high yield stability (Kemelow and Alemayehu, 2011; Saad *et al.*, 2014). Karami *et al.* (2005) reported that MP, GMP and STI are the most proper indices in barley for assessing tolerance to a given stress.

Correlation among Stress Indices and Grain Yield

The Pearson correlation coefficients of grain yield under a non-stress environment or limed treated (Yns) and grain yield under acid soil stress (Yst) conditions with various tolerance indices are shown in Fig. 3 and Fig. 4A, that Yns was significantly and positively correlated with Yst (r= 0.89**), mean productivity (r= 0.97**), geometric mean productivity (r= 0.96**), stress tolerance index (r= 0.96**), Acid soil or Aluminum tolerance index (r= 0.34**), Aluminum adaptation index (r= 0.96**) and tolerance index (r= 0.18**), while significantly and negatively correlated with stress susceptibility index (r= -0.34**).

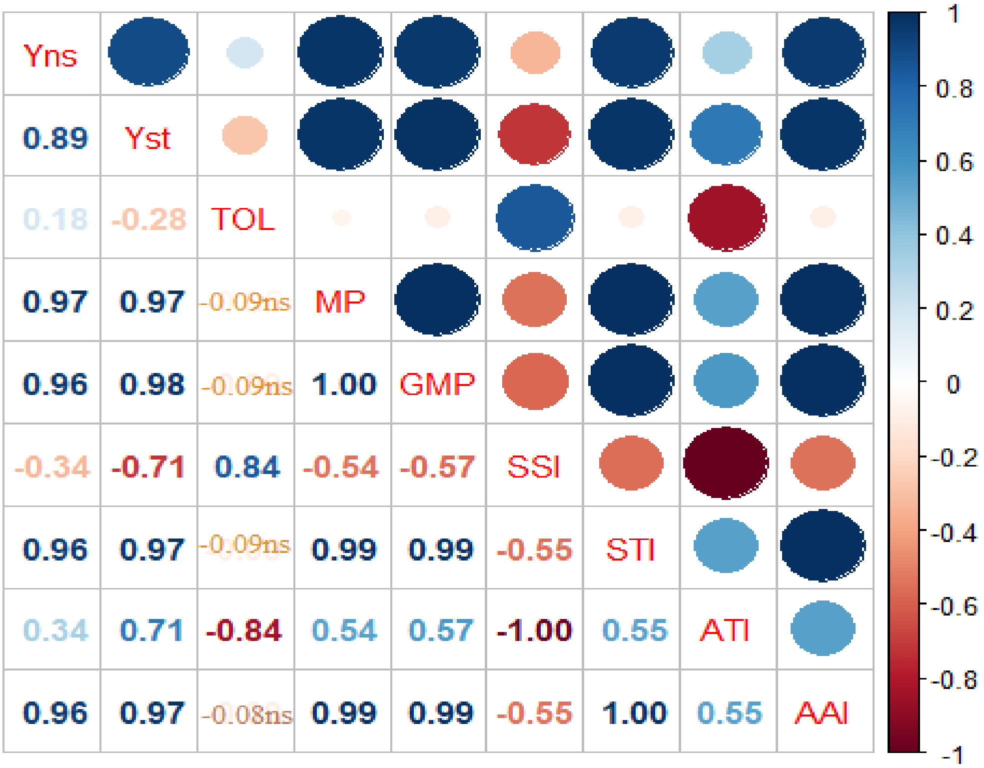
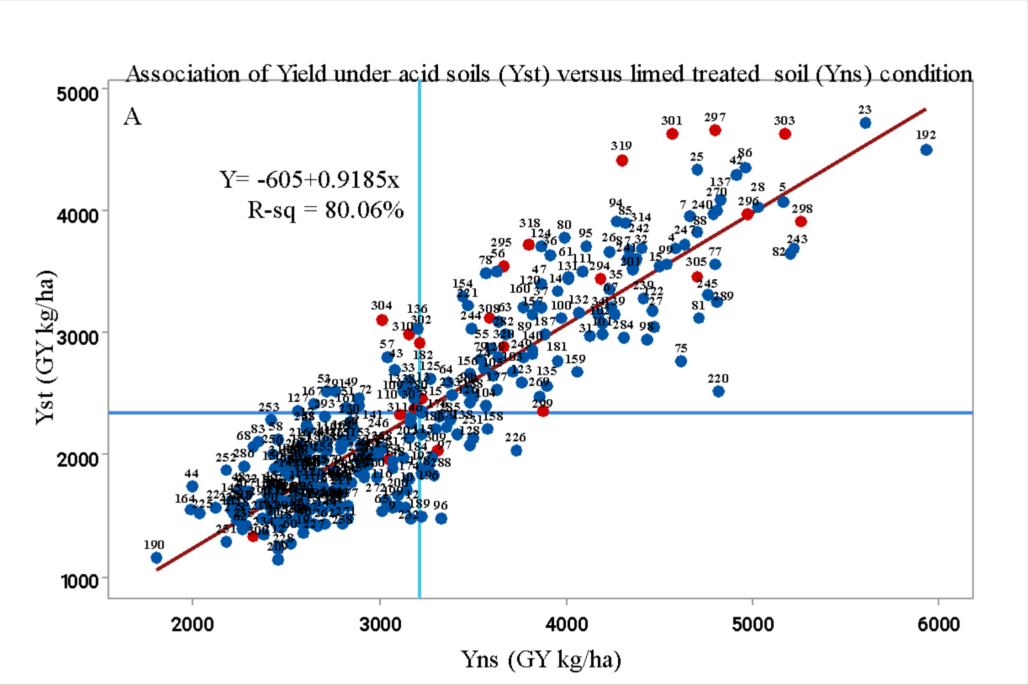


Fig 3. Heatmap of Pearson correlation coefficient matrix using grain yield and yield based stress indices of barley genotypes evaluated under acid soil stress(Yst) and non-stress(Ynst). SSI: Stress Susceptibility Index; TOL: Tolerance Index; STI: Stress Tolerance Index; AAI: Aluminum Adaption Index; MP: Mean Productivity; GMP: Geometric Mean Index; ATI: Al Tolerance Index

Similarly, grain yield in the Yst was significantly and positively correlated with mean productivity (r= 0.97^{**}), geometric mean productivity (r= 0.98^{**}), and stress tolerance index (r= 0.97^{**}), Aluminum tolerance index (r= 0.71^{**}), Aluminum adaptation index (r= 0.97^{**}) but significantly and negatively correlated with stress susceptibility index (r= -0.71^{**}) and (r= -0.28^{**}) tolerance index. Previous findings reported that MP, GMP and STI are the most appropriate indices in barley, wheat, maize and sorghum for assessment of stress tolerance and high-yielding genotypes (Karami *et al.*, 2005; Nazari and Pakniyat, 2010; Drikvand *et al.*, 2012; Saad *et al.*, 2014; Tandzi *et al.*, 2015; Teklay *et al.*, 2020). Indices STI, GMP, MP, AAI and ATA showed the existence of a strong positive correlation among themselves showing similarity between these indices for genotypes ranking (Fig. 5). Teklay *et al.* (2020) also reported similar results in sorghum genotype evaluation for stress tolerance. According to Farshadfar *et al.* (2001) most suitable indices for selecting stress-tolerant cultivars is an index that has a relatively strong correlation with the grain yield under stress and non-stress conditions. On the other hand, strong correlations were found among SSI and TOL depicting that they can be used interchangeably for screening under stress conditions (Fig. 4;

Fig. 5). Likewise, the significant negative correlation of indices with yield under stress suggests that relatively low yield reduction, low-stress susceptibility index and low tolerance index values could be used to select high yielding genotypes under acidic soil environments (Golabadi and Maibody, 2006; Talebi *et al.*, 2009; Tandzi *et al.*, 2015). The correlation coefficient of the tolerance index with yield under stress was r= -0.28 which shows selection based on tolerance should decrease yield in the stress environment and increase grain yield under non-stress as indicated in r= 0.18, despite a weak positive association.



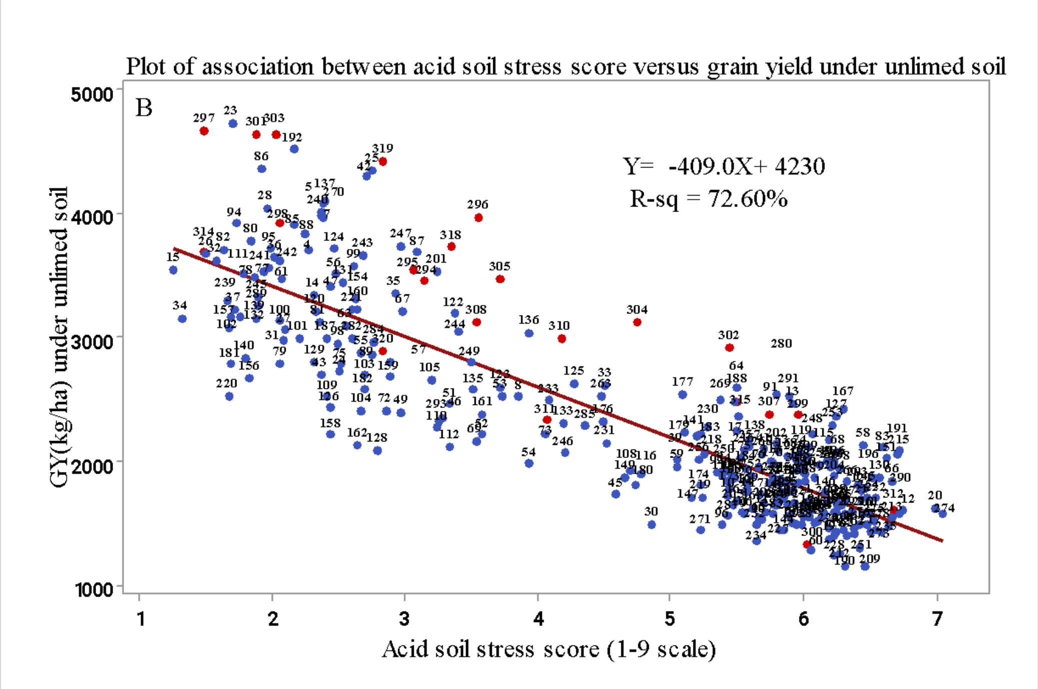


Figure 4. Interrelationship of grain yield of 320 barley genotypes grown under acid soil stress versus non-stress environments, broken line designate mean yield of respective environment (A); Grain yield under acid soil stress versus (1-9) stress scoring values (B); Improved varieties were designated with red color.

A positive correlation between TOL and Yns and a negative correlation between TOL and Yst suggested that selection based on TOL will lead to the reduction of yield under stress and an increased yield under non-stress conditions and this is in agreement with the study by Talebi *et al.* (2009) and Teklay *et al.* (2020). The negative association of SSI and TOL with grain yield under stress indicated that genotypes with low SSI and TOL values had lower yield differences between non-stress and stress environments. The association of grain yield under stress versus non-stress environments showed a significant positive ($r= 0.89^{**}$) correlation indicating that genotypes that performed well under non-stress also performed well under stress conditions. Moreover, significant negative association ($r = -0.85^{**}$) between grain yield under stress and stress score based on (1-9) scale in which score one designates stress-free whereas nine for acid soil stress susceptible genotypes (Fig. 4B). In general, this result depicts the prospect of some barley genotypes as a promising germplasm source for improvement of yield potential performance and acid soil tolerant variety development.

According to Falconer (1989), consistent performance of some genotypes under contrasting environments may represent nearly the same character determined by the same set of genes. Moreover, the result of correlation analysis among various indices displayed both positive and negative associations showing that some of the indices are generally similar but others are dissimilar in genotype ranking, respectively. Generally, the strong positive correlation between grain yield under stress and non-stress environment implied the possibility of direct selection for stress conditions based on performance under non-stress conditions (Horst, 2000; Negarestani *et al.*, 2019; Talebi *et al.*, 2009). However, Drikvand *et al.* (2012) reported a lack of association between yield under stress and non-stress environment suggesting the feasibility of an independent breeding approach.

Principal Component Analysis

The result of principal component analysis showed that the four principal components accounted for 100% of the variation. The first and second principal components accounted for 99.3% of total variability suggesting that the two principal components adequately explained the variation in the data. The first principal component (PC1) explained 74.6% with high loading due to grain yield in the stress (0.386), geometric mean productivity (0.378), stress tolerance index (0.375), mean productivity (0.375), Al tolerance index (0.280), Al adaptation index (0.375) and grain yield in the non-stress (0.343). The second principal component (PC2) also explained 24.7% of the total variation with high loading due to the tolerance index (0.634), stress susceptibility index (0.458), and grain yield under non-stress (0.305). PC1 showed a positive correlation with STI, ATI, AAI, GMP, and MP indices as well as grain yields under stress and non-stress, whereas PC2 showed a positive association with all stress indices except ATI (Table 4).

Figure 5. Biplot based on two components obtained from PCA using Yield under limed (Yns), Yield under unlimed(Yst), Tolerance index(TOL), Geometric mean productivity(GMP), Mean productivity(MP), Stress tolerance index(STI), Stress susceptibility index(SSI), Al tolerance index(ATI), Al adaptation index(AAI). Group:In (intermediate); Su (Susuptible); To (Tolerant)

Likewise, barley genotypes were subjected to biplot analysis to determine their relationship among stress indices (Fig. 5). Biplot of PC1 and PC2 for 320 barley genotypes described with genotypes number and/or varieties depicted that genotypes 222969-C(192), 16726-A(23), 24987-B(86), 17148(42), 1773-C(5), 16737-B(25), 16739-D(28), 212947-A(137), 242093-A(270), 235541-A(240), 3514-A(7), 1773-B(4), Balemi(314) and improved varieties HB-1307(303), Shege(301), Ardu12-60B(298), EH-1493(296), IAR/H/485(297), HB-1966(319) were among the genotypes located near to the stress indices (STI, ATI, AAI, GMP, GP) indicating strong association of these genotypes with the indices having high PC1 but low PC2 values. Moreover, these genotypes were characterized by high yield potential and STI values greater than 1 as well as small SSI values less than 1 which is an indication of good stress tolerance (data not shown). Golabadi and Maibody (2006), Negarestani *et al.* (2019) reported similar results of positive and strong correlations of MP, GMP and STI with Yns and Yst.

Table 5. Principal component analysis for grain yield of 320 barley genotypes under acid soil stress and non-stress conditions and stress tolerance indices.

	PC1	PC2	PC3	PC4	PC5
Indices[1]	Eigenvectors				
Grain Yield under Limed (YP)	0.343	0.305	-0.229	0.200	0.282
Grain Yield under Stress (YS)	0.386	0.010	0.040	0.371	0.280
Tolerance index (TOL)	-0.114	0.634	-0.582	-0.388	-0.012
Mean productivity (MP)	0.375	0.160	-0.095	0.295	0.289
Geometric mean productivity (GMP)	0.378	0.135	-0.090	0.271	-0.870
Stress susceptibility index (SSI)	-0.280	0.458	0.389	0.247	-0.014
Stress tolerance index (STI)	0.375	0.145	0.379	-0.441	0.009
Aluminum tolerance index (ATI)	0.280	-0.458	-0.389	-0.247	0.014
Aluminum adaptation index (AAI)	0.375	0.145	0.379	-0.441	0.009
Eigenvalue	6.713	2.224	0.053	0.009	0.0001
Variability (%)	74.6	24.7	0.6	0.1	0.000
Cumulative (%)	74.6	99.3	99.9	100.0	100.0

Table 6. Comparison of the mean performances of the top 10% genotypes with mean values of population for the studied barley genotypes under acid soil stress.

SN	Traits	Mean of selected genotypes ($\overline{X}$)	Population parameter(µ)	Change through selection ($\overline{X}$-µ)	Change as % of pop. parameter(m)	Z-test
1	DTH	78.57	66.15	12.41	18.77	10.22^{**}
2	DTM	134.25	120.09	14.15	11.79	8.74^{**}
3	GFP	59.50	53.96	5.53	10.25	10.245^{**}
4	PHT	107.03	93.84	13.19	14.05	9.75^{**}
5	FT	2.67	2.17	0.50	22.98	10.20^{**}
6	SL	8.10	6.80	1.30	19.13	9.26^{**}
7	HLW	66.03	61.69	4.34	7.03	11.77^{**}
8	TKW	50.29	41.26	9.03	21.88	11.19^{**}
9	GY	4021.92	2347.61	1674.30	71.32	11.56^{**}
10	BY	13156.82	7420.37	5736.45	77.31	11.83^{**}
11	SPW	2.54	1.78	0.76	43.06	10.72^{**}
12	NKPS	49.00	32.13	16.86	52.49	9.47^{**}
13	SWPS	2.18	1.54	0.65	42.21	10.65^{**}

Table 7a. Performance of top ten percent high yielding barley genotypes under acidic soil environments at Holeta and Jeldu testing locations.

Genotype	ID	DTH	DTM	GFP	PHT	FT	SPL	HLW	TKW	GY	BMY	SPW	NKPS
16726-A	23	73.5	130.0	56.0	108.5	2.1	7.3	63.7	42.9	4722.8	14817.4	2.5	43.1
IAR/H/485	297	76.8	137.0	58.8	111.7	2.3	7.1	64.2	43.7	4663.1	14706.1	2.4	49.2
HB-1307	303	68.0	131.5	61.0	97.4	2.4	6.3	62.5	44.5	4635.7	14431.6	2.2	42.7
Shege	301	78.0	132.8	54.8	108.3	1.9	7.3	62.3	47.1	4632.9	14459.0	2.7	51.0
222969-C	192	77.6	131.7	54.1	106.1	2.2	6.5	62.5	39.5	4510.4	14336.6	2.3	49.0
HB -1966	319	68.6	131.3	60.6	93.2	2.0	6.0	64.1	45.4	4420.5	13160.6	2.2	42.5
24987-B	86	70.5	128.8	57.3	91.8	2.5	6.5	62.6	37.0	4363.9	12423.7	2.0	40.5
16737-B	25	69.3	131.6	60.1	95.2	2.4	5.4	62.8	39.8	4342.0	12858.4	2.5	49.0
17148	42	69.3	134.0	62.0	94.9	2.1	6.1	64.3	45.6	4303.0	12210.7	2.1	40.4
212947-A	137	73.4	132.0	57.5	104.3	1.9	6.8	63.5	41.0	4095.7	12304.8	2.3	47.3
1773-C	5	86.0	138.4	52.9	107.0	2.4	6.7	63.3	42.8	4083.0	13475.7	2.7	49.7
16739-D	28	70.0	129.1	57.8	91.9	2.6	7.0	63.7	41.4	4038.4	12002.4	2.1	39.4
242093-A	270	78.9	136.8	57.0	106.9	2.1	6.6	64.5	42.2	4008.8	12430.1	1.9	45.2
235541-A	240	70.6	130.4	58.2	89.5	2.1	5.2	62.7	38.3	3981.0	11177.4	1.9	43.0
EH 1493	296	73.2	130.4	56.6	92.1	2.0	6.7	63.9	43.2	3968.9	11716.9	2.2	44.1
3514-A	7	68.6	132.0	61.1	93.3	2.1	6.3	63.8	43.8	3964.6	11084.0	2.2	44.5
Ardu12-60	298	79.3	135.3	55.6	101.6	2.1	6.6	64.3	41.3	3918.1	13052.4	2.3	49.0
64111-B	94	76.5	131.7	54.9	104.7	2.2	7.3	62.3	44.1	3913.4	13199.8	2.1	36.1
24987-A	85	70.3	131.3	59.1	93.5	2.3	5.4	62.1	38.8	3902.8	10438.3	2.4	49.9
24990	88	68.8	131.0	60.1	94.0	1.9	6.2	64.9	44.3	3835.8	11698.2	2.2	37.8
24965-C	80	73.5	132.5	57.8	97.4	2.2	7.4	62.3	45.4	3777.7	13094.5	2.0	33.7
236823-A	247	74.9	131.5	56.0	104.4	2.3	7.2	62.6	42.2	3732.1	10149.2	2.2	38.6
Ibon174/03	318	58.8	123.7	61.9	83.9	2.9	6.7	65.7	48.2	3724.2	9724.2	1.5	23.1
64116-A	95	75.7	130.8	54.9	104.0	2.2	7.4	63.9	43.4	3712.1	12792.5	2.2	38.5
208836-D	124	70.2	131.0	59.1	93.6	2.0	5.5	63.0	38.8	3710.8	10749.4	2.3	48.0
24970	82	68.2	133.4	62.2	96.6	2.1	6.4	63.7	43.8	3702.1	10338.0	2.1	43.3
1773-B	4	79.3	130.0	51.6	105.5	2.1	6.5	62.0	39.8	3699.5	13637.9	1.9	41.2
Balemi	314	75.8	132.4	55.9	109.6	2.1	7.8	63.6	48.4	3690.2	13896.0	1.8	25.2
24988-A	87	69.4	129.1	58.3	94.0	2.2	6.0	63.0	39.3	3683.0	9214.5	2.4	47.4
16737-E	26	70.5	129.3	57.6	90.7	2.1	5.1	62.1	39.6	3673.2	10810.6	2.3	44.5
235551-B	243	70.8	129.8	57.9	94.1	1.9	5.6	62.3	37.5	3658.1	10674.7	2.4	51.6
16862-B	36	74.0	132.7	57.3	105.3	2.4	8.0	63.8	47.6	3644.5	12901.1	1.8	24.8
Mean		66.2	120.1	54.0	93.8	2.2	6.8	61.7	41.3	2347.8	7420.5	1.8	32.1
Minimum		51.1	98.8	46.3	64.0	1.5	4.2	57.1	30.9	1142.8	3614.2	1.1	18.0
Maximum		87.1	138.4	62.2	113.7	2.9	9.2	71.5	54.9	4722.8	14817.4	2.9	54.5

Traits[1] (refer to table 4b)

Table 7b. Performance of top ten percent high yielding barley genotypes under non-stress environments at Holeta Jeldu and Midakegn testing locations.

Genotype	ID	DTH	DTM	GFP	PHT	FT	SPL	HLW	TKW	GY	BMY	SPW	NKPS
222969-C	192	77.0	130.6	55.8	115.0	2.7	6.9	65.0	44.3	5932.8	16082.2	3.1	52.3
16726-A	23	73.7	130.2	57.3	113.8	3.0	6.9	64.7	43.8	5604.7	15026.6	2.6	44.1
Ardu12-60	298	76.1	133.2	57.4	113.0	3.2	6.8	64.3	42.5	5264.6	14695.5	3.2	54.5
24970	82	67.1	131.3	61.6	99.9	2.9	6.0	64.8	47.0	5224.1	13287.1	2.5	44.6
235551-B	243	69.7	127.6	58.2	96.7	2.6	5.1	64.5	40.1	5200.0	12737.1	3.0	54.1
HB-1307	303	68.0	127.3	59.4	103.0	3.2	6.4	64.8	47.6	5174.4	12813.7	3.1	47.2
1773-C	5	83.5	135.4	54.6	111.7	2.7	6.6	64.4	45.4	5160.5	15486.7	2.8	48.6
16739-D	28	68.5	124.4	57.1	100.7	2.9	7.0	64.4	42.5	5020.5	13482.0	2.4	43.9
EH 1493	296	71.7	129.0	57.6	99.9	2.8	7.3	65.8	44.3	4976.9	12265.0	3.0	44.2
24987-B	86	69.6	128.9	58.9	99.0	3.1	6.8	65.1	39.0	4965.8	12589.5	2.6	48.7
17148	42	68.5	131.3	61.6	97.7	2.5	6.0	65.2	46.8	4915.0	12769.3	2.7	45.3
212947-A	137	71.5	132.4	60.0	113.7	2.8	7.1	64.2	44.7	4821.2	13027.8	3.2	54.0
233040-A	220	74.7	126.6	55.4	106.0	2.6	7.8	64.5	42.2	4813.1	13011.0	3.2	50.0
24639-B	289	79.5	133.2	55.9	110.3	2.7	8.6	63.0	43.3	4812.9	12582.1	3.3	53.1
242093-A	270	75.9	132.3	57.7	114.3	2.8	7.1	65.2	43.7	4805.9	13519.3	3.2	51.7
24955-B	77	69.7	127.5	57.6	106.3	3.4	8.2	64.6	53.4	4797.6	12930.1	1.9	23.9
IAR/H/485	297	77.9	133.4	57.5	114.0	3.0	6.9	64.8	43.9	4797.1	13235.0	2.7	47.6
235541-A	240	69.8	128.1	57.9	94.2	2.8	4.9	64.3	39.7	4787.2	12335.3	2.4	48.1
236819	245	69.0	128.7	59.2	105.9	2.9	6.5	64.4	44.8	4763.1	11970.8	2.8	49.2
24967-C	81	69.7	128.1	58.7	96.0	2.9	4.9	64.4	39.0	4709.1	12736.3	2.6	51.3
Cross41/98	305	75.3	128.7	55.7	103.5	2.6	7.3	65.5	44.8	4704.9	12256.4	2.8	48.2
24990	88	71.5	131.7	60.1	99.3	2.7	6.2	65.3	47.0	4702.0	12148.5	2.5	44.0
16737-B	25	69.3	130.2	60.1	97.0	2.8	5.2	64.9	41.0	4699.4	11589.7	2.8	50.5
3514-A	7	68.0	130.2	60.7	99.8	2.8	6.5	64.3	45.8	4665.3	11075.2	2.8	48.8
236823-A	247	73.4	129.7	57.3	113.0	2.7	7.3	64.5	48.0	4636.5	14575.4	2.6	40.5
24639-A	75	79.3	132.4	55.6	111.7	2.8	8.4	62.0	43.6	4616.2	13785.5	3.2	51.2
1773-B	4	79.5	131.9	54.8	110.5	2.7	6.0	64.3	43.4	4587.9	14319.1	2.7	45.7
Shege	301	77.1	132.8	56.9	116.6	2.6	7.5	63.9	47.1	4563.9	13812.9	3.8	55.0
64144-C	99	72.1	131.1	58.9	105.5	2.8	7.3	64.8	46.4	4548.2	13637.0	2.8	42.5
4492-D	15	73.7	129.5	57.7	118.6	3.0	7.6	64.4	52.3	4500.0	13613.9	2.3	33.9
16739-B	27	70.2	126.0	57.3	106.8	3.5	7.9	64.3	53.9	4471.6	12836.0	1.7	23.0
204802-B	122	78.8	132.4	55.9	106.5	2.7	7.0	64.3	44.4	4461.1	12146.0	3.0	42.5
Mean		64.5	119.4	56.7	103.3	3.0	7.0	63.9	44.5	3212.4	8748.8	2.1	35.6
Minimum		51.03	103.57	51.91	65.34	2.38	4.18	61.14	32.54	1791.54	5104.92	1.12	19.11
Maximum		83.61	136.49	63.90	121.42	3.79	9.03	68.94	58.59	5932.80	16082.20	3.99	60.55

Traits[1] (refer to table 4b)

However, 230619-B(209), 237021(251), 221325(109), 18304-C(60), 202850-B(118), 15271(19), 242098-A(271), 234308-A(227), 239519-B(262), 234312-B(228), 230631-C(212), 235252(234), 235262(235), 232216(217) genotypes including improved varieties HB-42(299), Derebie(309), Explorer(300) were among susceptible genotypes to acid soil stress as indicated in stress score and were also located near the stress indices (SSI and TOL) and correlated negatively with yield under both soil conditions (Fig.4 and 5). Besides, these genotypes were characterized by high TOL, SSI and stress score values. High values of these indices indicate the relative sensitivity of genotypes to stress (Rosielle and Hambling, 1981). Moreover, the susceptibility of some improved barley varieties to acid soil stress was also reported earlier by Getachew *et al.* (2019).

The stress tolerance index (STI) is considered a criterion for selecting a stress tolerant genotype. High STI value indicates high tolerance and high yield potential (Fernandez, 1992), and genotypes with lower SSI values less than unity are more stress tolerate (Amsal *et al.,* 2001; Kemelew and Alemayehu, 2011; Saad *et al.,* 2014; Negarestani *et al.,* 2019).

In the first quadrant (I) of the biplot (Fig. 5), genotypes with the loading of high PC1 and low PC2 scores were characterized as high yielding with good stress tolerance as well as low-stress score values. Likewise, those with intermediate values of both components had high grain yield and tolerance, those with low PC1 and high PC2 scores had high grain yield and susceptibility whereas those with low values of both components showed intermediate grain yield and susceptibility. Similarly, in the fourth quadrant (IV) genotypes with the loading of high PC1 and PC2 score were characterized as intermediate yielding and acid soil stress tolerant, genotypes with the loading of high PC1 and low PC2 were high yielder and tolerant to stress while those with low PC1 and high PC2 were low yielding and stress susceptible. Generally, genotypes that were associated with TOL and SSI were also characterized with high values of these indices as an indicator of sensitivity to acid soil stress (Fig. 5). Khalili *et al.* (2016) also used PCA to identify tolerant genotypes to moisture stress in barley. Likewise, the selection of genotypes that have high PC1 and low PC2 are suitable for both stress and non-stress environments (Golabadi and Maibody, 2006; Teklay *et al.,* 2020). Thus, considering the biplot genotypes with larger PC1 and lower PC2, scores are characterized as high-yielding (stable genotypes), and genotypes with lower PC1 and larger PC2 scores are low-yielding or unstable genotypes (Drikvand *et al.,* 2012). Generally, genotypes with both low PC1 and PC2 have low sensitivity to stress conditions but inherently have low yield potential whereas genotypes with low PC1 and high PC2 exhibit inferior yield performance and high sensitivity to stress (Teklay *et al.,* 2020).

Conclusion

The current study confirmed the severity of acid soils in barley growing areas as depicted by the percentage of yield loss under acid soil stress as compared to non-stress experiments.

Moreover, this study also revealed the existence of adequate levels of genetic variation in Ethiopian barley landraces under both acid soil stress and non-stress conditions indicating the potential for future barley genetic improvement. Therefore, the development and deployment of acid soil tolerant genotypes would be a sustainable and cost-effective strategy for resource-poor farmers. Accordingly, the currently identified high-yielding and tolerant barley genotypes need to be utilized for further adaptation studies and simultaneous breeding line extraction for subsequent crossing works and variety development. Furthermore, the national barley breeding program should effectively exploit variabilities available in Ethiopian barley landrace collections through further screening under critical acid soil environments.

Acknowledgments

Ethiopian Institute of Agricultural Research, Haramaya University, Hohenheim University, McKnight Foundation, Bioversity International, Ethiopian Biodiversity Institute and Barley Breeding Section at Holeta Research Center are duly acknowledged for material and financial support.

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Ethiop. J. Agric. Sci. 32(4) 30-55 (2022)

The Influence of Supply Network on Dairy Technology Adoption: Empirical Evidence from Urban and Peri-urban Dairy Farming Systems of Ethiopia

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Abstract

This paper aims at investigating how the supply network structure in which dairy farms are embedded influences their technology adoption. In order to consider the effects of network structure embeddedness on technology adoption, farm-level data were collected from 169 randomly selected dairy farms. Social network analysis was used to develop the structural characteristics and Poisson regression model was used to evaluate the influence of the network on technology adoption. The results indicate that the supply network interconnectedness increases farm's adoption of dairy technology while the supply network density decreases the likelihood of the adoption of dairy technology. Furthermore, the study shows the absorptive capacity positively moderates the effect of supply network accessibility on the likelihood of adoption of dairy technology in dairy farms. This study provides useful insights into the potential role of supply network structural characteristics and the moderating role of absorptive capacity on dairy technology adoption. Thus, in light of these findings, considerations should be given to policies that create an ecosystem of interactions through training, promoting fairs and innovation events to promote rapid dairy technology adoption by dairy farms.

Keywords: Supply network, innovation adoption, adaptive capacity, dairy farm, technology, Poisson model

Introduction

In Ethiopia, dairy production is generally a subsistence smallholder-based industry with relatively few small and medium commercial dairy farms. About 98.24% of the total cattle in the country are local breeds. The remaining 1.76% are hybrid and exotic breeds that accounted for about 1.54 and 0.22%, respectively. In 2019, close to 6.7 million dairy cows produced an estimated 3.6 billion liters of milk nationally, with most of it (over 95%) from local breeds (CSA 2019).

In an effort to improve the dairy sector, huge efforts have been made to disseminate dairy technologies through the support of governmental and non-governmental organizations in different parts of the country. However; the adoption of dairy technologies by farm households varies widely across different agro-ecologies and within the same agro-ecology based on various technical and non-technical determinant factors (Dehinenet *et.al*, 2014).

Previous studies on agricultural technology adoption have focused on the role farm-level characteristics have on technology adoption (Amare *et al.,* 2012; Asfaw *et al.*, 2011; Feder *et al.*, 1985; Sunding *et al.*, 1999). However, the agricultural innovation and technology adoption process involves several human and institutional actors rather than just technological and farm level characteristics (Weyori *et al*., 2018).

Given our current comprehension of factors affecting dairy technology adoption, the goal of this research is to examine how the network structure in which dairy farms are embedded influences technology adoption. In order to consider the effects of network structure embeddedness, we empirically address two interrelated research questions: First, what is the relationship between the structure of a farm's supply network and its technology adoption? Explicitly, we look at three important structural characteristics of supply networks. Second, what moderating role does a firm's absorptive capacity play in the association between the structural characteristics of a dairy farm's supply network and technology adoption? To test the hypothesized relationships empirically, we collected farm-level data from randomly selected dairy farms and used social network analysis to develop the structural characteristics.

The remainder of this paper is organized as follows. Section II provides the theoretical development of the research questions and the hypotheses. Section III describes the data collection, variables, and measures and presents statistical methods employed to test the hypotheses. We present results in Section IV, while Section V provides a discussion of the results, theoretical implications, and limitations of the study, as well as future research directions. Finally, the paper concludes with Section VI.

Theoretical Development and Hypotheses

Supply network

The dyadic perspective of buyer-seller relationship has primarily focused on linear or dyadic structure to capture the benefits of relationships between two parties. Hence, it fails to comprehensively capture a supply chain's dynamic, complex, and increasingly interdependent nature (Basole *et al*., 2018). However, a network approach provides a richer view by considering the various interactions taking place among firms in the supply network (Bellamy *et al*., 2014). A supply network is described by a directed network where each node represents an entity and each directed link denotes the material flow between two entities (from supplier to customer). A connecting rule then means a way that an entity selects its suppliers and customers in the supply network (Xuan *et al.*, 2011). The different firms in the supply network are generally referred to as supply network partners of a given focal firm in the network (Bellamy *et al.*, 2014).

The social network theory helps understand the benefits accrued due to the structural position of a given firm in a number of ways. Primarily, network theory focuses on explaining how patterns of social ties produce better economic outcomes and why inter-organizational networks are formed, collapse, succeed, or fail (Echols and Tsai 2005). In the supply network context, the "social" aspect refers to the interconnected network of suppliers, producers, service providers, and customers that engage in activities related to the procurement, use and transformation of raw materials in order to produce and deliver goods and services (Kouvelis *et al.*, 2006; Lamming *et al.*, 2000).

Supply network and technology adoption

The role of social networks and the behavior of other farmers in the process of technology diffusion are well established in adoption studies (Kassie *et al*., 2012; Bandiera and Rasul, 2006; Conley and Udry, 2010). In Ethiopia, the role of social networks on agricultural technology adoption has been revealed by adoption studies (Wossena et al., 2013; Amlaku *et al.*, 2012; Mekonnen et al., 2016).

Previous studies has shown that firms with broader social networks and greater social capital are more likely to become innovators or adopters of innovation (Jara-Rojas et al., 2012; Maertens and Barrett, 2012; Ramirez 2013; Runyan *et al*., 2006; Sligo and Massey, 2007; Wilson, 2000).

Structural characteristics of supply networks

According to Basole *et al.,* (2018), the structural characteristics of the supply network describe the topological nature of the network, including types and patterns of inter-firm relationships, the strength and nature of these relationships, the different tiers of relationships resulting from the tiered supply and delivery processes, the power, leadership, and influence in the supply network derived from these relationships. Bellamy *et al*., (2014) employed supply network accessibility and supply network interconnectedness to measure structural characteristics of supply network. These measures are important enablers of the flow of information and knowledge in the network. Thus, in this study we employ these two estimates to measure the supply network structural characteristics.

According to Bellamy *et al.,* (2014), supply network accessibility means how effectively a firm is able to access the different sources of information and knowledge assets in the network and supply network interconnectedness means how these sources of information and knowledge are structurally inter-linked together in the network.

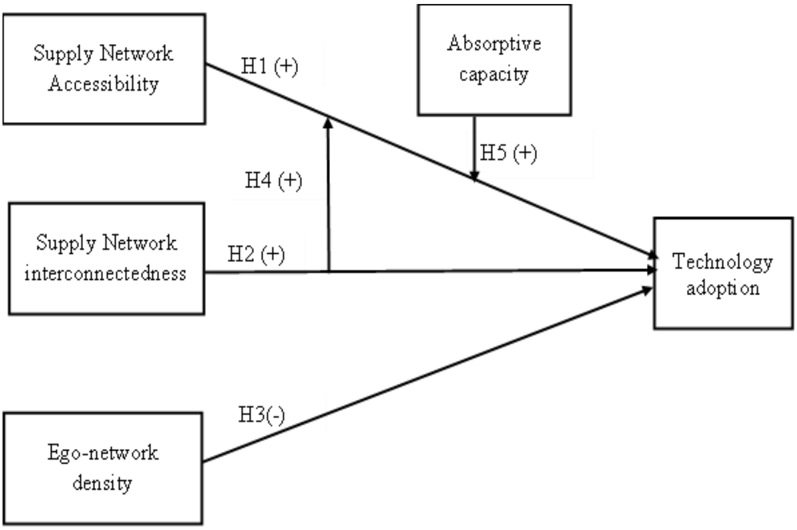

Figure 1: Conceptual model with proposed hypotheses (Own conceptualization)

We conceptually link the structural supply network characteristics of a focal firm (supply network accessibility, supply network interconnectedness, density and the interaction between supply network accessibility and absorptive capacity, and supply network density and network interconnectedness) with its technology adoption (Figure 1) above.

Supply network accessibility

Supply network accessibility refers to the effectiveness with which a firm can access information and knowledge from other members in its supply network, including indirect access to members with whom they do not share a direct relationship with (Bellamy *et al*., 2014). It also reflects the speed of information access. The position of a firm in the supply network can influence the way in which the firm innovates (Ahuja, 2000; and Schilling and Phelps, 2007). The level of accessibility in a dairy farm’s supply network is positively associated with its technology adoption (Hypothesis 1).

Supply network interconnectedness

It can be defined as the degree to which supply network partners of a focal firm are connected to each other, and thus share direct links amongst themselves. Supply networks are considered to be densely interconnected when there are a large number of shared linkages that exist between the supply network partners of a focal firm (Bellamy *et al.*, 2014). Supply network interconnectedness based on multiple knowledge connections brings knowledge exchange for a focal firm and ultimately enhances the flow of information and knowledge among its members (Inkpen and Tsang, 2005). Zaheer and Bell (2005) provided evidence that high interconnectedness positively influences improvements in the efficiency and performance of a buying firm. Therefore, Supply network interconnectedness positively influences dairy farm's technology adoption (Hypothesis 2).

Density in Supply Networks

A supply network density can be defined as the degree to which all actors within a supply network are connected to each other (Ahuja, 2000). It indicates the potential for collaboration among members in a focal dairy farm's supply network (Choi *et al.,* 2001). Previous studies showed the effect of network density on knowledge creation (McFadyen *et al.,* 2009) and on innovation (Carnovale and Yeniyurt 2015). On the other hand, Burt (1992) emphasizes the diversity of information available in a low-density network structure that can create opportunities for innovation. Given these controversies, some scholars suggested a contingency approach for the relationship between density and firm innovation. In which the context of the phenomenon under scrutiny is what dictates whether density's role is positive or negative (Adler and Kwon, 2002).

It is expected that the association between density and firm performance is much more pronounced in high-velocity industries such as the electronics industry and semiconductor industry (Bourgeois and Eisenhardt, 1988). Nevertheless, the dairy industry in Ethiopia is a low dynamic and more stable industry characterized by low rate of changes in technology and market conditions. Thus, long dairy technology life cycles and low-level new dairy technology generation are prevalent in such industries. Therefore, we posit that higher levels of density in dairy farm's supply network decreases dairy farm technology adoption (Hypothesis 3).

Interaction between supply network accessibility and interconnectedness

While both supply network accessibility and interconnectedness are individually important to drive the adoption of appropriate technology, the interaction between them can further influence technology adoption. We argue a positive effect of the interaction of supply network interconnectedness and supply network accessibility on firm technology adoption (Hypothesis 4).

Interaction between supply network accessibility and absorptive capacity

Cohen and Levinthal (1990) introduced the concept of absorptive capacity in the management literature and it is the key factor for enhancing the firm's ability to utilize and benefit from externally acquired knowledge. It is represented by the firm’s ability to recognize, assimilate, and leverage knowledge. It may unveil greater adoption and exploitability of a given technology than those firms with less absorptive capacity (Micheels and Nolan 2016). Though network provides accessibility to knowledge and new information, the accessibility of such information or knowledge from network structures and their innovation performance implications are contingent up on both the focal firm’s and alters absorptive capacity or capability (Zaheer and Bell 2005).

Previous studies have shown that both absorptive capacity and accessibility of information in the supply network are important for a focal firm to develop its innovation capabilities from external knowledge (Ernst and Kim, 2002; Bellamy et al., 2014). Research in agriculture has also shown that absorptive capacity is positively related to firm-level adoption of new agricultural technologies and practices in the Dutch pork industry (Tepic et al., 2012).

Finally, it should be noted that a dairy farm can still benefit from having access to knowledge in its supply network in the absence of high absorptive capacity, but its ability to influence this information to improve its innovation performance will be very limited. Thus, we propose the following hypothesis. Absorptive capacity of a dairy farm in the supply network positively moderates the influence of supply network accessibility on dairy technology adoption (Hypothesis 5).

Materials and Methods

Description the study area

This study was conducted in Addis Ababa, Bishoftu, Sebeta, and Mekele cities of Ethiopia. These areas were selected based on the Ethiopian control Bovine Tuberculosis Strategies project’s (ETHICOBOT) baseline survey result in order to look at dairy farms supply network patterns across geographic locations. The ETHICOBOTS project was a 5-year research project awarded to a consortium of researchers in Ethiopia and the UK, consisting of epidemiologists, geneticists, immunologists, and social scientists. ETHICOBOTS set out to tackle the high burden of bovine TB in the Ethiopian dairy farm sector and to investigate the consequences of the on-going centrifugal trade of potentially infected dairy cattle to low prevalence regions and farming systems on transmission. The map of the study area is shown in Figure 2 below.

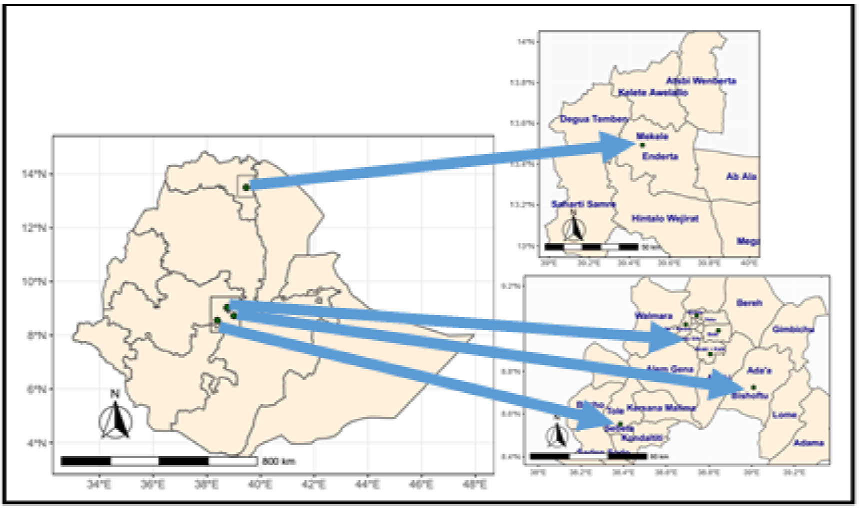

Figure 2: Map of the study area

Data types and sources

A survey methodology was employed to set up the quantitative part of our empirical research and to collect data to test the research hypotheses. Both qualitative and quantitative data types were used for cattle supply network analysis. In order to generate these data, secondary and primary data were collected for the study. Primary data were collected from sampled dairy farms in the study areas who are involved in dairy farm business.

Sampling procedure

The study followed a multi-stage sampling procedure to select the dairy farms in the study area. First, we stratified the study area into three strata based on the availability of market infrastructures or proximity to markets, i.e., near, middle and away from the markets. Then, we selected one sub-city/town from each stratum. Then, from each selected area, we selected one kebele or woreda from each selected sub-cities/town based on the dairy production. Finally, we randomly selected 169 dairy farms from the selected areas.

Data collection

The data collection was conducted using two survey instruments to achieve the objective of the study. One is using a structured questionnaire; each sampled dairy farm has been interviewed. The aim was to collect data related to dairy farm level characteristics. The second is related to the ego-network of the dairy farms in order to collect network data from the randomly selected dairy farms. For this, we administered the structured questionnaire developed by the EgoNet software based on the authors' information fed in to the program, which is important for the network data collection. Based on their links with suppliers and buyers in terms of goods exchange for the survey period, network data related to ego-alter and alter-alter relationships and attributes of alters were collected from the sampled dairy farms.

Variables and Measures

Dependent variable: dairy technology adoption

The study operationalizes dairy technology adoption as the number of different dairy technology components adopted. In livestock technology/adoption, there are a number of technology components that are often considered a technology package. These are the adoption of pure (exotic) breeds, improved crossbreds, the improved feeds and management, improved animal health management, and improved breeding or Artificial inseminations (AI services). Henceforth, we use the count of these dairy technology components adopted by the sampled dairy farms for the survey period as dependent with the value range of zero to five where zero stands for not adopting any of the stated technology components and five for a farm adopting all the five components.

Structural characteristics of supply networks

The study operationalizes three network structural characteristics:

Information centrality: used to measure supply network accessibility to represent the speed and extent of opportunities a firm has to access information and knowledge from other members in the supply network (Stephenson and Zelen, 1989). Information centrality is measured by the harmonic mean length of paths ending at a node i, with this length being smaller if i has many short paths connecting it to other nodes in the network:

$$IC_i = \frac{n}{nc_{ii}+\sum_{j=1}^{n} \quad c_{jj}-2\sum_{j=1}^{n} \quad c_{ij}} = \left[C_{ii} + \left(\sum_{j=1}^{n} \quad Cjj - 2\sum_{j=1}^{n} \quad C_{ij}\right)/n\right]^{-1} \qquad (1)$$

Where $B = D(r) - A + J, \qquad C = (C_{ij}) = B^{-1}$

First, the matrix B is constructed by taking the diagonal matrix D(r) of the number of direct ties firm i has, subtracting it from the adjacency matrix A of the supply network, and adding the matrix J with all elements at unity. Next, information centrality scores are calculated using element entries of C, the inverted matrix of B, and the number of firms in the network n. The index has a minimum value of 0, but no maximum value. This measure of information centrality focuses on a firm's opportunities to access information and knowledge contained in all paths that originate (and end) at a particular node in a network. This measure is rooted in the theory of statistical estimation, where a path connecting two nodes is considered as a signal and the noise in the transmission of the signal is measured by the variance of this signal. The measure of information available through each transmission would then be the reciprocal of the variance (Stephenson and Zelen, 1989).

Network efficiency is used to measure the interconnectedness of a firm's direct partner supply network (Burt, 2001). The notion of network efficiency suggests that, if a focal node has at least one pair of direct sources who are also directly connected to each other, then its network is considered to be inefficiently connected. Thus, a network is considered to be inefficiently connected in a sense that there is at least one tie in the network that indirectly connects the focal node to the same source of knowledge, resource, or information. This tie would be considered as a redundant tie. We capture supply network interconnectedness by assessing the number of shared relationships that exist between the supply network partners of a focal firm. As mentioned earlier, we are also interested in capturing the extent to which a firm's supply network partners are densely (sparsely) connected. Assessing shared relationships helps provide insights into how closely knit a focal firm's partners are with each other and into possible redundant ties that are built into the supply network. More formally, network efficiency accounts for the level of supply network interconnectedness by adapting the efficiency equation from (Burt, 1992):

$$Interc_i = 1 - Effic_i = 1 - \left[\sum_j \quad \left[1 - \sum_q \quad p_{iq} m_{jq}\right]\right] / \, n_i \qquad (2)$$

Where piq is the proportion of focal firm i's ties invested in the relationship with q, mjq is the marginal strength of the tie between members j and q (that are both directly connected to i) and ni is the total number of direct partners of focal firm i. Since our supply network representations are binary, the values of mjq are set to 1 if a tie is present between members j and q and 0 otherwise.

Ego network density: it is the third component of supply network structure employed in the study. The ego network density is operationalized as the summation of all ties that a particular firm has within its ego network, over the total possible number of pairs within the ego network (Carnovale and Yeniyurt 2015). Thus, the ego network density for our supply network is computed using the following algebraic formula (Borgatti, 1997) as follows:

$$Ego\ network\ density_i = \left[\frac{\left(\sum_j \quad \sum_q \quad x_{jq}\right)}{\left(\frac{\{N(N-1)\}}{2}\right)}\right] \times 100, \; j \neq q \qquad (3)$$

Where Xjq represents the relative strength of the tie between alter j and alter q, and N represents the number of alters to which ego i is connected. Because we treated supply network as either present or absent (i.e., they do not vary in terms of strength), all values of Xjq were set to 1 if a relationship existed and 0 otherwise. The term [N(N-1)] was divided by 2 to reflect that supply networks are undirected ties.

Control variables

Farm scale: it is a dummy variable. It is measured whether a given farm is small, medium or large farms. The small farms are defined as farms that have less than or equal to five cattle, medium farms are those farms that have more than five cattle and the large farms are state or private (commercial farms with official license of operation).

Farm age: The study also used firm age to control its effect. Since older firms are expected to influence more of their existing technological competencies while younger firms are expected to experiment more with new technologies (Sorensen and Stuart 2000). Farm age was calculated as the number of years from the date of the farm's founding to the survey year.

Farm size**:** influences a firm's level of innovation output and performance, as larger firms have more financial means and greater resources to invest in innovation-related activities than smaller firms (Bellamy *et al.*, 2014). Teece (1992) obtained that firm size can both positively or negatively influence its innovation output. In this study, farm size is operationalized as the quantity of cattle a given farm has sold during the survey year. It is a continuous variable and measured by counting the number of the cattle sold by the farm.

Sex of dairy farm owner or manager**:** In order to control the gender effect in the investigation, the study employed sex of farm owner or manager in the model. Lu *et al.* (2009) in their study used the dummy variable gender to control its effect in the estimation of the role of network relationship on buyer-seller relationship and performance.

Education level**:** It is a continuous variable and measured in the number of years in schooling of dairy farm owner or manager. The education level of owners or managers affects innovation and financial performances.

Location**:** It is a dummy variable and employed to measure the geographical location of the dairy farm. This variable has a role in order to measure the proximity of the dairy farms to research institutions and market, in general to control the effects that come from geographical differences.

Econometric Model specification

The study operationalizes technology adoption as the number of different dairy technologies adopted by cattle farms as the dependent variable. A count variable that takes on only non-negative integer values makes a linear regression model inappropriate as it assumes the distribution of residuals to be homoscedastic, normally distributed. This could lead to coefficient estimates that are both biased and inconsistent. Hence, Poisson and negative binomial regression are more appropriate models for count data (Greene, 2003).

The Poisson regression model specifies that yi given xi is Poisson distributed with density is given by:

$$f(X_i) = \frac{e^{-\mu_i}\mu_i^{y_i}}{y_i!}, \quad y_i = 0,1,2,\dots. \qquad (4)$$

and mean parameter is given by:

$$E[y_i|X_i] = \mu_i = exp(X_i'\beta) \qquad (5)$$

The model comprising (4) and (5) is usually referred to as the Poisson regression model. Given independent observations, the log-likelihood function is given by (Cameron and Trivedi, 2013)

$$lnL(\beta) = \sum_{i=1}^{n} \quad \{y_i X_i'\beta - exp(X_i'\beta) - lny_i!\} \qquad (6)$$

In the presence of overdispersion, the assumption of Poisson regression that the mean and variance are equal does not hold. However, the negative binomial model accounts for overdispersion and helps avoid spuriously high levels of significance due to coefficients whose standard errors are underestimated (Cameron and Trivedi, 1986).

Hence, the study employed the negative binomial model to check for the presence of overdispersion.

The negative binomial model has the following form (Hilbe, 2011):

$$l = \sum_{i=1}^{n} \quad \left\{y_i ln\left(\frac{\alpha exp(x_i'\beta)}{1+\alpha exp(x_i'\beta)}\right) - \frac{1}{\alpha} ln\big(1 + \alpha exp(x_i'\beta)\big) + ln\Gamma\left(y_i + \frac{1}{\alpha}\right) - ln\Gamma(y_i + 1) - ln\Gamma\left(\frac{1}{\alpha}\right)\right\} (7)$$

The above equations for the model are expressed as log-likelihood functions, as is typical for a count model.

Results and Discussion

Descriptive statistics

The descriptive statistics results are presented in Table 1. Results show that out of the total sample respondents, 37% of the dairy farms are owned by female owners and 63% by male owners. The mean value of owners' educational level attained was 8th grade, dairy farm age was 12 years and hired employees in farms was about 1. Furthermore, about 39% of the dairy farms are members of dairy producers' cooperatives. For the year 2018/19, the sample farms on average obtained a revenue of 111,676 birr with minimum and maximum value of 4,600 and 448,370 birr, respectively. The sample farms composition in terms of study area was 15% from Sebeta, 30% from Mekelle, 31% from Addis Ababa and the rest 16% from Bishoftu. In a similar fashion, 36 of the farms were small-scale farms, 47% medium-scale farms and the rest 27% were large-scale farms. With regard to dairy farms contact with support institutions (namely, research, agriculture offices, higher learning institutions), 49% of the farms contacted these institutes to seek support. At the same time farms have a long-established contact with their supply partners for exchanging goods, on average about 4 years old relationship.

Table 1: Descriptive statistics of farm level characteristics

Variable	Mean	Std.Dev.	Min	Max
Sex of Owner/ manager	0.63	0.48	0	1
Farm age	11.5	10	1	48
Education level	7.69	4.68	0	16
Hired employees	1.36	1.58	0	10
Cooperative membership	0.39	0.49	0	1
Farm sales	111,676.6	74,365	4,600	448,370
Sebeta	0.16	0.36	0	1
Mekele	0.36	0.46	0	1
Addis Ababa	0.31	0.47	0	1
Bishoftu	0.17	0.37	0	1
Small farm	0.36	0.48	0	1
Medium farm	0.47	0.5	0	1
Support services	0.49	1.13	0	6
Ties duration	4.04	4.83	0	36

Adoption of dairy technology adoption

The percentages of sampled dairy farms adopting each of the dairy technology components is depicted in Figure 3. According to the results, the crossbreed dairy technology component was the most frequently adopted dairy technology component with an adoption rate of about 90%. Next, veterinary services were the relatively frequently used dairy technology components, being adopted at a rate of approximately 85%. The third frequently adopted group of dairy technology components was AI services and adopted at a rate of 74%. It was also found that improved animal health care and feed practices were relatively the frequently used dairy technologies and adopted at rates of 60 and 51%, respectively. Dairy technology components with relatively low adoption rates included improved forage crops and pure breeds dairy cows at adoption rates of 25 and 14%, respectively. Among the total sample farms, 10% of the farms adopted neither of the dairy technology components.

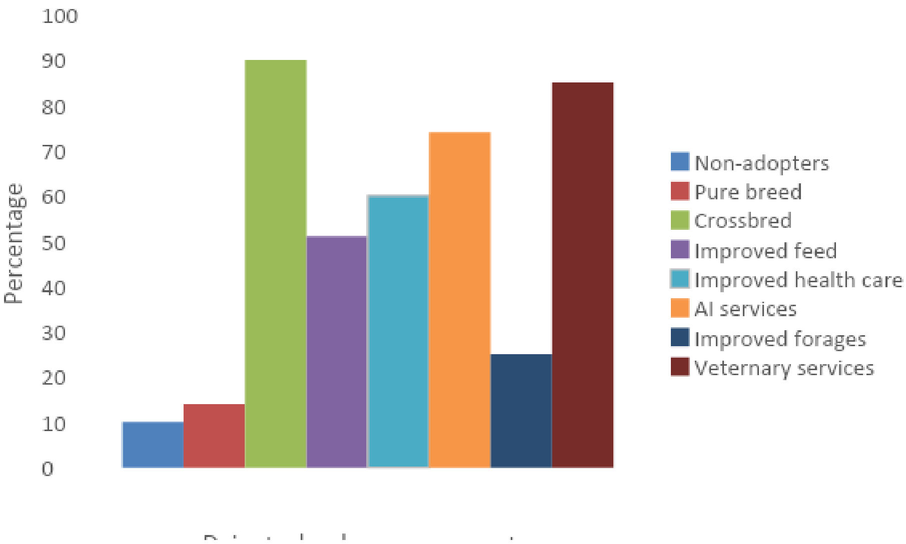

Figure 3: Dairy technology adoption

Diffusion of dairy technology components

Ryan and Gross (1943) in their study of the diffusion of hybrid seed corn in two Iowa communities have shown that the adoption of an innovation follows a normal, bell-shaped curve when plotted over time on a frequency basis. If the cumulative number of adopters is plotted against time, the result is an s-shaped curve. Figure 4 shows the plotted cumulative number of adopters for each dairy technology component's approaches to the ‘S’ curve. Diffusion of dairy technology for the dairy farm mainly started around 24 years ago in 1985. From 1985 to 1995, the diffusion of dairy technology components was so slow that there is no as such differences in the diffusion of the dairy technology components this could be attributed to the prolonged civil war from 1974 to 1991.Starting from 2000, a sudden rise of diffusion occurred and the gap among these technology components started to widen. Thus far, the crossbred dairy cows are the most widely diffused one, followed by diffusion of veterinary and AI services. Pure breeds are the least diffused dairy technology components in the sampled dairy farms over the diffusion period.

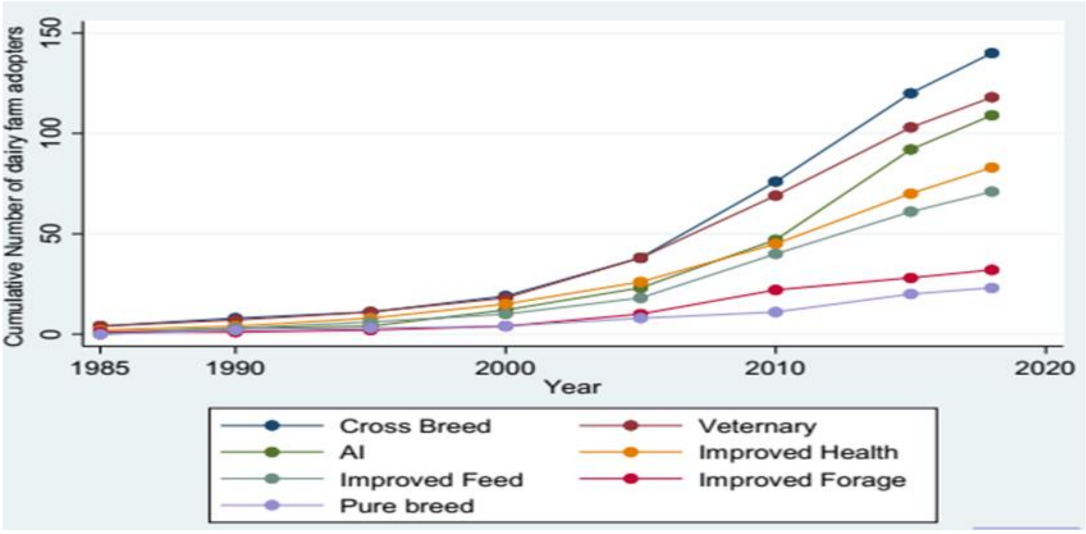

Figure 4: Dairy technology diffusion

Determinants of adoption of dairy technology

Empirical Model

Test for overdispersion

In order to check the presence of overdispersion problem in the count data, first we employed the negative binomial regression model and tested the dispersion parameter (alpha). Table 2 lists parameter estimates for empirical analysis of the negative binomial (NB) regression and Poisson regression (PR) models. The NB estimate of the overdispersion parameter is 0. This shows as there is no overdispersion problem and according to the LR test of H0: $\alpha=0$, the NB specification fails to reject the null hypothesis. This implies overdispersion and variance heterogeneity was not a problem in the count data. This test is also supported by the likelihood ratio (LR) test carried out to investigate whether or not the NB count data model reduces to the PR count data model. Test results demonstrate that the LR test statistic computed as LR = -2[LLNB - LLPR)] is not significant, where LL stands for log-likelihood values, and distributed as Chi-square with one degree of freedom. Hence, we employed the Poisson regression model under the robust standard error estimation specification.

Table 2: Poisson and Negative binomial regression model estimation results

VARIABLES	Poisson		Negative Binomial .	
	Coeff.	**St.Err.**	**Coeff.**	**St.Err.**
1. CONTROL VARIABLES				
1.1 Demography and socioeconomic variables				
Sex of Owner/ manager	0.102	0.066	0.102	0.066
Farm age	-0.001	0.003	-0.001	0.003
Education level	0.012	0.008	0.012	0.008
Hired employees	0.017	0.024	0.017	0.024
Cooperative membership	0.104	0.070	0.104	0.070
Firm sales	0.000***	0.000	0.000***	0.000
1.2 Location variables				
Sebeta	-0.133	0.101	-0.133	0.101
Mekele	0.138	0.090	0.138	0.090
Addis Ababa	0.000	.	0.000	.
1.3 Farm Scale				
Small firm	-0.251**	0.115	-0.251**	0.115
Medium firm	-0.293***	0.099	-0.293***	0.099
1.4 Institutional links				
Research link	0.050**	0.025	0.050**	0.025
AI Services	0.013**	0.007	0.013**	0.007
0. MAIN VARIABLES				
SN density	-1.331***	0.347	-1.331***	0.347
SN accessibility	-0.112	0.072	-0.112	0.072
SN interconnectedness	1.826***	0.483	1.826***	0.483
0. INTERACTIONS				
Veterinary*SN accessibility	0.00003**	0.000	0.000**	0.000
SN accessibility SN interconnectedness	0.180	0.204	0.180	0.204
Constant	1.103***	0.220	1.103***	0.220
(alpha)			0	
Pseudo r-squared	0.067		0.067	
Chi-square	108.857***		108.857***	
Akaike crit. (AIC)	523.550		523.550	
Bayesian crit. (BIC)	575.576		575.576	
Log likelihood	-243.775		-243.775	
N	148		148	

*** *p<0.01, ** p<0.05, * p<0.1*

Model estimates

The results of the Poisson regression are presented in Table 3. In order to confirm model stability and to make sure that any significant effect is robust to the introduction of other effects, we estimated three different Poisson regression models by inclusion of variables sequentially.

Each model performance was tested based on the likelihood ratio test. The likelihood ratio tests indicate that the two models have more explanatory power than model 1. Model 1 entails only the control variables. Some of the control variables are significant. Specifically, membership to cooperatives, farm sales and support services institutions are shown to positively and significantly affect the adoption of dairy technology. On the contrary, location variables (Sebeta) and farm scale have a negative significant influence on dairy technology adoption. This suggests that dairy farms in Sebeta area compared to dairy farms in Bishoftu (reference group) tend to adopt dairy technology less likely compared to the reference group and that small and medium scale dairy farms have a lesser dairy technology adoption compared to large-scale dairy farm (the reference group is large-scale dairy farms). This suggests that farm scale is positively associated with dairy technology adoption.

Model 2 introduces the main effects of supply network density, supply network accessibility and supply network interconnectedness. Results suggest that the level of dairy technology adoption increased with a decrease in supply network density ($p < 0.001$), thus providing support for hypothesis 3. The finding of the significant negative association of supply network density on dairy technology adoption suggests that in the context of the dairy industry, dense networks are not conducive in the adoption of dairy technology. This finding complies with the argument of Granovetter (1973). According to Granovetter (1973), actors of dense networks tend to interact frequently, a high share of the information circulating in this social system is redundant. He posits that new information is mainly obtained through relationships to actors who are not members of the closely connected part of the network, the ‘weak ties’, rather than through close relationships (strong ties). Granovetter mainly discusses the effect of social structures on issues such as new technologies and information about job offerings (Granovetter, 1973, 1985).

Model 2 also displays a positive significant ($p < 0.001$) relationship between supply network interconnectedness and adoption of dairy technology, showing support for hypothesis 2. The result of the positive significant effect of supply network interconnectedness on dairy technology adoption illustrates that interconnectedness enhances collaborative initiatives that provide access to knowledge, resources, and information from other partners in the supply network. This finding supports our hypothesis 2. This result is in agreement with the findings of Inkpen (1996) and Inkpen and Tsang (2005).

However, the model 2 result yields an insignificant relationship between supply network accessibility and dairy technology adoption providing no empirical evidence supporting hypothesis 1. Our prior expectation was based on the previous literature that focal firms with high network accessibility acquire more information in terms of volume and diversity from their network partners in the supply network in which they work (Schilling and Phelps, 2007). This result suggests that supply network accessibility, in isolation, may not be a significant driver in dairy technology adoption.

Finally, model 3 entails the interaction related to hypotheses 4 and 5, and represents the full model.

According to model 3 in Table 3, the negative association between supply network density and adoption of dairy technology (Hypothesis 3) remains throughout the full model except a few changes in the coefficient at a significant level of $p<0.001$. Furthermore, the positive effect of the supply network interconnectedness on adoption of dairy technology (hypothesis 2) remains the same in the full model. This effect is also significant at $p < 0.05$.

With regard to the interaction variables in model 3, the results suggest that the positive association between supply network accessibility and dairy technology adoption is positively moderated by a firm’s absorptive capacity ($p<0.1$), thus providing support for hypothesis 5. This result provides empirical evidence that while structural characteristics in a supply network can enable information and knowledge flows to enhance dairy technology adoption, this association can be moderated by dairy farms’ veterinary expenditures used as proxy for farms’ absorptive capacity. The results show that investing more in veterinary services as a proxy for Research and Development (R&D) and manifestation of absorptive capacity, can be used to positively moderate the effects of supply network accessibility on dairy technology adoption. In their study on the influence of supply network structures on firm innovation output, Bellamy *et al.* (2014) showed that R & D moderates positively the effects of supply network accessibility on firm innovation output.

However, we obtained non-significant association between the moderation of supply network interconnectedness on supply network accessibility on dairy technology adoption, which did not support hypothesis 4. Our prior expectation was that dairy farms that maintain high supply network interconnectedness with having higher levels of supply network accessibility in supply network experience much knowledge and information access and sharing that ultimately fosters technology adoption. In general the non-significant factors found in the study may warrant further study in the future by including other important variables.

Table 3: Poisson regression model estimation results

VARIABLES	Model 1		Model 2		Model 3	
	Coeff.	**St.Err.**	**Coeff.**	**St.Err.**	**Coeff.**	**St.Err.**
1. CONTROL VARIABLES						
1.1 Demography and socioeconomic variables						
Sex of Owner/ manager	0.068	0.065	0.083	0.066	0.102	0.066
Firm age	-0.002	0.004	-0.002	0.003	-0.001	0.003
Education level	0.009	0.008	0.009	0.008	0.012	0.008
Hired employees	0.027	0.023	0.022	0.022	0.017	0.024
Cooperative membership	0.196**	0.076	0.111	0.070	0.104	0.070
Firm sales	0.000**	0.000	0.000**	0.000	0.000***	0.000
1.2 Location variables						
Sebeta	-0.123	0.084	-0.158	0.100	-0.133	0.101
Mekele	0.157*	0.088	0.102	0.079	0.138	0.090
Addis Ababa	0.000	.	0.000	.	0.000	.
1.3 Farm Scale						
Small firm	-0.211*	0.127	-0.164	0.135	-0.251**	0.115
Medium firm	-0.192*	0.104	-0.199	0.125	-0.293***	0.099
1.4 Institutional links						
Research link	0.068***	0.018	0.058**	0.025	0.050**	0.025
AI Services	0.011	0.008	0.012*	0.007	0.013**	0.007
0. MAIN VARIABLES						
SN density			-1.325***	0.347	-1.331***	0.347
SN accessibility			-0.061	0.070	-0.112	0.072
SN interconnectedness			1.718***	0.478	1.826***	0.483
0. INTERACTIONS						
Veterinary*SN accessibility					0.00003**	0.000
SN accessibility SN interconnectedness					0.180	0.204
Constant	0.969***	0.222	1.093***	0.207	1.103***	0.220
Pseudo r-squared	0.030		0.060		0.067	
Chi-square	42.458***		77.664***		108.857***	
Akaike crit. (AIC)	593.856		523.247		523.550	
Bayesian crit. (BIC)	632.820		569.492		575.576	
Log likelihood	-283.928		-245.623		-243.775	
N	148		148		148	

**** p<0.01, ** p<0.05, * p<0.1*

Interaction/ Moderation effect

Further investigation of the interaction effects using the interaction plot tool provides additional information to help comprehend the interaction effects. We plot the predicted dairy technology adoption with changes in each corresponding variable, using high and low values of the variable values as one standard deviation above and below the mean, respectively.

The plots in Figure 5 show the interaction between a firm's supply network accessibility and its veterinary expenditures in two-way plots. The "low, mean and high veterinary expenditure" lines in Figure portray the moderating effect of veterinary expenditures, and explain the slopes of the effects of supply network accessibility on adoption of dairy technology when the values of veterinary expenditures are set to one standard deviation either below or above its mean value, and at the mean value. The graph shows that high veterinary expenditures positively moderate the effect of supply network accessibility on the likelihood of adoption of dairy technology in dairy farms.

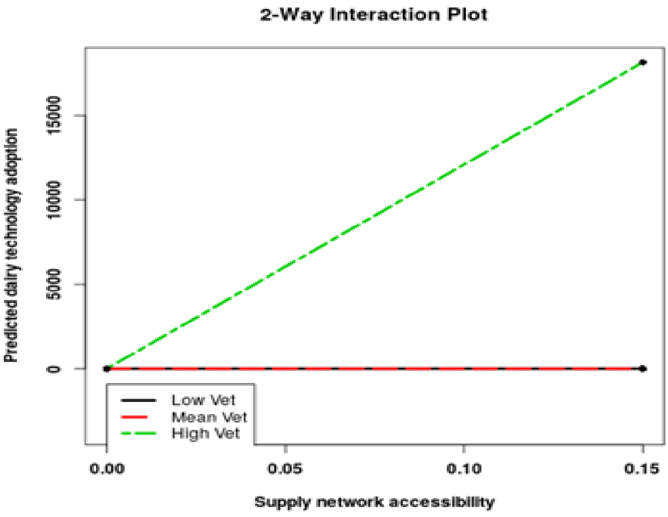

Figure 5: Interaction plot

Robust Estimation

Endogeneity

The study has also undertaken an endogeneity test. Because we are conducting experiments to predict the adoption of dairy technology network parameters (SN accessibility, density and interconnectedness), there could be an issue of endogeneity problem. Particularly, adoption might predict the network parameters and network parameters might predict adoption.

In order to address this potential endogeneity issue, the most and widely used methodological approaches in literature suggest running a two-stage least-squares regression with instrumental variables and employing the Hausman test (Greene, 2003). However, our model is a non-linear model; we opted for a non-linear instrumental variable estimation approach using the General Method of

Moments (GMM) estimator. The generic solution to this problem is a nonlinear instrumental variable approach as outlined in Mullahy (1997) and in Windmeijer and Silva (1997).

Next, we reviewed the literature to find appropriate instruments for supply network density, accessibility and interconnectedness. Bellamy *et al*., (2014) in his study selected instrumental variables from the count model considered as exogenous but found non-significant for the endogenous variables supply network accessibility and interconnectedness. Similarly, we employed this approach and identified the non-significant exogenous variables and potential instrumental variables form our Poisson regression model, namely sex of the owner, owner education level, farm age, and ties duration. Additionally, based on the studies conducted to address endogeneity by (Basole *et al*., 2017; Bellamy *et al*., 2014), we included network measure degree centrality. Centrality measures the involvement in the network (Knoke and Burt, 1983): the extent to which an actor is deeply involved in network relations (Burt, 1980; Wasserman and Faust, 1994). Ultimately, we totally chose sex of the owner, owner education level, farm age, and ties duration and degree centrality as instruments for potentially endogenous variables supply network density, supply network accessibility and supply network interconnectedness. Table 4 shows the result of the non-linear instrumental regression model estimated using the General Methods of Moments (GMM).

We conducted a test to test the validity of over-identification in our model since our endogenous model is an over-identified (more instrumental variables than endogenous variables). According to Hansen's test, we failed to reject the null hypothesis. Suggesting that all the instrumental variables employed in the model are valid. Then we look at the output of the endogenous model to investigate endogeneity. According to the result of the model, the estimated coefficients of the endogenous variables (supply network density, accessibility and interconnectedness) are not significantly different from zero suggesting that supply network density, accessibility and interconnectedness are exogenous variables. Hence, the parameter estimates for these network variables in our original count model do not appear to be affected by the endogeneity problem.

Table 4: The GMM estimate test for endogeneity

VARIABLES	Coeff.	Std.Err.
SN density	-3.113	(8.772)
SN accessibility	-0.595	(2.800)
SN interconnectedness	5.587	(18.27)
Cooperative membership	0.0854	(0.114)
Firm sales	-2.90e-07	(2.83e-07)
Sebeta	-0.149	(0.141)
Mekelle	-0.0715	(0.280)
Addis Ababa	-	
Small firm	-0.254	(0.169)
Medium firm	-0.257	(0.199)
Support services	0.0180	(0.145)
Constant	1.466***	(0.310)
N	148	

Theoretical implications

This study contributes to the growing literature of adopting a network analytic view of supply networks in the agriculture technology adoption. This has been realized by investigating how a dairy farm can accrue knowledge and information flow benefits about dairy technology from its supply network to enhance its technology adoption. The results of this study show that the benefit of low network density and high supply network interconnectedness along with the moderating effect of farm's absorptive capacity on accessibility in a supply network yields a higher likelihood of adoption of dairy technology. Furthermore, the study contributes to the literature the importance of the strength of weak ties (Granovetter 1973) and structural holes (Burt, 2001) in agricultural innovation and technology adoption in the context of the dairy industry.

Limitations and directions for future research

While this study focused on three network structural characteristics namely on network density, supply network accessibility, and interconnectedness, future research should further include other important network structural characteristics that may influence farm's technology adoption.

To add more, this study is based on first tier supply network partners of the ego network dataset. Hence for more information and investigate the role of supply networks on technology adoption, future study may conduct their investigation by incorporating second tier supply network partners.

Further, while we include a farm's veterinary expenditure as a reflection of a farm's absorptive capacity, there may be other important factors capturing the farm's amount of experience and potential ability to absorb incoming external knowledge. Future research should investigate further into other aspects that may affect a farm's ability to absorb knowledge residing in the supply network.

Conclusion

This study examined the association between supply network structure and dairy farm technology adoption. Particularly, we focused on three structural characteristics: supply network accessibility, interconnectedness and density. We also estimate the interaction effects of absorptive capacity and supply network accessibility, and the interaction effect of supply network accessibility and interconnectedness. The study employed the farm level and ego-network dataset of sampled dairy farms in the dairy industry.

Our findings suggest that high network density negatively influences farm technology adoption, which implies that weak ties are important in dairy technology adoption in the context of the dairy industry. The plausible explanation is embeddedness in strong ties may also lead to lock-in (Grabher, 1993) and can well have negative effects on farm technology adoption. Such effects were likely to occur in our study given the low dynamics of technology generation in the dairy industry.

The results also indicate that interconnected supply networks help in the adoption of dairy technology. Additionally, the results show that the influence of the supply network accessibility on farm dairy technology adoption can be enhanced by a farm’s absorptive capacity. In sum, the study contributes to the body of literature on both supply chain management and technology adoption in the context of the dairy industry by highlighting the role of the structural characteristics of supply networks, along with knowledge variables, in facilitating knowledge creation and thereby improving upon a farm’s technology adoption.

Thus, in light of these findings, considerations should be given to policies that create an ecosystem of interactions through training, promoting fairs and innovation events to promote rapid dairy technology adoption by dairy farms.

Acknowledgments

This research was financially supported by the Ethiopia Control of Bovine Tuberculosis Strategies (ETHICOBOTS) project funded by the Biotechnology and Biological Sciences Research Council, the Department for International Development, the Economic and Social Research Council, the Medical Research Council, the Natural Environment Research Council and the Defence Science and Technology Laboratory, under the Zoonoses and Emerging Livestock Systems (ZELS) program, ref: BB/L018977/1. SB was also partly funded by the Department for Environment, Food & Rural Affairs, United Kingdom, ref: TBSE3294.

The members of the Ethiopia Control of Bovine Tuberculosis Strategies (ETHICOBOTS) consortium are: Abraham Aseffa, Adane Mihret, Bamlak Tessema, Bizuneh Belachew, Eshcolewyene Fekadu, Fantanesh Melese, Gizachew Gemechu, Hawult Taye, Rea Tschopp, Shewit Haile, Sosina Ayalew, Tsegaye Hailu, all from Armauer Hansen Research Institute, Ethiopia; Rea Tschopp from Swiss Tropical and Public Health Institute, Switzerland; Adam Bekele, Chilot Yirga, Mulualem Ambaw, Tadele Mamo, Tesfaye Solomon, all from Ethiopian Institute of Agricultural Research, Ethiopia; Tilaye Teklewold from Amhara Regional Agricultural Research Institute, Ethiopia; Solomon Gebre, Getachew Gari, Mesfin Sahle, Abde Aliy, Abebe Olani, Asegedech Sirak, Gizat Almaw, Getnet Mekonnen, Mekdes Tamiru, Sintayehu Guta, all from National Animal Health Diagnostic and Investigation Center, Ethiopia; James Wood, Andrew Conlan, Alan Clarke, all from Cambridge University, United Kingdom; Henrietta L. Moore and Catherine Hodge, both from University College London, United Kingdom; Constance Smith at University of Manchester, United Kingdom;

R. Glyn Hewinson, Stefan Berg, Martin Vordermeier, Javier Nunez-Garcia, all from Animal and Plant Health Agency, United Kingdom; Gobena Ameni, Berecha Bayissa, Aboma Zewude, Adane Worku, Lemma Terfassa, Mahlet Chanyalew, Temesgen Mohammed, Miserach Zeleke, all from Addis ababa University, Ethiopia.

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Ethiop. J. Agric. Sci. 32(4) 56-72 (2022)

Susceptibility of African Bollworm, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) to Different Commercial Pyrethroid Insecticides on Cotton

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Abstract

The African bollworm, Helicoverpa armigera (Hubner) is an indigenous species in Africa and has been reported in the destruction of several crops in general and cotton in particular in Ethiopia. Currently, the management of H. armigera is mainly focused on the use of synthetic pyrethroids, which have already led to resistance selection pressure in several field populations of this insect. To know the status of different pyrethroid insecticides monitoring was exercised using populations of H. armigera collected from four different areas of the central and southern rift valley. This study aimed to screen the susceptibility pattern of four field populations of H. armigera to Aplhacypermethrin, lambda-cyhalothrin, and deltamethrin insecticides using third-instar larva immersion and square dip methods. The selected insecticides had been examined in seven concentration levels. For each concentration, thirty-third instar larvae were treated in three replications. An equal number of larvae were treated with tap water as control. The result indicated that Aplhacypermethrin displayed high acute toxicity to H. armigera populations from Werer, Gewane, and Merti Jeju whereas lambda-cyhalothrin and deltamethrin exhibited relatively low toxicity to the populations from Gewane and Werer. The LC_{50} value of the Goffa-Sawla populace became notably exclusive to most of the populations from Werer, Merti Jeju, and Gewane in each bioassay method. The pairwise correlation coefficients of LC_{50} values indicated that the commercial insecticides were not significantly correlated. Therefore, it is concluded that the recorded high levels of deltamethrin resistance in H. armigera from Gewane and Werer may lead to the development of resistance to deltamethrin. Further investigation on the tracking of resistance and its management is needed.

Keywords: Cotton, Helicoverpa armigera, Insecticide, Pyrethroid resistance

Introduction

Cotton, *Gossypium hirsutum* L. (Malvaceae), is one of the most valuable cash crops in the world grown for its fiber and the oil extracted from the seed (Malinga and Laing, 2022). Cotton production is a major economic component in sub-Saharan Africa, and is a significant contributor to economic growth (Amanet *et al*., 2019). In Ethiopia, cotton is a significant crop produced by both commercial and small-scale farmers in the Awash Valley, Southern Rift Valley, Gambella, Humera, and Metema. But, Ethiopia shares only 5% of the total cotton produced in Africa (Melesse *et al*., 2019). Its production can be challenging, as the crop is prone to attack by a wide variety of pests, especially African bollworm and sucking pests like aphids and whiteflies, among other factors.

The African bollworm, *Helicoverpa armigera* Hübner is an indigenous species considered to be a major and key insect pest of cotton in Africa (Cherry *et al*., 2003), and ranks as the most important lepidopteran pest on cotton in Ethiopia (Geremew and Ermias, 2006). Unlike most other arthropod pests, *H. armigera* is a polyphagous pest that infests more than 200 crop species worldwide, including cotton, pepper, corn, tomato, lucerne, soybean, sorghum, and tobacco (Cunningham and Zalucki, 2014). In Ethiopia, this pest feeds on a variety of plants, including beans, chickpeas, peas, sorghum, cotton, tomato, pepper, sunflower, safflower, flax, and Niger seed (Tsedeke, 1982; Waktole, 1996). The larva feeds on cotton young leaves, squares, flower buds, flowers, and bolls. Four heliothine species (*H. armigera*, *Pectinophora gossypiella*, *Diparopsis watersi*, and *Earias* spp.) are reported as being of economic importance, but *H. armigera* is the only species of major economic importance that causes 36-60% (Tsedeke, 1982; Waktole, 1996); and about 60% (Geremew and Ermias, 2006) yield losses.

Worldwide, up to 60% of all commercialized insecticides are used in cotton (Yada and Dutta, 2019). Chemical pesticides such as pyrethroids, carbamates, and organophosphates are applied to control Helicoverpa pests (Martin *et al*., 2000). Likewise, cotton producers in Ethiopia have been using chemical insecticides to manipulate pests for decades. To control these cotton pests more than four round sprays were allotted (EIAR, 2016). Geremew (2004) reported that with the use of such monologues chemicals, controlling these pests has proven tough. Excessive and continuous applications of pyrethroid insecticides for *H. armigera* control initiated in the mid-1980s in most countries have led to resistance selection pressure in several field populations of this insect (Brévault *et al*., 2008; Yadouleton *et al*., 2009). With this development of insecticide resistance, the control of *H. armigera* has become critical in many regions worldwide (Chaturvedi, 2007). Recent studies have reported the increased resistance of *H. armigera* to pyrethroids in Pakistan (Ahmad *et al*., 1995), South India (Ramasubramanian and Regupathy, 2004), Spain (Torres *et al*., 2002), and West Africa (Brun *et al*., 2010).

In Ethiopia, few studies reported resistance of *H. armigera* to lambda-cyhalothrin in the Dubti area (Germew, 2004) and endosulfan in the Werer area (WARC, 1998; Geremew and Surachate, 2005). In contrast, Lambda-cyhalothrin and Deltamethrin, the two commonly used synthetic pyrethroid pesticides, have shown efficacy in suppressing African bollworms in the Middle Awash area (Personal communication). Unfortunately, information about *H. armigera* resistance to different insecticides in different locations of Awash valley representing major cotton cropping systems is limited. Even the technical literature which has reported on control failures of *H. armigera* was too preliminary. Thus it was essential to understand the status of resistance to selected pyrethroid insecticides which are still in use in different locations to know their contribution to controlling failures. Therefore, the study was conducted to determine the sensitivity of different field-collected *H. armigera* populations to commonly used synthetic pyrethroid pesticides in laboratory settings.

Material and Methods

The experiment was conducted at Werer Agricultural Research Center (WARC) which is located in Amibara District, Gebresu zone of Afar National Regional State in Ethiopia during the 2017 cotton production season under laboratory conditions. The test insect, *H. armigera,* larvae were collected from different locations of Awash valley and Gofa-Sawla (Fig. 1), representing different cropping patterns and agro-ecosystems which are dominating with host crops of *H. armigera*.

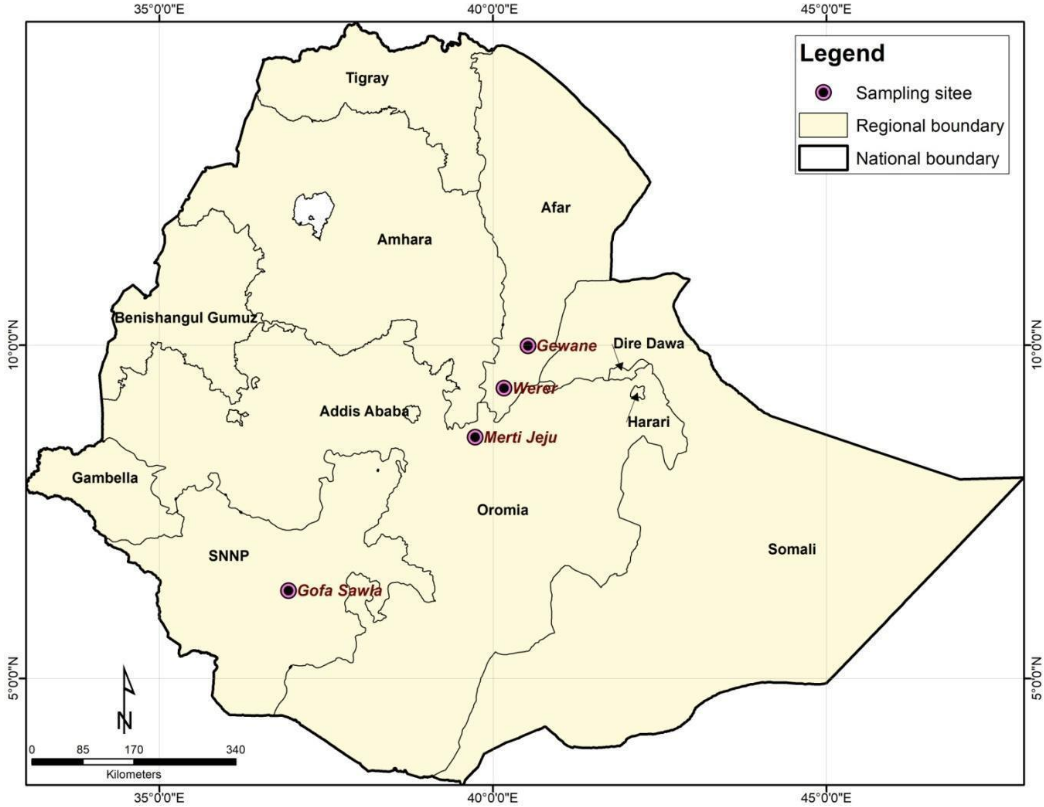

Figure 1. Map of Ethiopia showing selected sampling location of *H. armigera* larvae collection.

Collection and rearing of *H. armigera*

Field populations of *Helicoverpa armigera* were collected from unsprayed cotton farms in Middle Awash (Werer &, Gewane) and Upper Awash farms (Merti Jeju) with substantial pyrethroid pesticide use history which led to suspect the development of pyrethroid resistance. Besides, Larvae of *H. armigera* were also collected from chickpea small-scale farms at Gofa-Sawla, Southern Ethiopia, with no pesticide use history for the last six years, for the sake of comparison with those populations collected from cotton farms with a history of heavy pesticide use for several years. Detailed descriptions of four sample larvae collection areas are stated in Table 1.

Larvae collected in the field were introduced into plastic vials (4cm diameter; 5cm height) with a cover punched with holes to allow ventilation for the breathing of larvae. Each vial was filled with host plant leaves for feeding larvae throughout their transportation from the field to the laboratory. The field-collected larvae of *H. armigera* were brought to the entomology laboratory at Werer Agricultural Research Center and reared on natural hosts of cotton fruiting bodies till pupation at 29 $\underline{+}$ 2 ^{0}C, with a relative humidity of 48 $\underline{+}$4% and 12:12 h Light: Dark photoperiod. The culture was maintained location-wise separately. Then pupae were collected each morning and transferred to plastic pots (15 pupae/pots) with a size of 20cm height * 16cm width embedded with soil and placed in adult cages. Pairs of emerged male and female adult moths (1:1) were transferred into separate adult rearing cages (30cm height *27cm width). The adults were provided with a sugar solution and allowed for mating. The adult diet was prepared from five-gram sugar and two-hundred cubic centimeters of water (Geremew and Surachate, 2003). The adults were allowed to lay eggs on cheese close and a detached cotton branch was placed within the cage. The eggs hatch after 3 or four days. After hatching first instar larvae were reared in groups in large Petri plates provided with a natural diet i.e. cotton leaves. While larvae reached second instar status they were reared individually in a large petri dish with its natural diet of cotton leaves. Every morning the cotton leaves were changed and the petri-dish was cleaned throughout the rearing period. A pictorial representation of the rearing process is illustrated in Figure 2. The experiment was conducted using third-instar larvae.

Table 1. Geo-reference data of surveyed localities for *H. armigera* sampling

Collection Site	Agro Ecosystem	Host Plant	Altitude (m.a.s.l)	Latitude (E)	Longitude (N)
Werer	Middle Awash	Cotton	734.4	40^0 09' 811"	09^0 21' 243"
Gewane	Middle Awash	Cotton	567	040^0 31' 23"	09^0 59' 22.5"
Merti Jeju	Upper Awash	Cotton	1174	039^0 43' 93"	08^0 37' 111"
Gofa-Sawla	Southern Ethiopia	Chickpea	1260	036^0 56'	06^0 19'

Figure 2. Adult rearing and hatched larva feeding process (A) Adult rearing cage with sugar immersed cotton wool (B) *H. armigera* adult on top and side of the cage (C) Collection of hatched larva from the adult cages (D) Feeding larva with cotton

The serial concentration of test insecticides

All test insecticides namely alphacypermethrin **(**Fastac 100G/L**),** lambda-cyhalothrin **(**Karate 5%EC**),** and deltamethrin (Decis 2.5% EC) were obtained as commercial formulations available on the market in 2017. The required concentrations of test insecticides lambda-cyhalothrin (2, 1, 0.5, 0.25, 0.12, 0.0625 µL/mL and control); deltamethrin (3, 1.5, 0.75, 0.375, 0.1875, 0.046875 µL/mL and control) and alphacypermethrin (1.5, 0.75, 0.375, 0.1875, 0.046875, 0.0234375 µL/mL and control) were prepared from the formulated products by serially diluted the required quantities in tap water after accurate weightiness of insecticides

Laboratory Bioassay Method for Susceptibility Study

Bioassays were conducted using the fresh molted F_1 generation of third instar larvae of *H. armigera* by the victimization of the cotton square dip and larval immersion bioassay procedure suggested by Geremew *et al*. (2004). The experiments were arranged in a completely randomized design (CRD) with 3 replications. For every replicate of a serial concentration and control, 10 larvae were used.

Experiment I. Larval Immersion Experiment

Doses were applied in order of increasing concentration, and the same syringe was used to apply all doses of the same insecticide. For every treatment, 10 third instar larvae per replication were used. The larvae were dipped into individual dilution for 10 seconds and placed on tissue soft trays for gripping excessive liquid from the body. Larvae were transferred into a glass petri dish with an insecticide-free cotton square. The control larvae were treated with tap water. Observation of mortality started 24 h after treatment.

Experiment II. Square Dip Experiment

Medium-size cotton squares that weigh 700-1000 milligrams were collected from the unsprayed cotton field and dipped into the individual concentration of insecticide for 10 seconds and transferred onto a paper soft receptacle for air-drying. After 30 min of drying, these cotton squares were placed into glass petri dishes, and 10-third instar larvae used per replication were used for feeding on the treated. The control larvae were allowed to feed on tap water-dipped and dried cotton squares. Observation of mortality started 24 h after treatment.

Data Collected

The dose-mortality larvae were recorded after 24, 48, and 72 hours of treatment for larval immersion bioassay whereas after 24, 36, and 48 hours of treatment for square dip bioassay. Larvae were thought to be dead if they are ineffectual to maneuver once probed with a blunt probe or brush. Results were expressed as percentage mortality. The resistance ratio (RR) was determined as the ratio of the lethal dose for 50% (LD_{50}) of each field population to the LD_{50} of the Gofa-Sawla susceptible population (Torres-Vila *et al.,* 2002a, b). The calculated RR was used to categorize the tested population into different pesticide resistance groups in which RR=1 was considered as susceptible, 2-10 as low level of resistance, 11-30 as moderate resistance, 31-100 as high resistance, and above 100 as extreme resistance. The daily minimum and maximum temperature and RH of the laboratory during the study period were recorded (Table 2).

Table 2. Mean monthly temperature and relative humidity of the laboratory during the study period at Werer (2017)

Month	Temperature (^{0}C)		Relative humidity (%)
	Minimum	Maximum	
Month 1	27.6	33.9	57.0
Month 2	27.3	31.2	53.5
Month 3	26.6	29.5	45.2
Month 4	26.4	29.5	40.7
Month 5	25.4	29.0	40.1
Mean	26.6	30.5	48.1

Statistical Analysis

Mortality in the control was always <10%. Therefore, data from all bioassays were corrected for control mortality using Abbott's formula (Abbott, 1925):

Percent corrected mortality=(% mortality in treatment-% morality in control 100-% mortality in control)*100

The statistical analyses of data obtained from the dose-mortality experiments were performed by probit analysis (Finney, 1971) with SAS software version 9 (SAS Institute, 1999). The mortality data were arcsine transformed prior to analysis to stabilize variances. LC_{50} and LC_{90} (Lethal Concentrations that kill 50 and 90% larva, respectively), slope, and 95% Confidence Limit (CL) were also determined by probit analysis. The least significant difference (LSD) test was used to separate means at a 5% probability level. LD_{50s} and LD_{90s} of two different populations were considered significantly different when their 95% confidence intervals did not overlap. Cross-resistance among the insecticides was determined through pair-wise correlation coefficients of log LC_{50} values of the common populations for each insecticide

Results and Discussion

The current study assessed the susceptibility of three pyrethroids insecticides that were available on the market, and farmers have been applying them indiscriminately to manage an *H. armigera* pest. The results of this study showed the response of *H. armigera* pest to these insecticides across the sampled locations

Susceptibility of Helicoverpa armigera to Lambda-cyhalothrin

In larva immersion techniques, at recommended rate larval mortality was 90-100% mortality while in square dip techniques was 93.3-100% mortality in four *H. armigera* field populations (Table 3). For lambda-cyhalothrin insecticides, the four-times decrease dose (1.25 x 10^{-4} g. a.i/mL) precipitated 100% mortality (Table 3).

The Goffa-sawla populace had a relatively low value of LC_{50} and LC_{90} in both methods. Whereas, high LC_{50} (0.498µL/mL) and LC_{90} (2.870 µL/L) values had been acquired for the Gewane populace with showed low levels of resistance (RR = 6.73 -7.45-fold) difference compared to Goffa-sawla populations (Table 4). The Goffa Sawla population was significantly more sensitive to lambda-cyhalothrin than the Werer, Merti Jeju, and Gewane populations without any overlap of 95% CL (Table 4).

A determined resistance ratio of *H armigera* has shown that the Gewane population is resistant to the insecticide lambda-cyhalothrin to a low degree, compared to other populations studied. This indicates that lambda-cyhalothrin insecticide is less efficient in controlling the pest in Gewane regions. This might be the insecticide that was used for a long time in Middle Awash for controlling chewing and sucking pests. This suggests an enormous amount of insecticides is required for *H. armigera* pest management. Different scientists found the susceptibility pattern to different insecticide groups. Honnkaerappa and Udikeri (2022) reported the field-collected population *H. armigera* peak 14.18-fold resistance to lambda-cyhalothrin. Likewise, many studies reported *H armigera* has developed a low level of resistance (Avilla and González-Zamora, 2010; Karaagac *et al.*, 2013) and high-level resistance (Duraimurugan & Regupathy, 2005; Hussain *et al.*, 2014) to lambda-cyhalothrin. Geremew *et al.* (2004) also discovered similar results of high-level resistance in larva immersion and squared dip procedures in populations from these areas to Endosulfan insecticide. Additionally, a low level of resistance was reported for FAW (Gichere *et al.*, 2022); moderate resistance of *Spodoptera littura* (Sahd *et al.*, 2012) to lambda-cyhalothrin. The increase in the use of pyrethroids in Hunan Province results in rising resistance to pyrethroids is consistent (Huang *et al.*, 2006; Xie *et al.*, 2010).

Table 3. Percentage mortality of different *H. armigera* larvae populations (N=30) in different concentrations of lambda-cyhalothrin

Larva immersion					**Squared dip**				
Concentration (µL/mL)	Percent mortality				Concentration (µL/mL)	Percent mortality			
	Gofa Sawla	Merti Jeju	Werer	Gewane		Gofa Sawla	Merti Jeju	Werer	Gewane
2	100	100	100	90.0	2	100	100	96.7	93.3
1	100	96.7	86.7	70.0	1	100	90.0	83.3	73.3
0.5	100	83.3	70.0	53.3	0.5	100	76.7	63.3	53.3
0.25	83.3	63.3	46.7	26.7	0.25	93.3	56.7	46.7	33.3
0.12	66.7	40.0	23.3	13.3	0.12	73.3	36.7	23.3	16.7
0.0625	50.0	23.3	10.0	6.7	0.0625	56.7	20.0	10.0	3.3
0.03125	16.7	10.0	10.0	3.3	0.03125	23.3	6.7	3.3	3.3
Control	6.7	0	6.7	3.3	Control	3.3	3.3	6.7	6.7

Table 4. Comparative toxicity of lambda-cyhalothrin 5% EC to different *H. armigera* populations

Larva immersion

Location	N	LC_{50} μL/mL	95% CL (lower-upper)	LC_{90} μL/mL	95%CL (lower-upper)	The fit of probit analysis			**RR**
						Slope ± SE	χ^2 (df)	P	
Gofa-Sawla	180	0.074	(0.057 -0.094)	0.260	(0.192- 0.415)	2.36± 0.333	2.778 (4)	0.5957	_
Merti Jeju	180	0.153	(0.118 - 0.199)*	0.693	(0.476 - 1.226)	1.96 ± 0.250	0.512 (4)	0.9723	2.07
Werer	180	0.264	(0.199 - 0.361)*	1.419	(0.886 -3.022)	1.75± 0.236	2.15 (4)	0.7089	3.57
Gewane	180	0.498	(0.364 - 0.763)	2.870	(1.578 - 8.204)	1.69 ± 0.256	0.622 (4)	0.9606	6.73

Squared dip

Location	N	LC_{50} μL/mL	95% CL (lower-upper)	LC_{90} μL/mL	95%CL (lower-upper)	The fit of probit analysis			RR
						Slope ± SE	χ^2 (df)	P	
Gofa-Sawla	180	0.060	(0.044 -0.075)	0.193	(0.144 - 0.306)	2.52±0.384	0.976 (4)	0.9134	_
Merti Jeju	180	0.194	(0.147 -0.258)*	1.007	(0.657-1.969)	1.80 ±0.237	0.113 (4)	0.9985	3.25
Werer	180	0.302	(0.230 - 0.41)*	1.505	(0.949-3.162)	1.84 ±0.249	0.168 (4)	0.9967	5.03
Gewane	180	0.447	(0.334 - 0.651)*	2.338	(1.364-5.869)	1.78 ±0.261	0.797 (4)	0.9389	7.45

N= total number of larvae used for probit analysis, LC_{50} *= median lethal concentration,* LC_{90}*= the lethal concentration which killed 90% of the test H. armigera population, 95% CL= the lower and the higher confidence limits at which the* LC_{50} *and* LC_{90} *value can fall at 95% probability, SE= standard Error,* χ^2 *=Chi-square, RR (Resistance Ratio) =* LC_{50} *of the field population /* LC_{50} *of Goffa-Sawla population, superscript denoted astric*=the collected H. armigera populations were not significantly different (P<0.05) among each other in their susceptibility to lambda-cyhalothrin insecticide.*

Susceptibility of *H. armiger* to Deltamethrin

Helicoverpa armigera populations exposed to different concentrations of deltamethrin 2.5% EC experienced varying levels of mortality at different locations. Larvae from Goffa-Sawla exhibited 100% mortality at two times lower doses (1.5 x 10-4 g. a.i/mL) (Table 5). LC_{50} values suggest that Werer, Merti Jeju, and Gewane populations have been no longer extensively distinctive amongst every difference ($P < 0.05$) from the Goffa-Sawla population with no overlapping 95% CL (Table 5).

The LC_{50} values of deltamethrin were 0.690–1.257 µL/mL and 0.563-1.435 µL/mL for populations collected in the Werer, Merti Jeju, and Gewane with resistance ratio (RR= 3.63-9.25-fold) when compared to Goffa-sawla populations (Table 6). In general, the resistance of *H. armigera* to deltamethrin was lowest in the population collected from Merti Jeju, while the highest resistance was obtained in a population collected from Gewane (Table 6).

The present study suggests that deltamethrin can not provide effective control for this pest in all tested locations. This implies that insecticide control is in the field in question. Deltamethrin is registered in Ethiopia for controlling *H. armigera* and other pests and has long been used to control *H. armigera* and sucking pests either in single or combination in many cotton farms. But, because of the misapplication of a pesticide against *H. armigera* may result in the selection of resistant variants of the pest population. Many researchers reported the resistance level of this pest in many countries. Honnkaerappa and Udikeri (2022) reported about 24.95-fold resistance *H. armigera* to deltamethrin. Likewise, Tossou *et al.* (2019 found high resistance levels of *H. armigera* to deltamethrin on cowpea tomato and cotton farms. Similarly, Faheem, *et al*. (2013) and Hussain *et al*. (2014) stated low-to-high-level for variant *H. armigera* populations; the lowest level of resistance for the population *Spodoptera litura* to deltamethrin insecticide (Tong *et al.*, 2013). Sene *et al* (2020) mentioned deltamethrin had low and moderate susceptibility to the *H. armigera* population in tomato and cotton farms respectively.

Table 5. Percentage mortality of different *H. armigera* larvae populations (N=30) in different concentrations of deltamethrin 2.5% EC

Larva immersion					**Squared dip**				
Concentration (µL/mL)	Percent mortality				Concentration (µL/mL)	Percent mortality			
	Gofa Sawla	Merti Jeju	Werer	Gewane		Gofa Sawla	Merti Jeju	Werer	Gewane
3	100	93.3	80.0	86.7	3	100	90.0	80.0	83.3
1.5	100	76.7	56.7	66.7	1.5	100	76.7	50.0	60,0
0.75	93.3	50.0	30.0	43.3	0.75	96.7	56.7	23.3	33.3
0.375	76.7	26.7	13.3	20.0	0.375	76.7	40.0	3.3	6.7
0.1875	53.3	13.3	3.3	6.7	0.1875	56.7	20.0	3.3	3.3
0.09375	30.0	3.3	0	0	0.09375	26.7	6.7	0	0
0.046875	13.3	0	0	0	0.046875	6.7	0	0	0
Control	3.3	6.7	6.7	6.7	Control	6.7	6.7	0	6.7

Table 6. Comparative toxicity of deltamethrin 2.5% EC to different *H. armigera* populations

Larva immersion

Location	N	LC_{50} µL/mL	95% CL (lower-upper)	LC_{90} µL/mL	95%CL (lower-upper)	The fit of probit analysis			RR
						Slope ± SE	**χ^2 (df)**	**P**	
Gofa-Sawla	150	0.143	(0.104- 0.246)	0.572	(0.430- 0.966)	2.59 ± 0.563	0.517 (3)	0.915	_
Merti Jeju	150	0.690	(0.533 - 0.890)*	2.690	(1.863 - 4.894)	2.17 ± 0.313	0.433 (3)	0.933	4.83
Werer	150	1.257	(0.980 - 1.690)*	4.814	(3.146 - 9.990)	2.20 ± 0.331	0.044 (3)	0.998	8.79
Gewane	150	0.922	(0.717 -1.207)*	3.633	(2.446 - 7.017)	2.15 ± 0.314	0.203 (3)	0.977	6.45

Squared dip

Location	N	LC_{50} µL/mL	95% CL (lower-upper)	LC_{90} µL/mL	95%CL (lower-upper)	The fit of probit analysis			RR
						Slope ± SE	χ^2 (df)	P	
Gofa-Sawla	150	0.155	(0.097 - 0.234)	0.515	(0.391 - 0.870)	2.74 ± 0.626	0.884 (3)	0.829	_
Merti Jeju	150	0.563	(0.400 - 0.758)	3.111	(1.970 - 7.063)	1.727 ± 0.287	0.104 (3)	0.9913	3.63
Werer	150	1.435	(1.137- 1.899)*	4.712	(3.199- 9.103)	2.48 ± 0.371	1.689 (3)	0.639	9.25
Gewane	150	1.171	(0.935- 1.504)*	3.751	(2.643- 6.632)	2.53 ± 0.359	0.865 (3)	0.834	7.55

N= total number of larvae used for probit analysis, LC_{50} = median lethal concentration, LC_{90}= the lethal concentration which killed 90% of the test H. armigera population, 95%CL= the lower and the higher confidence limits at which the LC_{50} and LC_{90} value can fall at 95% probability, SE= standard Error, χ^2 =Chi-square, RR (Resistance Ratio) = LC_{50} of the field population / LC_{50} of Goffa-Sawla population, superscript denoted astric=the collected H. armigera populations were not significantly different (P<0.05) among each other in their susceptibility to deltamethrin insecticide*

Susceptibility of *H. armigera* to Alphacypermethrin

Alphacypermethrin induced 100% *H. armigera* larvae mortality at the indicated rate (1.0 x 10^{-3}g.i/mL) on Werer, Merti Jeju, and Gewane populations. Subsequent insecticide dilutions resulted in reduced percent mortality of larvae (Table 7). Goffa-Sawla population was significantly different (P <0.05) from Werer, Merti Jeju, and Gewane populations with non-overlapping 95% CL (Table 8). There was only a 1.6-fold difference in tested populations on the basis of $LC_{50.}$ These showed that the pest has responded to narrow variability in different geographical locations; there have been no control failures, given the reduction in the use of insecticides in sampled areas. Alphacypermethrin is a new insecticide that was registered for controlling this pest (BASF Chemical Company, 2014). A similar result reported by Ishtiaq *et al.* (2012) mentioned that the reduced use of insecticides in controlling pests results in a low level of resistance. The result contradicts, Ahmad *et al.*(1998) reported there was a chronological increase of *H. armigera* insecticide resistance to alpha-cypermethrin due to subjection to continuous high selection pressure.

Table 7. Percentage mortality of different *H. armigera* larvae populations (N=30) in different concentrations of alphacypermethrin 100G/L.

Larva immersion					**Squared dip**				
Concentration (μL/mL)	Percent mortality				Concentration (μL/mL)	Percent mortality			
	Gofa Sawla	Merti Jeju	Werer	Gewane		Gofa Sawla	Merti Jeju	Werer	Gewane
1.5	100	100	100	100	1.5	100	100	100	100
0.75	100	100	96.7	100	0.75	100	93.3	96.7	90.0
0.375	100	90.0	83.3	83.3	0.375	100	80.0	83.3	76.7
0.1875	90.0	73.3	73.3	63.3	0.1875	86.7	76.7	66.7	56.7
0.09375	76.7	60.0	53.3	46.7	0.09375	70.0	60,0	53.3	43.3
0.046875	56.7	43.3	40.0	30.0	0.046875	53.3	36.7	36.7	26.7
0.0234375	26.7	16.7	16.7	10.0	0.0234375	23.3	16.7	16.7	10,0
Control	0	0	6.7	6.7	Control	10.0	0	3.3	6.7

Table 8. Comparative toxicity of alphacypermethrin 100G/L to different *H. armigera* populations

Larva immersion									
			95% CL		95%CL	The fit of probit analysis			
Location	N	LC$_{50}$ µL/mL	(lower-upper)	LC$_{90}$ µL/mL	(lower-upper)	Slope ± SE	χ^{2} (df)	P	RR
Gofa-Sawla	180	0.043	(0.031 - 0.055)	0.157	(0.114- 0.265)	2.28 ± 0.366	0.992 (3)	0.803	_
Merti Jeju	180	0.070	(0.051- 0.091)*	0.335	(0.232 - 0.591)	1.88 ± 0.261	2.039 (4)	0.729	1.62
Werer	180	0.080	(0.057 - 0.107)*	0.471	(0.310 - 0.922)	1.66 ± 0.236	0.978 (4)	0.913	1.86
Gewane	180	0.083	(0.078 - 0.133)*	0.459	(0.318 - 0.806)	1.97 ± 0.256	2.62 (4)	0.620	1.93
Squared dip									
			95% CL		95%CL	The fit of probit analysis			RR
Location	N	LC$_{50}$ µL/mL	(lower-upper)	LC$_{90}$ µL/mL	(lower-upper)	Slope ± SE	χ^{2} (df)	P	
Gofa-Sawla	180	0.049	(0.036 - 0.063)	0.186	(0.134 - 0.320)	2.21 ± 0.347	1.666 (3)	0.664	_
Merti Jeju	180	0.079	(0.055 -0.107)*	0.528	(0.338- 1.096)	1.55± 0.228	1.648 (4)	0.8001	1.62
Werer	180	0.086	(0.062 -0.115)*	0.516	(0.336-1.029)	1.65 ± 0.234	0.977 (4)	0.9133	1.76
Gewane	180	0.095	(0.100- 0.185)*	0.852	(0.527- 1.871)	1.61± 0.226	0.743 (4)	0.9459	1.94

N= total number of larvae used for probit analysis, LC$_{50}$ = median lethal concentration, LC$_{90}$= the lethal concentration which killed 90% of the test H. armigera population, 95%CL= the lower and the higher confidence limits at which the LC$_{50}$ and LC$_{90}$ value can fall at 95% probability, SE= standard Error, χ^{2} =Chi-square, RR (Resistance Ratio) = LC$_{50}$ of the field population/LC$_{50}$ of Goffa-Sawla population, superscript denoted astric=the collected H. armigera populations were not significantly different (P <0.05) among each other in their susceptibility to alphacypermethrin insecticide*

Cross Resistance Pattern

Any insecticide's effectiveness could be hampered by the possible issue of cross-resistance. According to the current study, the three pyrethroid insecticides log LC_{50} were compared pair-wise correlation across common populations, and the results revealed non-significant ($P< 0.05$) positive correlations present among the insecticides (Table 9). Thus each insecticide could have a cross-resistance to each other. This resistance development might be due to the over-dependence of farmers on a similar group of insecticides in the study areas. Scholars at different times reported that insecticides could have a cross-resistance to chemicals belonging to the same group and from different groups (Honnkaerappa and Udikeri, 2018, 2022; Ishtiaq *et al*., 2012; Ramasubramanian and Regupathy, 2004; Saddiq, *et al*., 2015; Sene *et al*., 2020; Tong *et al*., 2013).

Table 9. Pairwise correlation coefficient comparisons of log LC_{50} values *Helicoverpa armigera* for different insecticides

Larva immersion			
Insecticides*	Lambda-cyhalothrin	Deltamethrin	Alphacypermethrin
Lambda-cyhalothrin	1.00		
Deltamethrin	0.63^{ns}	1.00	
Alphacypermethrin	0.80^{ns}	0.93^{ns}	1.00
Square dip method			
Lambda-cyhalothrin	1.00		
Deltamethrin	0.80^{ns}	1.00	
Alphacypermethrin	0.90^{ns}	0.86^{ns}	1.00

Superscript ns correlation is non-significant at the 0.05 level

Conclusion

Results from this study revealed high levels of pyrethroid resistance in several populations of *H. armigera* in Werer and Gewane locations. An increasing resistance pattern was observed as we moved from the Gofa-Sawla to the Gewane areas. A resistance contrast was also recorded between populations of *H. armigera* from cotton and chickpea fields. The current bioassay test showed low efficacy and the development of a low level of resistance in the *H. armigera* population to lambda-cyhalothrin in Werer and Gewane locations. The efficacy of deltamethrin also turned into a reasonable decrease with very high percentages of survival at dose-response and resistance levels in the Gewane and Werer *H. armigera* populations in comparison to lambda-cyhalothrin. This indicated that *H. armigera* may have developed resistance to deltamethrin and is exceedingly unlikely to be successful in eliminating this pest. Alphacypermethrin insecticide may be used for the resistance management program but careful selection of insecticide is crucial due to the presence of cross-resistance. For the development of more tailored, cost-effective, and sustainable IPM strategies against this highly polyphagous pest, further investigation is needed to assess the insecticide resistance profiles of *H. armigera* to other insecticides.

Acknowledgments

The authors acknowledge the Ethiopian Institute of Agricultural Research for providing research facilities and financial support for the study.

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Ethiop. J. Agric. Sci. 32(4) 73-87 (2022)

Growth Performance and Carcass Characteristics of Tigray Highland Lambs Fed Grass Hay and Supplemented with Different Levels of Lablab (*Lablab Purpureus*) Hay in Northern Ethiopia

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Abstract

The study was conducted for ninety days of feeding trial using forty-eight male lambs aged 8-9 months with average body weight of 18.33 ± 0.04 kg with the objectives to evaluate the effect of supplementation of different levels of Lablab purpureus *hay on body weight gain and carcass characteristics of Tigray Highland Lambs. The experiment was arranged in four blocks with twelve replicates and four treatments in a randomized complete block design. The treatments were ad libitum feeding of grass hay with no supplement of lablab (T1, control), grass hay supplemented with 1.0 % of BW of lablab (T2), grass hay supplemented with 1.5 % of BW of lablab (T3) and grass hay supplemented with 2.0 % of BW of lablab (T4)* Lablab purpureus *hay on dry matter basis. Supplementation increased (P<0.01) total DM intake (*gday^{-1}*) with values for T1 (781.6), T2 (843.6), T3 (916.9) and T4 (919.7). Daily weight gain, final BW,* slaughter weight*, empty BW, hot carcass weight, dressing percent and* rib-eye muscle area *were higher (P<0.01) in the supplemented treatments. Sheep on the T3 supplementation had significantly (P<0.05) heavier* total edible offal*, whereas those on grass hay alone (T1) exhibited heavier (P<0.05)* total nonedible offal*. It was concluded that supplementation of Tigray Highland Lambs with different levels of* Lablab purpureus *hay promoted BW gain, favors carcass characteristics, dressing percentage and increased the proportion of edible offal. The use of lablab hay in the diets of Tigray Highland Lambs would benefit smallholder farmers to utilize this legume crop and reduce the cost of purchasing expensive commercial and agro-industrial by-products of Crude Protein sources.*

Keywords: Carcass characteristics; Tigray highland sheep; Grass hay; Lablab purpureus hay; Weight gain;

Introduction

Sheep and goats are widely reared in crop–livestock farming systems and are distributed across different agro ecological zones of Ethiopia. Although diverse sheep and goat resources are found in the country, their productivity is low partially because of inadequate year-round nutrition, in terms of both quantity and quality. The major feed resources in the country are natural pasture and crop residues (CSA, 2021). They are generally low in nitrogen, energy, vitamins, and minerals; consequently, affecting microbial growth and fermentation in the rumen, resulting in low feed intake and digestibility that lead to decline in growth rates of animals and delay the attainment of slaughter weights and adversely affect meat/mutton yield and quality (Muchenje et al., 2008 cited by Mekonnen et al., 2016).

A sustainable way of improving the feeding value of poor-quality crop residues and pastures, especially for resource poor smallholders, is through inclusion of forage legumes in the ration of animals. According to Gezahagn et al., (2014), most herbaceous legumes have crude protein content which is usually required to support lactation and growth (greater than 15%), suggesting the adequacy of herbaceous legumes to supplement basal diets of predominantly low-quality pastures and crop residues. Forage legumes can be grazed, harvested, and fed fresh or stored as hay or silage (Harricharan et al., 1988). According to Andrea and Pablo (1999), *Lablab purpureus* combines a great number of qualities that can be used successfully under various conditions. Its first advantage is its adaptability, not only is it drought resistant, but it is also able to grow in a diverse range of environmental conditions worldwide. Staying green during the dry season, it has been known to provide up to six tonnes of dry matter/ha. Being palatable to livestock, it is an adequate source of much needed protein and can be utilized in several different ways. It can be grazed in a pasture setting or as a companion crop to maize or cut as hay. *Lablab purpureus* can be used advantageously as a cover crop for mulching. Its dense green cover during the dry season protects the soil against the action of the sun's rays and decreases erosion by wind or rain. As green manure, it provides organic matter, minerals and fixes nitrogen into the soil thereby improving crop yields in an economic and environmentally friendly manner.

Supplementing animals with commercial protein supplements, agro-industrial by-products such as different oil seed cakes from edible oil, brans and milling industries are practiced in the country. However, they are inaccessible and if any too expensive for the smallholder farmers of the rural and peri-urban areas of the country. Production and feeding of herbaceous legumes through intercropping with food crops were encouraged by extension agents to improve the nutrient supply to livestock (Solomon, 2001). The present study was, therefore, conducted with the objective of investigating the effect of supplementing a basal diet of grass hay with protein rich herbaceous legume specie (*Lablab purpureus*) on growth performances and carcass characteristics of Tigray Highland Lambs.

Materials and Methods

Description of the study area

The study was conducted at Abergelle International Livestock Development PLC center, located 25 kms north of Alamata District, Ethiopia (altitude 1529 m above sea level, latitude 12°32’58’’N, longitude 39°38’34’’E), 625 km north of Addis Ababa and about 155 km south of the Tigray Regional capital city, Mekelle. Average maximum and minimum temperature were 23.9 °C and 14.1°C, respectively. Average annual rainfall ranges from 600 to 800 mm which is highly variable from year to year and erratic in nature.

Feeds preparation and feeding

The experimental feeds were composed of natural grass dominated by *Cynodon dactylon* hay as a basal diet and herbaceous legume forage *Lablab purpureus* hay as a supplement. The grass hay was harvested manually at the end of the rain season (1st week of September) at a stage of maturity with high leaf to stem ratio. To prevent bleaching that may happen during drying, the harvested grass was turned up frequently and dried for two days. Then grass hay was transported to the experimental site, chopped manually into small pieces of about 5-7 cm, further air dried under shade and stored separately till the feeding trial started.

Lablab purpureus seeds were collected from forage seed multiplication reserves in the Bureau of Agriculture of Southern Zone of Tigray. Seeds were sown at the recommended rate of 18-20 kg/ha for pure stand (Alemayehu, 1997) at the fattening center’s forage production field. Hand weeding was continued until the forage reach for harvest in September 2019 Rain fed *Lablab purpureus* growth was monitored until the 20–30% blooming stage (Berhane and Eik, 2006) and hand-cut during the first week of September 2019. Manual chopping was done to 5-7 cm length and the chopped material was air dried under shade then stored in a dry place until use for feeding. The supplement hay is expected to contain CP to meet the minimum recommendation for intensive feeding (i.e., 14% CP), according to NRC (2007). Individual feed troughs were used to offer the feeds. Grass hay was provided to all animals *ad libitum* at a rate of 20% refusal as a basal diet. The daily legume hay supplement was offered once a day at 1600 pm. Feed offered and refused was weighed and recorded daily. Common salt blocks and water were available to the animals all the time throughout the experimental period.

Animals and their management

Forty-eight male lambs aged 8-9 months with initial body weight (BW) of 18.33 ± 0.04 kg (mean ± S.D.) were purchased from surrounding village farmers by asking the owners about their lambs’ age and checking the dentition of each lamb. The sheep were held in quarantine for 21 days and observed for any health problem. During this time, a plastic ear tag identification number was applied for each sheep, vaccinated against bovine pasteruolosis, anthrax and sheep pox. Animals were also treated against internal and external parasites using anti-helminths (Albendazole) and acaricides (Steladon) as per the recommended dosage. The animals were placed in individual pens equipped with a drinking bucket and a feeding trough in a well-ventilated concrete floor experimental barn.

Experimental design and treatments

A randomized complete block design consisting of four treatments and four blocks was used for the study. Sheep were blocked according to their initial body weight (BW) and randomly allocated to different levels of *Lablab purpureus* hay supplement, namely 0% BW (Control, Treatment 1), 1.0% BW (Treatment 2), 1.5% BW (Treatment 3) and 2.0% BW (Treatment 4). These levels were chosen to accommodate the inclusion rates of forage legumes suggested by Devendra (1988) and adjusted based on weighing of animals every 10 days intervals. All animals were fed in individual pens and *Lablab purpureus* hay was provided every evening at 16:00 hr separately for each pen. Common salt blocks and water were available at free access to the animals throughout the experimental period.

Data collection and analysis

Feeding trial

After an acclimatization period of 14 days to the experimental diets and pens, the feeding trial was conducted for 90 days. The daily feed offered, and refusals were weighed and recorded for each sheep. Daily dry matter and nutrient intake were calculated as the difference between the feed offered and refused. Samples of feed offered were collected per batch while samples of refusal were taken from each sheep daily and pooled per animal over the experimental period and stored in plastic bags. Sub-samples of feed offered, and refusals were taken after thorough mixing for determination of nutrient composition, and the sub-samples taken were dried at 60^{o}C for 72 hours in a forced draft oven to make it ready for grinding and chemical analysis.

Body weight change and feed conversion efficiency

Body weight of the animals was taken at the beginning of the feeding trial and every 10 days interval during the 90 days of feeding. All animals were weighed in the morning hours before feed provision using weighing balance with a sensitivity of 100 grams. Average daily body weight gain was calculated as the difference between final live weight and initial live weight divided by the number of feeding days. Feed conversion efficiency was determined by dividing the daily average body weight gain (ADG) by daily total DM intake of the animal.

$$\text{Average daily body weight gain} = \frac{\text{Final body weight} - \text{Initial body weight}}{\text{Number of feeding days}}$$

$$\text{Feed conversion efficiency} = \frac{\text{Average daily body weight gain in gram}}{\text{Daily dry matter intake in gram}}$$

Digestibility trial

Following the feeding trial, digestibility trial was conducted and four sheep from each treatment were harnessed with a fecal collection bag to collect feces for determination of digestibility. The sheep were accustomed to the fecal collection bags for three days. This was followed by collection of feces for seven consecutive days. During this period, feed offered and refused were recorded and samples of feed offered were pooled per treatment, while samples of feed refused were pooled per animal. Fresh feces were collected into a fecal collection bag fitted to the animal. The total fecal output was collected by emptying the bag twice per day at 6:00 AM and 6:00 PM per animal were weighed and recorded for each sheep throughout the digestibility trial. The feces were weighed fresh, thoroughly mixed and 20% of the total feces samples (224 samples) were sub sampled for each sheep and stored in a deep freezer at -18°C. The samples were pooled per animal across the collection period and 20% of the composite sample was taken, weighed and partially dried at 60°C for 72 hours. The partially dried fecal samples were milled by Wiley mill to pass through a 1mm sieve and stored in airtight polyethylene bags pending chemical analysis. Apparent digestibility of DM and other nutrients were determined as a percentage of the nutrient intake not recovered in the feces using the formula (McDonald et al., 2010).

$$\text{Percent of apparent digestibility} = \frac{(\text{Nutrient intake} - \text{Nutrient in feces})}{\text{Nutrient intake}} \text{ X } 100$$

Bodyweight change measurement

The bodyweight was measured using a suspended or hanging scale, which had 50 kg weighing capacity, with 100 g of calibration or sensitivity. Lambs were weighed at the beginning of the experiment and subsequently every 10-days interval in the morning hours after overnight fasting of feed and water to avoid residual feed effect from previous day. Daily body weight gain was calculated as the difference between final and initial live weight divided by the number of feeding days. Similarly, feed conversion efficiency (FCE) was computed as a proportion of daily body weight gain to daily feed intake.

Chemical Analysis

Samples of feed offered refusals and feces were ground to pass through a 1 mm sieve mesh. Analysis for DM, ash and N contents was done according to AOAC (2005) procedures. Total nitrogen (N) content was determined by using Kjeldahl method and crude protein (CP) was calculated as N*6.25. Neutral detergent fiber

(NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined by using the procedures of Van Soest and Robertson (1985). The energy value of the treatment feeds was estimated according to McDonald et al. (2010) as metabolizable energy (ME, MJ/Kg DM) = 0.016 x DOMD, where DOMD (g) indicates digestible organic matter per kilogram of dry matter.

Carcass and non-carcass parameters

At the end of the feeding and digestibility trials, all lambs were transported to Abergelle International Export Abattoir for slaughter. The lambs arrived at the slaughterhouse two days before slaughter to allow for muscle glycogen to be replenished by the body as much as possible. Sheep were fasted overnight, then weighed and slaughtered for carcass evaluation. The weights of the edible and non-edible components of the carcass were measured and recorded for each sheep. The empty BW was calculated by subtracting the weight of the alimentary tract contents from the slaughter weight. The cross-section of the rib-eye muscle was traced on transparency paper between the 11th and 12th ribs (Galal et al., 1979) of the left half side of the carcass after freezing, and the area was measured using a planimeter. The rib-eye area was taken as the mean of the two sides of the ribs. In the present study, heart, liver, kidney, empty gut, kidney knob and channel fat, omental fat and tongue were considered as edible offal. Blood, gut content, spleen and pancreas, testicles and penis, skin, feet, gall bladder and urinary bladder were categorized as non-edible offal.

Dressing percentages on slaughter weight basis $= \frac{\text{Hot carcass weight}}{\text{slaughter weight}} \ast 100$

Dressing percentages on empty body weight basis $= \frac{\text{Hot carcass weight}}{\text{empty body weight}} \ast 100$

2.5.7 Statistical Analysis

The statistical model used for analysis of data on feed intake, BW change and apparent digestibility coefficient was:

$$Y_{ij} = \mu + T_i + B_j + e_{ij}$$

where Y_{ij} is the individual weight, μ the overall mean, T_i the effect of the i^{th} level of *Lablab purpureus* hay supplement (i = 1–4), B_j the effect of j^{th} block (j = 1–4) and e_{ij} is the residual.

Data on carcass parameters was analyzed using the statistical model:

$$Y_{ij} = \mu + T_i + e_{ij}$$

where Y_{ij} is the response variable, μ is the overall mean, T_i the effect of the i^{th} level of *Lablab purpureus* hay supplement (i = 1–4), and eij is the random error

The data collected were subjected to one-way analysis of variance (ANOVA) using STATA (2022) Version 16. When significant, pairwise comparison among the treatment groups was employed by the Bonferroni method.

Results and discussion

Chemical composition of experimental and refused feeds

Chemical composition of the experimental diets used in the experiment is indicated in Table 1.

Table 1. Chemical composition of experimental and refused feeds on DM basis.

Experimental feeds	DM%	Nutrient composition (DM%)						
		CP	OM	Ash	NDF	ADF	ADL	DOMD
Grass hay	91.20	10.15	88.53	11.47	68.56	44.25	5.78	51.36
Lablab purpureus hay	89.21	19.94	91.36	08.64	45.86	37.65	7.24	70.12
Hay refusal								
T1	91.79	7.84	92.87	7.13	70.21	52.42	8.36	39.76
T2	90.03	09.23	89.54	10.46	48.56	39.12	8.95	29.41
T3	89.97	11.12	89.32	10.68	47.63	38.89	8.47	28.93
T4	89.95	11.53	89.12	10.88	46.23	38.42	8.25	28.36

DM=dry matter, CP=crude protein, OM=organic matter NDF=neutral detergent fiber, ADF=acid detergent fiber, ADL=acid detergent lignin, DOMD=digestible organic matter in dry matter

The grass hay DM content in the current study was 91.2% which was higher than the values 90.5% and 90.9% reported by Mamo et al. (2021) and Challa (2020), respectively and disagrees with the higher values (ranging from 92.3 to 93.7%) reported by authors (Mekonnen, 2017 and Abuye et al., 2018). On the other hand, OM content of the grass hay was higher than the 87.8% reported by Challa (2020) and lower than the 91.6% reported by Abuye et al., (2018) and the 90.5% reported by Diriba et al., (2013). The NDF, ADF and ADL values 68.56%, 44.25% and 5.78%, respectively, reported in the current study were higher than the values 52.82%, 37.59%, 6.71% reported by Abuye et al., (2018) and lower than the values 72.4%, 44.5%, 8.3% reported by Challa (2020). This could be attributed to the stage of maturity of the natural grass during cutting for hay where grass hay cut at 20 – 30% flowering stage is expected to have less DM% and higher OM% with lower ADF and ADL content than over-matured grass hay. Even though the CP content of the basal feed, grass hay was lower than the other treatment diets as expected, its CP content was higher than the lower limit of 7% CP required for optimum rumen function (Van Soest, 1994). As a result, the natural pasture diet (T1) can be considered as adequate for maintenance requirement of animals in terms of its CP content. As reported by Topps (1995), when the CP content of roughages is below 7%, there will be impaired rumen function resulting in poor digestion of feeds, low DM intake and poor animal performance. The 10.15% CP content of grass hay used in this study was higher from the range 7.07% - 8.49% reported by Tusa et al., (2021), Challa (2020) and Mamo et al., (2021). This could be attributed to the stage of maturity of the natural grass during cutting and the drying technique followed to keep the green color expected to have high CP%.

The DM, NDF, ADF and ADL contents of *Lablab purpureus* hay (91.20, 70.56, 47.25 and 05.98%, respectively), reported by Diriba et al., (2013) were higher than values obtained for the same nutrients in the current study. Values obtained in the current study were also lower than values reported by Mekonnen (2017) for the same nutrients. In terms of chemical constituents, herbaceous legumes are primarily characterized by high N content. Crude protein content of herbaceous legumes under local conditions varied from 15% in trifolium to 26% in vicia with a mean of about 19% (Seyoum, 1995). The CP content of *Lablab purpureus* hay used in this study was comparable to the value19.23% reported by Hunegnaw and Berhan (2016), 19.93% reported by Abuye et al., (2018) and lower than the 21.0% and 25.1% reported by Challa (2020) and Diriba et al. (2013), respectively. The NDF, ADF and ADL contents of the refusals were higher than the corresponding contents of feeds offered, whereas the CP contents of the refusals were lower than the corresponding contents of feeds offered. This could be explained as animals selectively eat the nutritious parts of the feed preferring leaves and twigs than the stem parts. The high ADL content in the refusals could be attributed to refusals mainly constituted the stem part of the feed, which indicates that the lignin must have been mainly contained in the stem than the leaves and twigs.

The higher DOMD obtained from the two feed staffs may be attributed to their lower NDF and ADF concentrations. The relatively higher percentage of CP and intermediate fiber fraction content of the grass hay may have occurred from the optimal stage of harvesting and proper drying timing. As plants mature, the cell wall constituent increases and therefore, the structural carbohydrates such as cellulose and lignin increase, and the percentage of the CP normally decreases (McDonald, 2002). Longer periods of exposure of the harvested grass to sunshine causes bleaching which causes the green color of the grass to disappear and consequently the CP content of the hay decreases.

Dry Matter and Nutrient Intake

Average daily dry matter and nutrient intake of Tigray Highland Lambs fed grass hay alone or supplemented with graded levels of *Lablab purpureus* hay is given in Table 2.

Table 2: Average daily dry matter and nutrient intake of Tigray Highland Lambs fed grass hay alone or supplemented with graded levels of *Lablab purpureus* hay

Parameters	Treatments				SEM	SL
	T1	T2	T3	T4		
Dry matter intake (g day^{-1})						
Grass hay DM	781.6^{a}	667.2^{b}	648.7^{c}	637.4^{c}	3.00	*
Supplement DM	0	176.4^{c}	268.2^{b}	282.3^{a}	2.94	*
Total DM	781.6^{c}	843.6^{b}	916.9^{ab}	919.7^{a}	2.88	**
Total DM (g/kg BW)	43.4^{c}	46.9^{b}	50.9^{ab}	51.1^{a}	0.16	**
Total nutrient intake						
CP (g day^{-1})	58.5^{c}	63.5^{b}	69.5^{ab}	70.2^{a}	0.24	*
OM (g day^{-1})	384.7^{d}	416.7^{c}	458.0^{b}	464.4^{a}	1.66	*
NDF (g day^{-1})	250.1^{d}	280.4^{c}	319.1^{b}	334.1^{a}	1.75	*
ADF (g day^{-1})	151.0^{d}	181.0^{c}	217.7^{b}	239.1^{a}	1.84	*
Digestible (D) nutrient intake (g day^{-1})						
DDM	430.9^{d}	499.9^{c}	541.4^{b}	551.1^{a}	2.50	*
DCP	37.3^{c}	41.2^{b}	44.5^{ab}	43.8^{a}	0.14	*
DOM	226.4^{d}	259.8^{c}	282.4^{b}	290.1^{a}	1.33	*
DNDF	120.4^{d}	154.2^{c}	171.8^{b}	187.7^{a}	1.40	*
DADF	77.3^{d}	93.0^{c}	109.3^{b}	124.9^{a}	0.99	*

^{a,b,c,d} Means within a row with different superscripts differ significantly (P < 0.05); * = (P < 0.05); (P < 0.01); ** = (P < 0.01); SEM=standard error of means; SL=significance level; ns=non-significant; DM=dry matter; BW=body weight; OM=organic matter; CP=crude protein; NDF=neutral detergent fiber; ADF=acid detergent fiber; ADL=acid detergent lignin; ME=metabolizable energy; GH=grass hay; LP=Lablab purporeus; T1=control (grass hay) T2=T1+ 1.0%BW LP hay; T3=T1+ 1.5%BW LP hay; T4=T1+ 2.0%BW LP hay;

Significant (P< 0.05) differences were observed among treatments in the mean daily DM and nutrient intakes. The mean total DM and total DM (g/kg BW) intake of the control group (T1) was significantly (P>05) lower than the treatment groups supplemented with different levels of the *Lablab purpureus* hay. Dietary protein supplementation is known to improve intake by increasing the supply of nitrogen to the rumen microbes. This has a positive effect on increasing rumen microbial population and efficiency, thus enabling them to increase the rate of breakdown of the digesta. When the rate of breakdown of digesta increases, feed intake is accordingly increased (Van Soest, 1994). In the current study a significant (P>0.05) difference in CP intake between T1 and the supplemented group T2, T3, and T4 was observed. Total NDF and ADF intake was lower (P>0.05) for T1 than the supplemented groups. This might be associated with the availability of CP in the diets that lambs offered feed having low CP content (T1) consumed relatively low DM due to the longer retained digesta in the rumen causing longer period of gut fill as explained by (Van Soest, 1994).

In a study on Arsi-Bale sheep fed Desho grass hay and supplemented with 150, 300 and 450 grams of *Vicia villosa* legume, daily DM intake and daily body weight gain of experimental sheep showed significant ($P < 0.05$) improvement with increased level of inclusion into the basal ration (Mergia et al., 2021). Supplementation also showed a positive effect on growth performance and carcass characteristics which agreed with the current study.

Body weight change and feed conversion efficiency

Growth performance parameters of lambs fed on grass hay supplemented with graded levels of *Lablab purporeus* hay are presented in Table 3.

Table 3. Growth performance parameters of lambs fed on grass hay supplemented with graded levels of *Lablab purporeus* hay.

Growth performance parameters	Treatments				SEM	SL
	T1	T2	T3	T4		
Initial body weight (kg)	18.3	18.3	18.4	18.4	0.00	ns
Final body weight (kg)	22.8^{d}	23.4^{c}	24.8^{b}	25.3^{a}	0.05	*
Body weight change (kg)	4.4^{d}	5.1^{c}	6.5^{b}	6.9^{a}	0.05	**
Average daily weight gain (g/day)	49.3^{d}	56.8^{c}	71.9^{b}	77.0^{a}	0.58	**
Feed conversion efficiency (g gain/g fed)	0.063^{b}	0.067^{b}	0.078^{a}	0.084^{a}	0.00	*

^{a,b,c,d} *Means within a row with different superscripts differ significantly (P < 0.05); * = (P < 0.05); (P < 0.01); ** = (P < 0.01); SEM=standard error of means; SL=significance level; ns=non-significant; T1=control (grass hay) T2=T1+ 1.0%BW LP hay; T3=T1+ 1.5%BW LP hay; T4=T1+ 2.0%BW LP hay.*

The average daily gain and feed efficiency were linearly increased (*P* < 0.01) with increasing levels of *Lablab purpureus* hay supplementation. The final body weight of lambs in the control group T1 with value 22.4 kg was lower than the supplemented group T4 which recorded the highest value (25.3 kg) followed by T3 and T2 with values 24.8 and 23.4 kg, respectively. The ADG of lambs increased with the increase in crude protein contained in the experimental forage legumes hay. In the current study, grass hay supplemented with increased levels of legume hay inclusion showed increased daily DM intake and daily body weight gain of lambs. The higher final body weight and ADG of lambs supplemented with *Lablab purporeus* hay in T4 could be attributed to the higher CP content that may favor better intake and digestibility of the basal feed. This agreed with the work of Jalel (2020) who reported natural pasture hay supplemented with wild silver leaf desmodium at levels of 200, 300, 400 g/head/day on dry matter basis improved body weight of sheep and correspondingly increased the net income from the sale of sheep at the end of the feeding trial and concluded supplementation of wild silver leaf desmodium to natural grass hay at 400 g appears to be the best level for Horro sheep in growth and daily body gain.

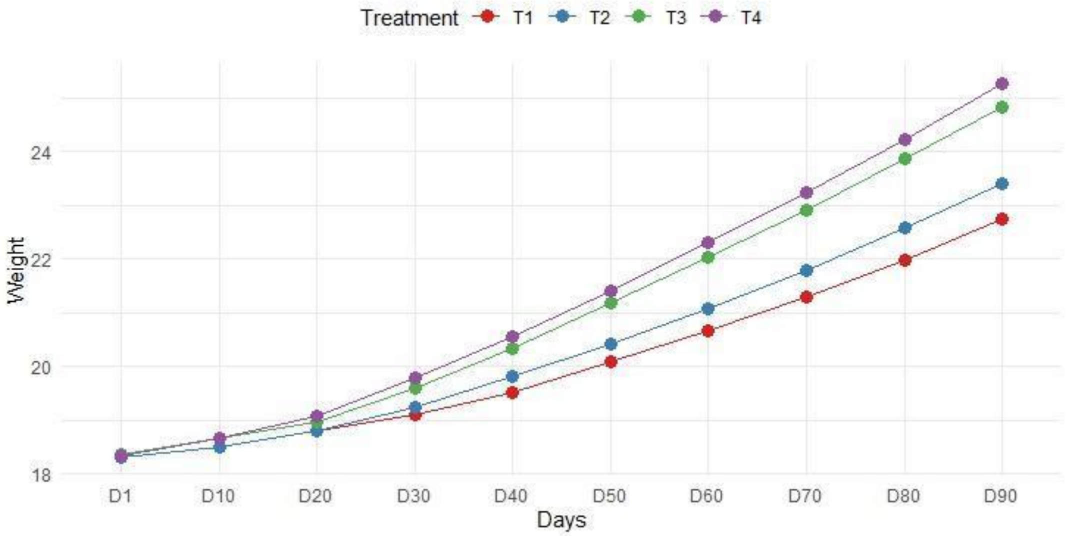

Figure 1. Growth curve of lambs fed on grass hay supplemented with graded levels of *Lablab purporeus* hay

Carcass parameters

Carcass characteristics of the Tigray Highland Lambs fed grass hay supplemented with graded levels of *Lablab purporeus* hay were assessed and results for slaughter weight, empty body weight, hot carcass weight, dressing percentage, forequarter, hind quarter, rib-eye muscle area and edible and non-edible offal components are indicated in Table 4.

Table 4. Carcass characteristics of lambs fed on grass hay supplemented with graded levels of *Lablab purporeus* hay

BW parameters	Treatments					
	T1	T2	T3	T4	SEM	SL
Slaughter weight (kg)	22.8^{d}	23.4^{c}	24.8^{b}	25.3^{a}	0.05	**
Empty body weight (kg)	18.5^{cd}	19.0^{ac}	20.6^{a}	20.4^{ab}	0.04	*
Hot carcass weight (kg)	7.8^{bc}	7.9^{b}	9.5^{ab}	10.0^{a}	0.05	**
Dressing percentage						
Slaughter weight base	34.2^{cd}	33.8^{cd}	38.3^{ab}	39.5^{a}	0.11	**
Empty body weight base	42.2^{c}	41.6^{cd}	46.1^{b}	49.0^{a}	0.14	**
Forequarter (kg)	3.9^{d}	4.4^{c}	5.0^{ab}	5.3^{a}	0.03	*
Hind quarter (kg)	3.5^{d}	4.0^{c}	4.7^{a}	4.6^{ab}	0.02	*
Rib-eye muscle area (cm^2)	6.4^{cd}	7.0^{bc}	7.6^{ab}	9.0^{a}	0.05	**
Total edible offal (kg)	4.2^{dc}	4.5^{bc}	5.0^{a}	4.8^{ab}	0.01	*
Total nonedible offal (kg)	9.1^{a}	8.4^{b}	8.2^{bc}	7.9^{dc}	0.03	*

$^{a,b.c.d}$ *Means within a row with different superscripts differ significantly ($P < 0.05$); * = ($P < 0.05$); ($P < 0.01$); ** = ($P < 0.01$) SEM=standard error of means; SL=significance level; BW: body weight; SW: slaughter weight; T1=control (grass hay) T2=T1+ 1.0%BW LP hay; T3=T1+ 1.5%BW LP hay; T4=T1+ 2.0%BW LP hay; TEO: total edible offal; TNEO: total non-edible offal.*

The offal components were categorized into edible (head with tongue, heart, kidney, liver with bile, empty gut, tail and fat from kidney, omentum and heart) and non-edible (skin and legs, penis, testis, lung with trachea, esophagus, spleen, bladder and gut contents) based on the eating habit of the people living around the area where the experiment was conducted.

There were significant (P<0.01) differences in slaughter weight between the control group (T1) and the supplemented groups (T2, T3 and T4). Significant (P<05) differences in empty body weight between T3 and T1 was observed with minor differences between the supplemented groups. Hot carcass weight was significantly (p<0.01) higher for T4 than T1 with an increasing value from T1 to T2 and T3. Significantly (p<0.01) higher rib eye muscle area differences were observed between T4, and T1 where T3 and T2 showed a slight increase than T1. Rib-eye muscle area is mostly used as a tool to indicate the proportion of carcass muscling (Wolf et al., 1980). Greater rib-eye muscle area is associated with a higher production of lean in the carcass and higher lean-to bone ratio. In the present study, lambs assigned to the T4 diet showed significantly (P<0.01) higher rib-eye muscle area than the T1 and T2. The current study agrees with (Abuye et al., 2018; Mekonnen et al., 2017) who reported that nitrogen rich leguminous forage had significantly improved slaughter weight, empty body weight, hot carcass weight, and rib-eye muscle area in sheep feeding trials. This study also agreed with the work by Berhan and Asnakew (2015) who reported that the carcass yield of goats as measured by the average values of slaughter weight, empty body weight, hot carcass weight, dressing percentage and rib eye area was superior for concentrate supplemented groups.

Significantly increased total edible offal with increasing level of supplementation for Horro sheep fed natural grass hay and supplemented with Gebisa-17 and Beresa-55 cultivars of *Lablab purpureus* and concentrate mixture was reported by (Abuye et al., 2018). The authors further reported that, total edible offal values ranging from 3.75 to 4.89 Kg which agrees with value obtained in the current study (4.2 to 5.0 Kg). Similarly, comparable total edible offal values ranging from 3.08 to 4.9 Kg for the same breed was reported by (Girma and Mengistu, 2017). A slightly higher than the current study (ranging between 4.2 and 5.0 kg) weight of total edible offal ranged between 4.3 and 5.8 Kg was reported by (Mekonnen et al., 2017) for the Horro sheep breed.

In agreement with the present finding, Hirut (2008) and Michael and Yayneshet (2014) reported negative effect of level of supplementation on the percentage of total non-edible offal in Hararghe and Tigray highland sheep, respectively. The highest value of gut contents weight was recorded for lambs assigned to fed T1 and T2 diet rather than T4. The heaviest gut content of lambs fed T1 and T2 diet might be due to the higher roughage or relatively poor-quality feed used. This was agreed with the views of Van Soest (1994) and Pond et al., (1995) in that non-supplemented animals fill their gut with less digestible roughage, which would retain in the gut for longer time to be degraded by rumen microbes.

Conclusion

The CP content of grass hay was indeed sufficient to meet the maintenance requirement but was relatively low to meet the growth demands of lambs for minimum exportable weight of 25 kg, indicating the need for supplementation of grass hay-based diets with forage legumes such as *Lablab purporeus*. A higher total DM and/or nutrient intake and superior daily body weight gain was recorded in lambs supplemented with *Lablab purporeus* hay. Similarly, slaughter weight, empty body weight, hot carcass weight and dressing percentage on slaughter weight basis and mean rib eye muscle area were all higher in lambs supplemented with *Lablab purporeus* hay. Supplementation resulted in higher body weight gain, carcass yield characteristics, total edible offal components and decreasing trend values for total non-edible offal components in Tigray Highland Lambs fed grass hay. Further studies need be focused on further determination of the level of supplementation of *Lablab purpureus* hay.

Acknowledgements

The author would like to acknowledge Abergelle International Livestock Development PLC for granting access to necessary facilities at the center for this research work. The author also gratefully acknowledges the support of Abergelle International Export Abattoir for access to slaughter facilities and conducted measurements of carcass parameters.

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Ethiop. J. Agric. Sci. 32(4) 88-104 (2022)

Ovum Pick up and *In Vitro* Embryo Production in Boran and Crossbred Dairy Cattle

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Abstract

*This study was conducted to study the potential of Boran (Bos indicus) and Boran * Holstein Friesian Crossbred cows for non-stimulated transvaginal oocyte collections and in vitro embryo production. Follicular aspirations were done using a vacuum pressure pump and Aloka SSD Prosound-2 ultrasound device. 266 aspirations were made in Boran (n=148) and Crossbred (n=118) cattle. The mean number of punctured follicles for combined collections was 7.68 ± 0.4 for both genotypes. The mean number of recovered oocytes for all collections was 2.98 ± 0.2 for both genotypes. The mean number of punctured follicles was 7.27 ± 0.4 and 8.22 ±. 0.44 for Boran and Crossbred cattle, respectively. The mean number of recovered oocytes was 2.65 ± 0.22 and 3.42 ± 0.26 for Boran and Crossbred cattle, respectively. Differences were observed (p<0.05) in the mean number of punctured follicles and recovered oocytes between the genotypes. The oocyte recovery rate for the total puncture sessions were 45.8%. There was no difference between the breeds regarding the number of quality oocytes collected. Higher numbers (p<0.001) of GIII oocytes were collected in all aspirations compared to GI and GII quality oocytes. The maturation rate of Boran and Crossbred cattle oocytes was 51.65% (47/91) and 56.8% (50/88), respectively. Cleavage rate of Boran and Crossbred cattle oocytes was 40.7% (37/91) and 31.8% (28/88), respectively. There was no difference (p>0.05) in maturation and cleavage rate of oocytes between the genotypes. A total of 21.5% (14/65) of cleaved oocytes developed to morula stage embryos from both genotypes. Relatively similar patterns were observed in maturation process and embryo development between Boran and Crossbred cattle oocytes. OPU/IVF procedures could be used in local and crossbred heifers as an alternative breeders technology options in animal breeding programs to best exploit the genetic potential of local and exotic breeds.*

Keywords: Estrus cycle; ovarian follicle; transvaginal ovum pickup; ultrasound.

Introduction

The advent and advancement of reproductive technologies have wide opened research and experimentation avenues to manipulate reproduction both in in-vitro embryo production (IVEP) and multiple ovulation and embryo transfer (MOET) or *in vivo* derived embryo technologies. This has been used to improve reproductive performance in various species of farm animals. Artificial insemination (AI) is the most widely used assisted reproductive technique (ART) in dairy cattle breed improvement programs. Its application brings a wide range of benefits to dairy cattle production compared to natural mating practices (Baruselli *et al.,* 2018a). Artificial insemination and estrus synchronization deployment in dairy cattle breed improvement has a fairly long history in Ethiopia. The country has a huge cattle population and enormous diversity of genetic resources that could be exploited through the application of advanced reproductive technologies OPU/IVEP included. The female individual has an average of 200,000 oocytes by the time of puberty. Although between 20 and 40 follicles are recruited during follicular selection, only a single dominant follicle will eventually ovulate while the rest will be atretic. This most inefficient natural cycle repeats year round if it is not interrupted by pregnancy culminating in less than 10 offspring as life-time productivity at best.

Technology options such as the ultrasound guided trans-vaginal follicular aspiration (TVFA) or ovum pick up (OPU) has opened a great opportunity to best exploit the surplus follicular reserve which otherwise would be wasted. OPU, after it was originally established by Pieterse and his colleagues in 1988; it has become a field of great interest due to its potential commercial application (Pieterse *et al.,* 1988). OPU is the most flexible and repeatable technique to produce embryos from nearly any given live donor including cattle of high genetic value. The application of this technique to juvenile calves can further accelerate genetic gain by substantially decreasing the generation interval. It also suits bovines with genital tract illness or low sensitivity to super ovulatory treatments.

The adoption of these techniques can improve the options for selective breeding and hence hastens genetic gain from superior dams and sires by facilitating dissemination of genetic material and shortening the generation interval and increased desired genetic progress from the dam side (Meuwissen, 1991).

Reproductive physiology of zebu cattle breed is not identical to *Bos taurus* cows, and differences in a number of reproductive characteristics are known to exist (Viana *et al.,* 2000; Viana *et al.,* 2010a). Greater number of growing follicles throughout the estrous cycle in zebu cattle and recovery of more cumulus oocyte complexes (COCs) per ovum pick up (OPU) session compared to *Bos taurus* cattle accounted as considerable deference between the breeds (de Roover *et al.,* 2008).

OPU/IVEP techniques help to boost reproductive efficiency of local zebu breeds and make the best use of advanced reproductive biotechnology tools. Thus, the aim of this study was to evaluate alternative reproductive techniques such as OPU/IVEP and assess the potential of Boran breed for non-stimulated follicular aspirations and *in vitro* embryo production, for dairy cattle genetic improvement and multiplications.

Materials and Methods

Location

Experiments were conducted at Holeta and Debre Zeit Agricultural Research and National Agricultural Biotechnology Research Centers, Ethiopia. Holeta is located 29 km west of the capital city, Addis Ababa, with Longitudes 38º38’ east’ Latitude 09º04’ north and with Altitude of 2,390 meters above sea level. The minimum and maximum temperatures at Holeta are 6.13°C and 22.8°C, respectively. The rainfall pattern is bimodal with short rains from March to May and long rains from June to August. The mean annual rainfall is about 1,243.7 mm with peak rain in August (HARC, 2019). Debre Zeit Agricultural Research Center is located 45 km east of Addis Ababa (8°46′13.57"N, 38°59′50.45"E) at an altitude of 1920 meters above sea level. The average annual temperature is 18.7°C with an average annual rainfall of 757.05 mm (DZARC, 2020). The National Agricultural Biotechnology research center is located in Holeta town and has similar agro ecology with that of HARC.

Experimental Animals

Experimental animals at Holeta (n=12) and Debre Zeit (n=25) Agricultural Research Centers were employed for oocyte aspiration and IVF work. Indigenous Boran (n=20) and Boran * Holstein Friesian (HF) Crossbred (n=17) cows were employed in this study. Animals used in this experiment (heifers n=12 and cows n=25) were less than ten years of age. Breeding and clinical records of all animals were reviewed, and females with reproductive problems were excluded from the study. Cows underwent a thorough reproductive examination prior to the commencement of the study. Animals were allowed to graze on natural pastures. Hay made from straw and grass constituted the major proportion of the roughage supply. Concentrates, composed of wheat by-products or maize; Noug seed cake (*Guizotia abyssinica*) and salt were used as supplementary feed. Water was provided ad-libitum.

Media preparation

The media for oocyte collection, maturation, fertilization and culture were purchased from Mini Tube readymade stock solution for IVEP. The stock solutions were reconstituted for the final working solution. The BO IVEP ready-to-use media was also used for oocyte maturation, fertilization and culture. Tissue culture grade double distilled water purchased from the local market. Distilled water produced at the laboratory was used for non-biological laboratory routines. Media was prepared under a biosafety cabinet, pH was adjusted accordingly and syringe filtered using 0.22µ filter.

Ovum pick up

OPU could be performed routinely twice a week without pre-stimulation and without any detrimental effects on fertility of the donor cows (Galli *et al.*, 2001). The OPU set-up had a real-time B-mode ultrasound system (Aloka SSD Pro-Sound 2, Japan) with a 6.5-MHz convex sector probe transducer (Hitachi Medical Co., Tokyo, Japan) that was used to visualize the ovaries and a needle guide system (Mini-tube, GmbH, Germany). Visible follicles ≥ 2mm in diameter were aspirated using a disposable 1.2x75mm (for cows) hypodermic needle that was connected to a 50ml falcon tube via a silicon Teflon tube through the OPU probe holder to the warm block of the vacuum pressure. The 0.9x70mm hypodermic disposable needle was used for heifers (Mini-tube, Germany). A vacuum pressure pump (Mini-tube, GmbH, Germany) with adjustable aspiration volume, adjusted between 72-80 mmHg to optimize the pressure, was employed for aspiration. The vacuum pressure had a medium warming block temperature (37^{0}C) at a flow rate of 15-20 ml/min, and was used to recover follicular fluid. Oocytes were collected into a phosphate buffer solution (PBS) preparations supplemented with heparin 20µg/ml, 2% FCS, 50µg/ml gentamicin, and 2.4mg/ml HEPES and maintained at 37^{0}C. Each aspirated animal was given 2-3 ml of 2% lidocaine for epidural anesthesia before follicular aspiration procedures.

In vitro oocyte maturation

Prior to *in vitro* maturation, COC's were washed three times in TCM supplemented with 2.4mg/ml HEPES, 10% FCS and 0.1 mg/ml gentamicin sulfate and 10 µg/ml Pluset® FSH+LH. At each collection procedure COCs of each breed were separately cultured for 24hr in 500 µl drops of maturation media supplemented with 10%FCS, 10 µg/ml Pluset® FSH+LH, 0.1mg gentamicin, 2.2mg/ml NaHCO3 in five well embryo culture dishes under mineral oil at 39°C under an atmosphere of 5% carbon dioxide at maximum humidity. The pH of the maturation media was adjusted between 7.2-7.4. Quality oocytes, grade I, II and III were used in the maturation experiment. Denuded grade IV oocytes were discarded from the experiment. After 24hr of incubation oocytes were examined morphologically for cumulus cells expansion, increase in perivitelline space, extrusion of first polar body and change in cytoplasmic color and zona pellucida shape, denoting maturation and readiness for exposure to sperm. Maturation rate was calculated from the total oocyte ready for insemination over total incubated oocyte for maturation.

Semen preparation

Frozen semen was subjectively checked for motility and viability before semen was processed for in vitro fertilization. Straws of semen less than 40% motility were not used in this experiment, So as to not influence the result of fertility rate of oocytes.

Swim up

For swim up semen preparation procedure; 2ml TALP semen capacitation medium added and equilibrated at 5% CO_2 at 39°C for an hour in 15 ml test tube. Two straws of semen were thawed at 35 °C for 30 seconds and added to a 15ml conical tube during every fertilization experiment. The thawed semen was expelled to 2ml semen preparation media in a 15ml conical tube. The semen centrifuged at 200g for 5 minutes and 1ml of the supernatant discarded. 250µl sperm suspensions added to four 2ml test tubes containing 1ml sperm preparation media (TALP) and the test tubes placed in 39°C incubator at 5% CO_2 for an hour. The supernatant (800ul) from each test tube taken and the combined samples were centrifuged at 100g for 5 min. 500µl of the supernatant was discarded from the final sample. Sperm concentration was checked using a hemocytometer and a microscope (40 X magnifications).

Percoll density gradient centrifugation

Percoll 90% was prepared by adding 1 volume of sperm-TALP medium as a diluent to 9 volumes of Percoll (1:9 v/v) and Percoll 45% was prepared by adding 1 volume of Percoll 90% to 1 volume of sperm-TALP medium (1:1 v/v) (Garcia-Herreros *et al.,* 2010).

Two straws (0.5 ml) of frozen bull semen were thawed at 35°C for 30 second and gently layered over the two layers of Percoll 45% and Percoll 90% into a 15 ml conical centrifuge tube. The sperm sample was centrifuged for 10 min at 800g at room temperature. The supernatant was discarded by aspiration. The re-suspended pellet washed and centrifuged at 200g for 5 minute at room temperature. Recovered spermatozoa were re-suspended with 0.5 ml of sperm-TALP medium. Sperm concentration was calculated with a hemocytometer. 250 µL of the diluted sperm suspension was added to each well. Fertilization plates were returned to the incubator and the sperm and COCs were co incubated for 18 to 22 hrs. To evaluate efficiency of DGC, viable and dead remaining cells in the different percoll layers were checked by subjectively counting under microscope (100X).

In vitro fertilization

Fertilization plates were prepared by placing 500 µl drops of IVF-TALP in a five well embryo culture dish and covered with 500 µl mineral oil. The COCs were washed by HEPES-TALP prior to fertilization. Fertilization plates with IVF-TALP were placed in an incubator at 39°C in an atmosphere of 5% CO_2 and allowed to equilibrate for at least 2 hrs. The PH of the capacitation and fertilization media was adjusted at 7.4 and 7.8, respectively.

10 to 20 COCs removed from maturation drops and washed. Each group of 10 to 20 COCs was placed in a fertilization media of TL fertilization supplemented with 6mg/ml BSA, 0.11mg/ml Na pyruvate and 10µg/ml Heparin.

Statistical Analysis

Data were grouped according to breed and parity of animals, oocyte quality/grade for once and twice weekly oocyte collection scheme. Analysis of variance was used to compare the mean number of viable oocytes collected from the two OPU procedures and each breed. Maturation rates were calculated by the number of oocytes presenting expanded CCs, first polar body formation and increased perivitelline space on the total evaluated oocytes that resulted from different breeds; and cleavage rate were analyzed by Mann-Whitney U-Test, Kruskal-Wallis H-Test and Fisher exact test. Results are presented as mean ± SEM and SD and level of significance was held at P<0.05.

Results

Oocyte collection

A total of 1800 follicles ≥ 2mm were punctured and 825 oocytes were retrieved during the entire experiment. The proportion of oocyte recovery for the whole puncture sessions was 45.8%. The mean number of punctured follicles for heifers and cows was 13.53±5.10 and 7.93±.85, respectively. The mean number of aspirated follicles from heifers and cows was 5.72±2.09 and 3.47±1.07, respectively. There was significant difference (p<0.001) in mean number of pre OPU follicular count between heifers and cows. There was also a difference (p<0.001) in the mean number of aspirated oocytes between the groups.

There was a difference (p<0.001) in mean number of recovered oocytes per session between once (5.70 ± 2.10) and twice (2.96 ± 2.0) a week collection scheme. There was no difference between the breeds regarding the number of quality (morphological assessment) oocytes collected by both (once and twice weekly) collections. However, higher numbers (p<0.001) of GIII oocytes were collected in both aspirations compared to GI and GII quality oocytes.

In vitro oocyte maturation

The overall maturation rate of oocytes aspirated from Boran and Crossbred cattle was 54.12% (97/179). The maturation rate of Boran and Crossbred cattle oocytes was 51.65% (47/91) and 56.8% (50/88), respectively. Maturation rate in terms of COCs expansion was 74.7% (n=72) and 78.4% (n=45) for Boran and Crossbred cattle oocytes, respectively. The proportion of increased perivitelline space in matured Boran and Crossbred heifers oocytes were 45.1% (n=72) and 52.3% (n=45), respectively. 54.9% (n=72) of Boran and 67.0% (n=45) Crossbred cattle oocytes exhibited the first polar body at the end of maturation. There was no difference (p>0.05) in maturation rate of Boran and Crossbred cattle oocytes. The color and shape of aspirated oocytes were not identical. Small, partially denuded and very dark oocytes had shown no palpable change during maturation.

Plate A. Comulus cells expansion after 24hrs maturation

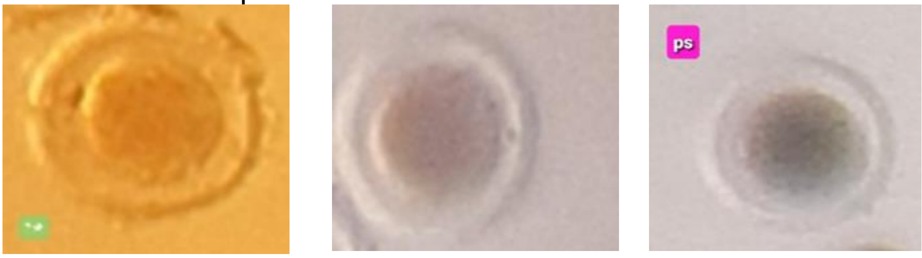

Plate B. First polar body extrusion

Figure 1: Plate A) Cumulus-cells expansion after 24hrs maturation; Plate B) 1PB extrusion.

The maturation rate of oocytes in BO maturation media in terms of COCs expansion, first polar body extrusion and increased perivitelline space was 88.2%, 68.2% and 47.3%; (n=64), respectively. The maturation rate in TCM based maturation media in terms of COCs expansion, first polar body extrusion and increased perivitelline space was 57.97%,49.3% and 50.7%: (n=53), respectively. The proportion of oocytes matured in BO media was (53.5%, n=40) and (48.7%, n=24) for purebred Boran and crossbred cattle, respectively. The proportion of matured oocytes in TCM-199 based maturation media was (69.2%, n=32) and (43.3%, n=21) for Boran and their crosses, respectively. There was no difference (p>0.05) in maturation rate of Boran and crossbred cattle oocytes cultured in TCM-199 based or BO maturation media.

Table 1: Comparison of Boran and Crossbred cattle oocyte maturation rate (% ± SD)

Breed	N	Cultured oocyte	COC expansion	1PB extrusion	Increase in perivitelline space
Boran	72	68.9±0.42	74.7 ±0.50	54.9 ± 0.41	45.1 ±0.37
Crossbred	45	73.9±0.33	78.4 ±0.43	67.0 ± 0.42	52.3 ± 0.40

Semen viability and in vitro fertilization

Semen viability

The percentage of subjective motility of the HF bull frozen thawed semen that used for percoll density gradient centrifugation treatment was 59.3% ± 3.63 immediately at thawing prior to centrifugation. The percentage of sperm motility after processing by Percoll separation techniques was 74.4%. There was a significant difference (*p*<0.05) in motility between initial and processed semen motility. The proportion of motile spermatozoa at the 45% and 90% percoll layers was 27.4% ± 3.48 and 33.9% ± 2.63. The proportion of motile and dead sperm cells at the bottom (pellet) was 74.4 ± 2.78 and 25.6 ± 2.78, respectively. The mean concentration of sperm cells for percoll and self-migration separation techniques was 58.0% and 18.4%, respectively. There was a significant difference (*p* < 0.05) in the sperm cells concentration values between the sperm separation methods. There was a significant difference (*p* < 0.05) between sperm viability before and after processing. However, there were no significant differences for the sperm motility between the sperm preparation methods.

The comparison of dead and motile sperm cells at different layers of percoll gradient centrifugation treatment indicated in **Table 2**.

Table 2: Sperm viability after percoll density gradient centrifugation (%) ± SEM

Motility	Initial	45% percoll	90% percoll	Pellet
Viable	59.30 ± 3.63	27.40 ± 3.48	33.90 ±2.63	74.40 ± 2.78
Dead	40.70 ± 3.63	72.60 ± 3.48	66.10 ± 2.63	25.60 ± 2.78

In vitro fertilization

The cleavage rate for all inseminations combined was 36.31% (65/179). Cleavage rate of Boran and Crossbred zygotes was 40.7% (37/91) and 31.8% (28/88), respectively. Twenty two percent (14/65) of cleaved zygotes were developed to embryos in 72 hrs post insemination. There was no difference (*p*>0.05) in cleavage rate between the zygotes of the two genotypes at 48 hrs of post insemination. The proportion of cleaved zygotes was slightly higher in Boran oocytes than their crosses. The cleavage rate for BO and TCM-199 based media was (30.0%) 32/110 and (46.4%) 33/69, respectively. There was no difference (*p*>0.05) in cleavage rate with the two media treatment groups (*p*>0.05). A total of 21.05% (14/65) of cleaved zygotes were developed to morula stage embryos from both genotypes. 24.3% (9/37) of Boran and 17.86% (5/28) of Crossbred cattle cleaved zygotes were reached morula stage embryos after 72 hrs of post insemination incubation. Comparison of maturation and cleavage rate between the breeds and media employed indicated in **Table 3**.

Table 3: Comparison of Boran and Crossbred oocyte after in vitro maturation and fertilization (%) ± SEM

Breed	Media	n,(oocyte)	n, %(Matured)	n, %(cleaved)
Boran	BO	57	26 (45.6)	20 (35.1)
	TCM-199	34	21 (61.8)	17 (50.0)
Crossbred	BO	53	31 (58.5)	13 (24.5)
	TCM-199	35	19 (54.3)	15 (42.9)
Total		179	97 (54.2)	65 (36.3)

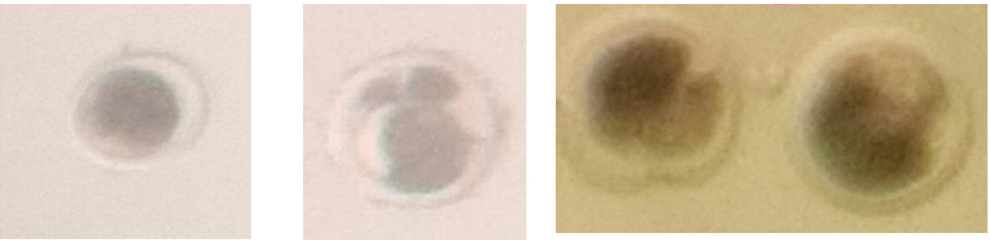

Plate A. Cleaved Boran zygote at 48 hrs. post insemination

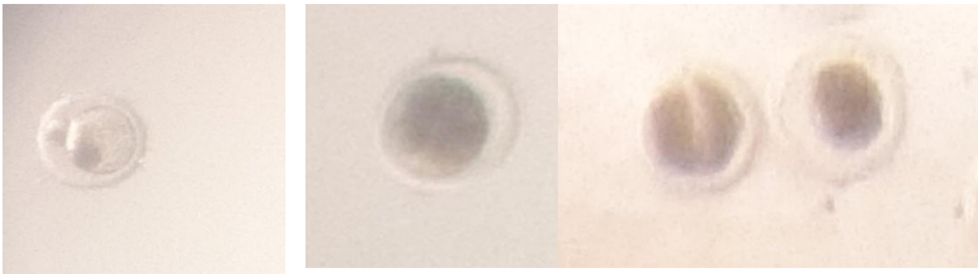

Plate B. Cleaved Crossbred zygote at 48 hrs. post insemination

Figure 2: Plate A Boran and Plate B Crossbred cleaved zygote at 48 hrs. post insemination

Plate C Plate D

Figure 3: Plate C & D. Cleaved Crossbred zygotes with 2^{nd} polar body at 48 hrs. post insemination.

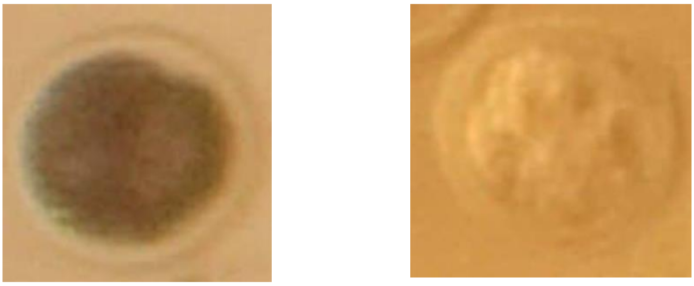

Plate A Plate B

Figure 4: Plate A Boran & Plate B Crossbred cattle morula stage Embryos after 72hrs incubation.

Discussion

Ovum pick up

In this study there was a difference ($p<0.001$) in the mean number of oocytes collected per session between once and twice a week collection scheme. The mean number of oocytes collected in once weekly collection schemes is higher than the number of oocytes collected per session in twice weekly collections. This result agreed with Imai *et al.* (2006) that reported the once weekly OPU scheme produced two times more oocytes than twice a week per donor per OPU session collection. Imai *et al.* (2006) also reported that the number of collected oocytes per each session and the percentage of oocytes developed to the blastocyst stage in once weekly OPU schemes are higher than twice a week OPU collections.

The oocyte recovery rate in both breeds was less than 50% which was lower than the average value reported in literature (Tamassia, et al., 2003). This could be due to technician skill on aspiration and searching, vacuum pressure and also animal handling facility. The Aloka ultrasound used for this experiment has had high screen resolution; however the open crush for animal restraint allows sun rays that disturb vision. Bols *et al.* (2004) reported that ultrasound screen resolution and probe characteristics have a great impact on oocyte recovery efficiency and, in reducing the risk of causing unnecessary damage to the ovarian tissue.

In vitro maturation

Morphological assessment of the proliferation of cumulus oophorus cells is the measure for the success of in vitro oocyte maturation (Lojkić *et al.,* 2014). The success of in vitro oocytes maturation is approximately 90%, even though only 30% of these oocytes develop to the stadium of the blastocyst (Lonergan, *et al.,* 2003). In this experiment the maturation rate of oocytes aspirated from Boran and Crossbred cattle was lower (54.12%) than the normal oocyte maturation reports in the literature by (Lonergan, *et al.,* 2003). The lower maturation result could be attributed to the newly established laboratory set up; mainly to media optimization and maintenance of culture environment (temperature regulation, gas phase and pH). Culture conditions can influence the kinetics of early development (Langendonckt *et al.,* 1997); however the main factors controlling this parameter are intrinsic to the oocyte (Brevini-Gandolfi *et al.,* 2000), the sperm (Ward *et al.,* 2001) or both. Problematic power fluctuations in incubation conditions that occurred regularly believed to be so damaging to the gametes within the laboratory set up, altering gas phase, pH and overall incubation conditions. Small pH deviations in culture conditions are actually large changes in H^+ concentration (Swain, 2010). Additionally, factors that influence oocyte quality, such as age of the donor, the stage of the estrous cycle, nutritional status, genetic potential, presence of a reproductive disorder, and others (Lonergan *et al.,* 2016), might have impact on the quality of aspirated oocytes in both genotypes of cattle. Further studies are elaborate the intrinsic quality of the oocyte as one of the major factors affecting early embryonic development (Krisher, 2004), and also the crucial role of embryo culture conditions in determining blastocyst quality (Rizos *et al.,* 2002), the precise selection of competent oocytes is vital for IVP technologies in livestock.

Lonergan *et al.* (2001) demonstrated that events further back along the developmental axis determine the proportion of immature oocytes reaching the final developmental stage or its ultimate fate of development. There was heterogeneity in oocyte maturation which was arising from the variability of aspirated oocytes. The total number of aspirated grade I oocytes was less than 20%. The mean number of oocytes per collection session was 11.41 ± 0.18 and few grade I quality oocytes were cultured per each incubation. According to Douville and Sirard, (2014), antral follicles in random ovaries will be in the growing, plateau and atretic phase. This situation is reflected in the morphology of the cumulus-oocyte complexes recovered from these follicles and is partially associated with outcome (Blondin and Sirard, 1995). Oocytes with a partially denuded or atretic-like cumulus have a lower competence compared to other groups (Sirard, 2011).

Selection of uniform oocytes from a group of a limited number of high grade oocytes per OPU session was a limiting factor. Boran cattle contributed for most of the denuded oocytes. Though, there was no difference ($p>0.05$) in the total number of discarded oocytes between Boran and Crossbred cattle.

The ratio of cumulus cell expansion in crossbred cattle oocytes was slightly higher than Boran cattle oocytes. Cumulus cell expansion was more extensive and broad following 22hr of maturation in the oocytes of both breeds. Sixty percent of the total cultured oocytes exhibited first polar body extrusion. The degree of nucleus maturation is measured as a percentage of oocytes in the stage of metaphases II with the first polar body expelled (Lojkić *et al.,* 2014). The first polar body extrusion was more prominent in Crossbred oocytes (67.0%) than the Boran cattle oocytes (54.6%). Around 90% of cultured immature oocytes will reach MII at the end of maturation under proper conditions (Lonergan, *et al.,* 2003). Though, oocyte cytoplasmic maturation and full acquisition of developmental competence are in many cases not automatically accompanying the nuclear maturation and may account for fertilization and/or development deficiencies (Watson, 2007). The heterogeneous source of the aspirated immature oocytes retrieved from ovarian follicles at different phases of the follicular growth can result in compromised developmental competence due to improper completion of the cytoplasmic and nuclear maturation (Mermillod *et al.,* 1999).

The ultimate test of the quality of an oocyte is its ability to be fertilized and develop to the blastocyst stage, to establish a pregnancy and ultimately to produce a live calf (Lonergan *et al.*, 2001). To this end, minimizing the factors responsible for poor oocyte and semen quality should get focus above and beyond incubation conditions and working environment optimization. These results indicate the importance of further studies to investigate the local cattle oocyte acquisition of developmental competence and optimization of in vitro culture conditions for the improvement of the bovine IVP system in our laboratory conditions.

Semen viability and in vitro fertilization

Frozen thawed semen samples had shown a range of variability in motility (45-75%) during semen preparation for IVF. The sperm quality parameters (motility, morphology, concentration, viability) were evaluated immediately after thawing and after sperm preparation for IVF. It was reported that mammalian spermatozoa have high expressive heterogeneous traits in morphology, motility and nuclear stability. Spermatozoa metabolic activity in the female genital tract is varied from in vitro conditions and is not adapted to survive for long time in in vitro conditions (Van S. A. and de Kruif A. 1996). The frozen thawed straws of semen for fertilization had a highly inconsistent percentage of motility. There were also observable physical defects, unresolvable clots and debris in the population of thawed semen during sperm separation procedures. Parrish *et al.* (1995) reported that frozen bull spermatozoa after thawing have lower percentage of progressive motility (30 to 70%), though the percentage of morphologically normal spermatozoa in thawed ejaculate is equal to fresh semen. Straws of semen evaluated for less than 40% motility were not included in this experiment.

Percoll density gradient centrifugation and self-migration swim up techniques were used for semen characterization and optimization experiments, for selecting hyper-motile sperm from the pool of semen population. There were significant differences ($p < 0.05$) in sperm motility between initial sperm and sperm after Percoll separation techniques. There were also significant differences ($p < 0.05$) in the sperm cells concentration values between the sperm separation methods. Comparing the results of sperm viability before processing with the results after sperm processing it was found that there were significant differences ($p < 0.05$) between them. However, there were no significant differences for the sperm motility between the sperm preparation methods.

Even though a great deal of sperm cells were found and left at each stratum of the percoll layer, Percoll density gradient centrifugation method was helpful in enhancement of the sperm quality by separating high rate of progressive motility and morphologically normal spermatozoa. In this study the swim up method yields lower concentration of sperm cells than the percoll gradient centrifugation technique. Comparing swim up method and Percoll gradient Parrish *et al.* (1995) obtained similar sperm motility results for both methods, although a lower concentration resulted for swim up method. There was inconclusive report on semen purification methods however numerous studies investigating which method, among many, are better for sperm enrichment.

The result of this study showed again that the sperm recovery rate following percoll gradient largely depends on initial semen quality; which indicates the importance of initial semen quality evaluations for frozen thawed semen prior to swim up and percoll procedures. These semen preparation methods would not spare the need for proper semen handling. Poor handling of stored semen (improper top-upping and shortage of LN_2 supply) was the culprit for deterioration of the quality of semen on top of individual bull variability. The sperm recovery rate from poor semen samples such as liquefaction defects, unresolvable clots or rare viable sperm was far from satisfactory. The repeated experimentation made on semen prepared for IVF indicated a small proportion of motile sperm was obtained from a relatively poor quality semen sample.

The results of this experiment in which a lower proportion of matured oocytes were developed to fertilization suggests that the events around the time of maturation might be important in determining the developmental competence of the oocyte. However, whether or not maturation was solely responsible for the observed decrease in fertilization was questionable. It should be noted that despite the extrinsic factors surrounding the oocyte the intrinsic factor (quality of each oocyte) might have had effect on both maturation and fertilization of the oocytes. This would suggest that a proportion of the heterogeneous oocytes aspirated from small follicles had not been competent for maturation and contributed to a lower maturation and fertilization rate. For years, there was doubt in defined media that it was the major cause of limited developmental competence of oocytes, although this media was allowing the culture of oocytes up to blastocyst stage (Sirard, 2018). The average success rate plateaued at 30-40% of oocytes developing to the blastocyst stage despite the addition of hundreds of different products, cytokines, growth factors, anti-oxidants, in addition to the introduction of new types of incubators, and reduced oxygen tension (Hansen 2006). Nowadays, attention turned towards the source of oocytes as a potential explanation for the limited success rates of IVF. The morphology of oocyte-cumulus complexes obtained when all follicles are aspirated from ovaries varies greatly (Sirard, 2018).

Irrespective of the breed and the media used for maturation and fertilization, only a very low number of oocytes were cleaved (19), few of them (4) grew to morula stage and none of them developed to blastocyst stage. As reported by Lequarre *et al.* (2003), the frequency of embryos reaching the blastocyst stages is far from what is normally observed in embryos produced in vivo. In this experiment 66% of matured oocytes could not reach cleavage and embryonic development. Research report indicated 60 to 70% laboratory losses of in vitro matured oocytes due to the inability of the embryo to properly undergo cleavage and development to blastocyst stage (Lequarre *et al.*, 2003).

There are many factors that can interfere in embryo development in cattle causing embryo cleavage to cease, and most of the embryonic block occurs during the fourth or between the fourth and fifth cell cycle transition (Memili and First, 2000). This developmental block is observed in many species, with the peculiarity that it shows up at different stages (i.e., fourth cell cycle in cattle; fifth in rabbits, third to fourth in humans; second in mice; (Memili and First, 2000), and in the fourth cell cycle in cats (Hoffert *et al.*, 1997). This species-specific block moment is concurrent with the maternal-embryo transition, the developmental stage when embryos conclude the major genome activation (De Sousa *et al.*, 1998b) and must rely on the mRNAs transcribed from its own genome to continue development.

It would seem that a number of factors such as donors' age, nutritional status, oocyte aspiration pressure, media composition and optimization, pH, temperature regulation and incubator and working environment might have affected embryo production efficiency. Even though IVF technology progressed from where it was 40 years ago and its techniques employed in multiple animal species, the technology is not yet completely matured or satisfactory; a number of problems remain to be solved and several procedures still need to be optimized (Sirard, 2018). IVEP procedures are not easily repeatable and adapted in a new laboratory set up. Every step of the procedure should be optimized and the incubation environment should upgrade to optimal condition. In a new laboratory set up most of the approach was fraught with technical difficulties which cloud the overall effort exerted to adapt and optimize the procedures.

The challenge for the future is optimization of different stock solution preparations, incubator conditions and working environment, and to secure the source of quality oocyte and semen for the attempt to amplify the maturation, fertilization and embryo culture conditions. The development of a complex technology such as in vitro embryo production requires years of experimentation, to create the right incubation environment for oocytes, spermatozoa and early embryos (Sirard, 2018).

The quest for defining optimal culture conditions allowing for the development of bovine zygotes to blastocysts took place including focus on co-culture systems (Edwards *et al.*, 1997), media composition (Holm *et al.*, 1999) as well as the physical design of the culture platforms (Smith *et al.*, 2012). These efforts all became extremely relevant to prevent adverse effects of improper in vitro culture conditions, particularly in new IVF laboratory setups.

Conclusion

The lower maturation rate of both Boran and Crossbred cattle oocytes could be attributed to the newly established laboratory set up; mainly to media optimization and maintenance of culture environment. The decrease in the number of matured oocytes that developed to fertilization suggests that the events around the time of maturation might be important in determining the developmental competence of the oocyte. Uncontrolled factors such as electric flex laboratory equipment optimization and less exposed lab technicians might also have contributed to the low outcome. The intrinsic factor (quality of each oocyte) might have an effect on maturation, fertilization and developmental competence of the embryo. Relatively similar patterns of maturation process and embryo development were observed between Boran and Crossbred cattle oocytes. OPU/IVF procedures could be used in local and crossbred heifers without adverse effect on the normal ovarian activity. Alternative ART techniques (OPU, IVF) for dairy cattle genetic improvement and multiplication work were tested and adopted in the country.

Recommendations

Further research and experimentations are needed on the extrinsic and intrinsic factors affecting oocyte yield & quality, to optimize and create the right *in vitro* environment for oocyte maturation, fertilization, embryo culture and development, sperm purification and quality analysis methods, embryo freezing and cryopreservation procedures. Capacity building in human and physical infrastructure is crucial to be benefited from the knowledge based economy such as IVEP.

Acknowledgements

The authors gratefully acknowledged the financial and research inputs support of this study by the Ethiopian Institute of Agricultural Research (EIAR), National Agricultural Biotechnology Research Center (NABRC).The financial support of Agricultural Growth Project (AGP II) of the (EIAR).The provision of experimental animals by Holeta and Debre Zeit Agricultural Research Centers.

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Ethiop. J. Agric. Sci. 32(4) 105-118 (2022)

The Warehousing Strategies Adopted to Contain Maize Post-Harvest Storage Losses in Zimbabwe

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Abstract

This study examined the warehousing strategies adopted in Zimbabwe to contain maize post-harvest storage losses. The government of Zimbabwe has invested heavily on various schemes aimed at boosting agricultural productivity for maize which is a staple grain for the populace. Despite all these efforts, the challenge of food insecurity has continued to confront Zimbabwe as a nation. On the same note, there have been various reports of maize losses in storage hence the study examined the warehousing strategies adopted to contain maize post-harvest losses in Zimbabwe. Primary data were collected from 225 employees in the Grain Marketing Board of Zimbabwe (GMB), the Ministry of Lands, Agriculture, Fisheries, Water, and Rural Development (MLAFWRD) and agricultural experts through the questionnaire and in depth interviews. The study found out that the Grain Marketing Board has effective warehouse strategies for the containment of maize post-harvest losses. However, while there were effective warehousing strategies, the losses due to the absence of sound post-harvest storage practices remained a concern. The study recommended a change in organisational operational culture to sensitise all human resources involved in maize storage in the Grain Marketing Board of the criticality of reducing maize post-harvest storage losses in Zimbabwe.

Keywords: warehousing strategy; post-harvest losses; maize; storage; storage technology.

Introduction

The primary focus of many developing countries has been on economic growth and food security (African Union Commission, 2018). However, to ensure food security, effective warehousing is necessary because of the seasonal production of most agricultural produce. The United Nations (2018) notes that world hunger has been reduced significantly but it is on the increase again. Conflict, drought, and disasters associated with climate change were among the reasons causing this increase in world hunger (United Nations, 2018). Maize is produced seasonally; therefore, it is necessary to develop effective warehousing strategies to guarantee its availability all year round (Kumar Deepak and Kalita Prasanta, 2017). These warehouses can be grouped into four types which are agricultural warehouses, container terminals, air cargo complexes and industrial warehouses (Sharma, 2013).

Storage is a critical activity which involves holding and preserving the grains after harvesting until they are dispatched for consumption (Ugochukwu Albert and Peter Phillips, 2018). Warehouses are responsible for protecting and maintaining the quality of the maize to ensure availability throughout the year. Storage facilities are important in preventing the storage losses through reducing the effect of rodents, microorganism, pests and environmental induced factors to supply food to the increasing global population (Eme, 2013). Many innovations in maize storage have been developed for use at the farm level and for bulky national storage reserves. The storage of many food grains needs scientific and modern techniques because most grains are affected by biological activities and a variety of insect-pests (Makami, 2014).

According to Banasik et al. (2017), when grain is produced commercially, merchants often provide empty sacks to farmers for filling them at the farm. These merchants then collect the packaged grain from the farm, or the farmer will transport it to the nearest collection depot (Banasik et al., 2017). During this process, the farmer needs to store the bagged sacks of grain for a period of time before they are delivered to the collection depots (Banasik et al., 2017). In this process precautions need to be taken to maintain the safety and quality of the grains (Jakfar et al., 2021). Moisture and termites usually affect maize grains during this process and keeping the bagged maize of the ground and fumigation is necessary. According to Smitiri (2015), the risk of rain at the temporary storage stage requires the covering of storage bags with waterproof sheeting. Fumigation of the bagged maize is usually not necessary if the storage period is not long (Kondratjev, 2015). Used maize storage sacks must be inspected, cleaned and fumigated before use (Kondratjev, 2015).

Metal drums and plastic drums can be used for the storage of grains and notes that plastic drums are weaker as compared to metal drums (Madel, 2014). If constructed well and fitted with gaskets, these metal drums can be modified to be airtight. This makes them safe from rodents and effective against insects (Emeka, 2014). However, there is need for their protection from sunshine and heat to reduce condensation through locating them in shaded and well aerated places (Emeka, 2014). According to Makami (2014), in some countries, modern grain storage facilities have been developed for the warehousing of maize for a long duration. These include Concrete/cement silos which are made of cement and other imported materials. They are durable but expensive structures to construct. Significant resources are required for their erection (Makami, 2014). They are suitable for bulky storage and their distinguishing feature is that they are robust and provide many years of satisfactory service (Makami, 2014). Metal Silos can also be used for maize storage. These are suitable for storing large grain quantities (over 25 tonnes) and are considered too costly for on-farm, small scale storage (Emeka, 2014).

Organisations planning for a new grain store should make an effort to seal it effectively and make it air-tight (Jarkfa et al., 2021). The advantages of sealed maize storage facilities are many such that the low costs incurred during construction should not be considered (Jarkfa et al., 2021). The fumigation costs of stored grain are much cheaper and effective as compared to the use of chemicals (Smitiri, 2015). The grain stored in sealed storage facilities can be protected from insects because the sealing restricts pest access for re-infestation (Kondratjev, 2015). Total grain protection can only be possible if the grain is fumigated in well-sealed storage facilities [9].

Adequate air supply in grain storage facilities is necessary in grain storage and warehousing (Jarkfa et al., 2021). During storage, there is need for ambient aeration, which entails injecting air through grain to maintain required temperature (Makami, 2014). This is very critical in grain storage management as it preserves grain from infestation and deterioration in conditions where the moisture content of the stored grain is more than its safe level (Makami, 2014). Airtight storage techniques used for providing storage for food grains in the absence of oxygen are effective because insects-pests are eliminated in the storage facility (Jarkfa et al., 2021). This can be in the form of hermetic storage which is yet another way for the warehousing of grain and containing post-harvest storage losses. Hermetic storage technology shields the stored grains from moisture migration, rodents and insect-pest (Makani, 2014). This is achieved through creating favourable storing conditions in the storage facilities. Hermetic storage technology has been proved to be effective and efficient to store grains without affecting their quality aspects for long periods (Smitiri, 2015). Hermetic storage facilities are large with storage capacity ranging from ten to thirty thousand tonnes and their use started in the last decades of the 20th century (Singh et al., 2017). Hermetic storage facilities have been proved to be suitable for the storage of grains with recommended moisture content for up to four years without deterioration (El Taliawi Ola and Zeger Van Der Wal, 2019). Hermetic storage structures are very reliable in protecting the grains and reduce the storage losses up to 0.15% (Singh et al., 2017).

Grains stored in hermetic storage structures do not require any chemical protection and fumigation as an effective storing condition would have been developed by modifying the storage structure atmosphere (Jarkfa et al., 2021). Construction of hermetic storage facilities is based on the amount of maize grain which needs to be stored. The capacity range of the facilities varies between 0.59 to 1 tonnes for super grain bags, 5 to 30 thousand tonnes grains can be stored in the hermetic storage facilities called bunkers and cocoons (Singh et al., 2017).

Fumigation and treatment of the stored grains should be done at regular time intervals to reduce pest infestation (Makami, 2014). This is based on the fact that if insects in the stored grain are left untreated, the grain quality will deteriorate and become unsalable in the market and in some cases it can be reduced to dust because of the pests feeding on it (Makami, 2014). The stored grains can become mouldy as a result of the heat and moisture caused by the insects in the storage facilities. Grain insects and pests are usually present on most farming areas, harvesting equipment, stock feed, old seed, grain spills and these can enter storage facilities easily (Eme, 2013). In some cases, insects are moved into storage areas through the grain handling equipment (Eme, 2013). This validates the need for insect control systems to be put in place so as to reduce grain post-harvest storage losses (Eme, 2013). Effective use of insect control systems maintains grain quality and value (Eme, 2013). Grain fumigation chemicals protect grains in all storage types but they need to be sprayed evenly to grain and storage facilities for positive results (Eme, 2013). This can be achieved by making use of correctly calibrated grain chemical application equipment. Training of warehouse employees is necessary to ensure that the correct quantity of the chemical is used during fumigation as under-dosing can lead to reduced protection, while overdosing is costly (El Taliawi Ola and Zeger Van Der Wal, 2019).

It is important to note that in Zimbabwe, all grains are stored and managed by the Grain Marketing Board (GMB) which is a State Owned Enterprise. All farmers are required to deliver their maize for storage to the GMB except for contract farmers. Most of the agricultural goods such as maize and wheat are produced only in a certain season but the consumption of these take place all year round hence the importance of agricultural warehousing. In order to ensure food security in Zimbabwe, maize storage plays a critical role through the reduction of quantity and quality losses. Adopting proper and effective warehousing strategies will also reduce the government’s burden on food subsidies in Zimbabwe. The main objective of this study was to examine the warehousing strategies adopted to contain maize post-harvest storage losses in Zimbabwe. The study sought to answer the question, ‘How sound are the warehousing strategies adopted for containing maize post-harvest storage losses in Zimbabwe?’ This study also sought to prove the null hypothesis that is; ‘Zimbabwe does not have effective warehousing strategies for containing maize post-harvest losses’, with the opposite being the alternative hypothesis.

Material and Methods

Study area

The study was conducted in the Grain Marketing Board of Zimbabwe (GMB) which has 78 storage depots scattered around the country. These depots are categorised as Class 1, Class 2 and Class 3 depending on the level of activity in each depot and storage capacity. The class 1 depots have the largest storage capacity and the highest level of activity. The depots in this category were 15 in total and this study targeted these depots because they provided the largest storage capacity for maize in Zimbabwe. The target population for this study was made up of the managers and employees of GMB in all its 'Class 1' depots. The Ministry of Lands, Agriculture, Fisheries, Water, and Rural Development (MLAFWRD), as the parent ministry, was also part of the study. There were also agricultural experts who possessed knowledge about maize warehousing.

Method of Data Collection

Questionnaires and in depth interviews were used to collect data. 225 questionnaires were administered and 36 in depth interviews were conducted in this study.

Sampling Techniques

Quota sampling was used to select the institutions in this study. Purposive sampling was used to select the Class 1 depots and snowball sampling was used to select respondents in the GMB, Ministry of Lands, Agriculture, Fisheries, Water, and Rural Development (MLAFWRD) and agricultural experts.

Data Analysis

Descriptive statistics, in particular, the frequencies, measurement of dispersion (mean and standard deviation) were used to analyse the data. The Relative Importance Index (RII) was also employed to describe the relative contributions of variables with regards to objectives of the study. The Formula for RII =x=1x=5n/(63x5) where x represents the response e.g. 1 = strongly disagree and 5 = strongly agree, while n is the frequency of people who respond to x. One Sample Chi-square was the inferential statistics that was used to test the hypotheses of the study. Qualitative data was analysed thematically. Table 1 shows an analysis of the target population

Table 1: Sample Size Summary

Participants	**Target Sample**	**Data Collection Tool**
MLAFWRD (AGRITEX Officers)	18	Interview
GMB's Board Members	3	Interview
Top Management (Operations; Corporate Secretary; Strategy and Business Development; Enterprise Risk; and Training and Development)	5	Interview
Depot or Assistant Managers	5	Interview
Agricultural Experts	5	Interview
Total Number of Interviews	**36**	
Respondents From 15 GMB's Class 1 Depots		
Depot Managers or Assistant Managers	15	Questionnaire
Supervisors	30	Questionnaire
Fitters	45	Questionnaire
Handy Persons	45	Questionnaire
Clerks	45	Questionnaire
Silo Operators	45	Questionnaire
Total Number of Questionnaires	**225**	

The variables that were measured in this study were: (1) Sound management of assets and premises used in maize warehousing (2) Effective organisation of the warehouse processes (3) Use of appropriate technology in the warehouses (4) Capacity building and sound leadership in maize warehousing (5) Sound planning of the warehouse processes

Results and Discussion

Response Rate

There was a remarkable response from the participants and respondents. Table 2 show the response rate.

Table 2: Questionnaire Response Rate

Respondents From 15 GMB Class 1 Depots		
Depot Managers or Assistant Managers	15	Questionnaire
Supervisors	30	Questionnaire
Fitters	45	Questionnaire
Handy Persons	45	Questionnaire
Clerks	45	Questionnaire
Silo Operators	45	Questionnaire
Total Number of Questionnaires	**225**	

According to Table 2, the sample target for the questionnaires was 225, and there were responses from 211 people (94% response rate). The response rate for questionnaires, of 94%, is very high considering that Saunders et al., (2015) set the minimum acceptable response rate at 67%. Data were also collected using interviews. Table 3 shows the interview response rate.

Table 3: Interview Response Rate

Participants	**Target Sample**	**Data Collection Tool**
MLAFWRD (AGRITEX Officers)	18	Interview
GMB's Board Members	3	Interview
Top Management (Operations; Corporate Secretary; Strategy and Business Development; Enterprise Risk; and Training and Development)	5	Interview
Depot or Assistant Managers	5	Interview
Agricultural Experts	5	Interview
Total Number of Interviews	**36**	

According to Table 3, out of the targeted 36 interviews, the researcher managed to conduct 23, indicating a response rate of 64%. Interviews are difficult in terms of making appointments and agreeing on time and Saunders et al., (2015) argue that an interview response rate of at least 50% is acceptable. Therefore, a 64% response rate for this study was above the minimum limit.

Demographic Profile of Respondents

Gender, age, highest educational qualification, and the number of years the respondent was working for GMB are the respondent characteristics presented. Respondent characteristics are paramount in that they are an indicator of the quality of responses the research is likely to get, a key determinant of the validity of the final results.

The 211 questionnaire respondents were required to indicate their gender. The question on gender was asked in order to determine the extent to which GMB enhances gender equity. Gender balance has an influence on a company's performance as any strategies can be subjected to close scrutiny by both the males and females, who are also part of the maize value chain actors. Figure 1 shows the findings on gender.

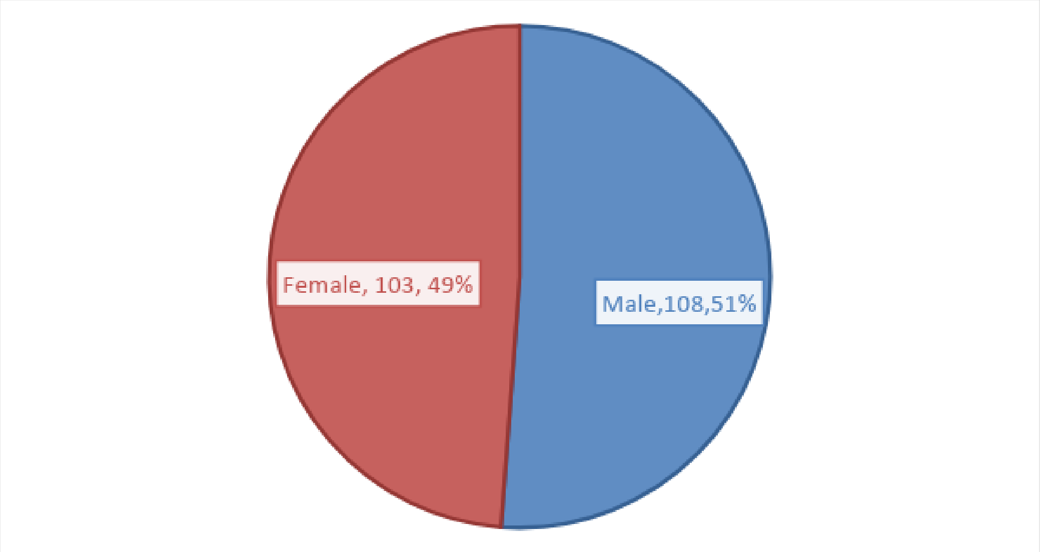


Figure 1: Gender of Respondents

Figure 1 shows that, out of a total of 211 respondents who participated in this study, nearly an equal number of males (51%) and females (49%) participated. This could also imply that GMB is a gender-balanced organisation, which could have a positive implication on performance, including warehousing operations. Having adequate gender balance is essential for enhanced organisation performance as there is sharing of ideas.

The respondents were also required to indicate their ages. The question on age was asked in order to establish the level of maturity of the people who provided the answers to the questions.

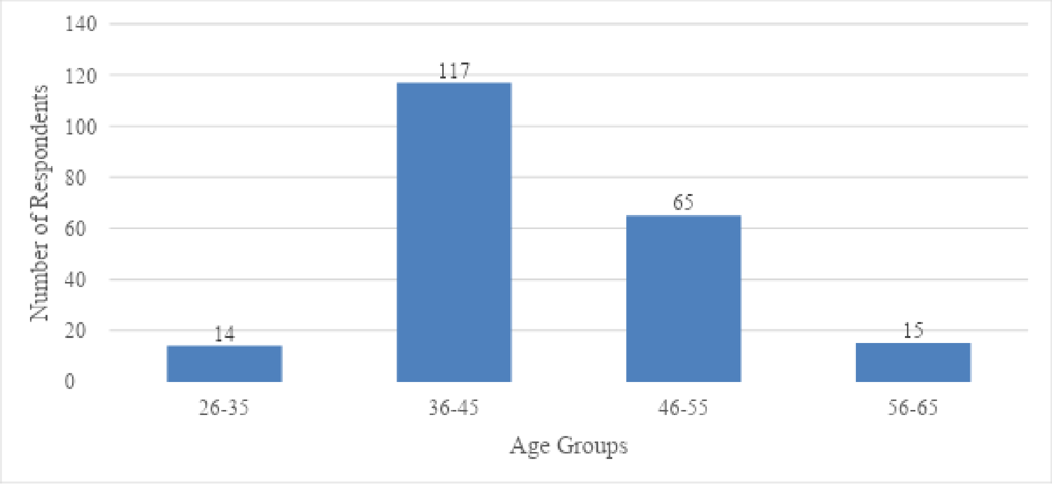


Figure 2: Age Groups of Respondents

Figure 2 shows that the majority of the sample 55.5% were aged between 36 and 45 years, and a significant number were between 46-55 years old. These results seem to indicate that most of the respondents in this research were mature people, meaning a high potential for reliable results.

The respondents were asked to indicate their highest educational qualifications. Table 4, shows the findings on educational attainments.

Table 4: Highest Educational Level

Educational Level	Number of Respondents	Percentage of Respondents
Diploma	82	38.9
First Degree	102	48.3
Masters	27	12.8
Total	211	100.0

According to Table 4, all the respondents were educated with at least a diploma, 48.3% having an undergraduate degree and 12.8% having a master's degree. In terms of occupation status most respondents, 76.3% were non-managerial employees and their supervisors (14.2%), and the remainder very few managers, both middle and top level management. Higher levels of educational attainment of the respondents have can mean the respondents sampled are knowledgeable about the phenomenon being investigated, thus valid responses are possible.

There respondents were required to indicate their work experience in GMB. The question on work experience was asked to determine whether the respondents have been working for GMB for a period long enough to be able to provide reliable answers. Table 5 shows the findings on work experience.

Table 5: Tenure of Employment in GMB

Number of Years	Number of Respondents	Percentage of Respondents
3-5 years	5	2.4
6-10 years	107	50.7
11-15 years	96	45.5
16-20 years	3	1.4
Total	211	100.0

According to Table 5, with regards to tenure, just over half the sample, 50.7% had worked for the company for 6 to 10 years, nearly an equal number (45.5%) have tenure of between (11-15) years. The findings show that most of the respondents had adequate working experience to be in a position to comment about the operations in GMB.

Warehousing Strategies Adopted to Contain Maize Post

-Harvest Losses in Zimbabwe

Descriptive statistics: mean and standard deviation, and the relative importance index were used to identify and examine the warehouse strategies adopted to contain maize post-harvest losses in Zimbabwe. Based on a Likert scale of 5 ranging from 1 (no adoption) to 5 (mostly adopted), and a mean close of 3 or close to 3 implying no decision made with regards to level of adoption. Table 6 illustrates the results of the study.

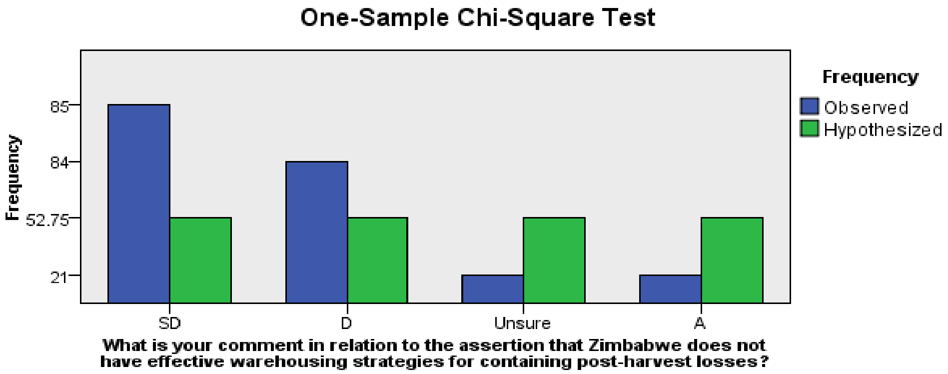
Table 6: Maize Warehousing Strategies Adopted in Zimbabwe

Strategies	N	Mean	Std. Deviation
Sound management of assets and premises used in maize warehousing	211	4.3033	1.18841
Effective organising of the warehouse processes	211	4.2986	.78130
There is use of appropriate technology in the warehouses	211	4.0047	1.34341
There is capacity building and sound leadership in maize warehousing	211	4.0000	1.34164
There is sound planning of the warehouse processes	211	4.0000	1.34164

Table 6 indicates that Zimbabwe has several warehouse strategies in place to contain maize post-harvest storage losses. Mean scores of above 4 indicate the majority of the respondents agreed of the presence of strategies in the organisation. The results indicate that Zimbabwe has a sound management system of assets and premises used in grain warehousing (mean=4.30, Std Dev=1.2), effective organisation of warehouse processes (mean=4.30, Std=0.78) and makes use of appropriate technology in the warehouses (mean=4.01, Std Dev = 1.34). In addition results illustrate that Zimbabwe has capacity building and sound leadership, and sound planning of warehousing processes in place.

With regards to the assertion that Zimbabwe does not have effective warehousing strategies for containing maize post-harvest storage losses, One Sample Chi-square test, a non-parametric, was the test statistic employed to test the hypothesis.

The non-parametric test was used in favour of the more powerful One Sample t-Test which violated the sample size assumption. T-test requires samples less than 30. The One-Sample Chi-Square results in Figure 2 show the findings.



Total N	211
Test Statistic	76.450
Degrees of Freedom	3
Asymptotic Sig. (2-sided test)	.000

1. There are 0 cells (0%) with expected values less than 5. The minimum expected value is 52.750.

Figure 3: One-Sample Chi-Square: Effectiveness of Warehousing Strategies in Zimbabwe

The results in Figure 3 indicate significant differences in the hypothesised frequencies (N=52) and the expected frequencies ($X^2(3) = 76.45$, $p<0.01$). Higher frequencies were observed in people disagreeing with the assertion that Zimbabwe does not have effective warehousing strategies for containing post-harvest losses (N=169), while lower frequencies were observed in the number of people agreeing (N=21) and not use (N=21) than the hypothesised (N=52).

The results from the study suggest that Zimbabwe has effective warehousing strategies for containing maize post-harvest storage losses. However, while there were effective warehousing strategies in the GMB, interviews conducted suggests that losses due to the absence of sound post-harvest storage practices remained a concern in Zimbabwe. This is similar to what was experienced in Nigeria. In order to ensure that the quantity and quality of food produced was preserved, there was the formulation of the national storage policy of the Federal Government of Nigeria (FGN). The FGN stipulated that 5% of food production be stored by the federal government for strategic reserve purposes, 10% by the state government as buffer stock, and 85% stored at the farm by individual farmers or by traders in food warehouses (Kalita, 2015). However, Jeremiah (2015) argues that, despite having up to 1.3 million tons of grain storage capacity and more than 48 warehouse facilities for its grains reserves program (SGR), weak management of warehoused grain by staff at these facilities resulted in huge post-harvest losses (up to 50% in some cases). The grain losses suffered were mainly due to the lack of knowledge and ineffective stored grain management practices.

Maize is the most critical grain crop in Zimbabwe because it is a major feed grain and a staple food for all the population. Thus, the containment of post-harvest food losses is an important step in ensuring future world food security in a sustainable way. Table 6 also showed that most of the respondents were in agreement with the view that Zimbabwe makes use of appropriate technology in grain warehouses. New and efficient technology is necessary in warehousing. Technology strategy involves the duty of building, maintaining and making use of a company’s technological resources. However, planning, organising, and relevant technology are all dependent on leadership. Sound leadership is important for efficient and effective warehousing operations.

This study pointed out that Zimbabwe ensures capacity building and sound leadership in warehousing, with a mean score of 4.0. This is very important because warehousing and its management cannot be appreciated differently from the general functions of management. According to Sayeed (2013), the four functions of warehouse management are planning, organising, leading, and controlling. More so, from a warehousing perspective, the key functions are (i) receiving, quality control, and put-away/storage and (ii) picking, sorting, packing, and shipping (Sainathuli et al., 2014).

The study results in Table 6 also show that Zimbabwe is able to ensure sound management of assets and premises in warehousing. Maize storage assets are very critical in the containment of post-harvest storage losses. However, Jurevicius (2013) points out that the resources or assets, themselves, do not provide any benefit for an institution if they are not managed to capture their value. Moreover, almost all of the interview participants pointed out that the grain storage assets require sound management, including proper maintenance. If the assets are well maintained, the maize will not be damaged by moisture and pests. Asset management must be given high priority and viewed as a financial concept, managed alongside core business functions such as Finance, Human Resources, and Information Technology (Abdullahi, 2015). According to Bourne Humphrey and Mark Jenkins (2013), the assets need to be managed, not just maintained. This will help to reduce maize post-harvest storage losses and ensure food security in Zimbabwe.

Conclusion and Recommendations

The study concluded that GMB has effective warehouse strategies for containment of maize post-harvest losses. However, while there are effective warehousing strategies, the losses due to the absence of sound post-harvest storage practices remain a concern in GMB. The implementation of every strategy needs to be monitored in order to be effective. The maize storage assets, that is; the maize storage silos, storage sheds, storage bags need to be managed well. This task is done by the human element involved in maize storage hence it is recommended that GMB should constantly monitor the implementation of their warehouse strategy. The human element is important in most strategies as it implements the strategy. Consequently, they should be involved in the strategy development process in order to comprehend it and be able to put it into action. The Government of Zimbabwe should prioritise the training of grain handlers in the Grain Marketing Board on grain handling in order to improve the grain storage practices. A change of organisational operational culture is needed to sensitise all human resources involved in grain storage of the criticality of reducing maize post-harvest storage losses. This is because, while there were effective warehousing strategies, the losses due to the absence of sound post-harvest storage practices remain a concern in GMB.

Acknowledgments

The authors gratefully acknowledge the Ministry of Lands, Agriculture, Fisheries, Water, and Rural Development (MLAFWRD) for granting permission to conduct this study. The authors also acknowledge the GMB staff in all 15 Class 1 depots in Zimbabwe for participating in this study.

Funding: No funding was received for this study. The contributors used their own

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Ethiop. J. Agric. Sci. 32(4) 119-128 (2022)

Effects of Social Media on Trainers' Work Performance at the Agricultural and Rural Management Training Institute, Ilorin, Nigeria

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Abstract

The study assessed the effects of social media on trainers' work performance at the Agricultural and Rural Management Training Institute, Ilorin, Nigeria. Systematic random sampling procedure was employed in the selection of 91 respondents for the study through the use of structured questionnaire. Data collected were analysed using descriptive statistics and Chi-square. Results showed that the frequently used media on a daily basis, were Twitter (83.5%), emails (79.1%), WhatsApp (76%), and Facebook (72%) while Linkedin (29.3%) were used on weekly basis. Trainers used social media to connect with families and friends (64.1%), source for journals (19.2%), collaborative research (18.8%) and as well as for online dating (20.7%). Furthermore, 38.0% of the respondents accessed social media from their personal office (68.4%), individual homes (59.6%) and departmental office (23.2%). Trainers agreed that social media were essential office tools (57.0%), retarded their work (38.2%) as well as wasted their time (11.6%). Chi-square analysis results showed a significant relationship between social media usage and age ($R = -0.212, p \leq 0.05$) as well as work experience ($R= -0.39, p \leq 0.005$). Social media has both positive and negative effects on trainers' work performance. Social media usage should be controlled during working hours to improve the work performance of trainers at ARMTI.

Keywords: Social media, Trainers, Work performance, ARMTI

Introduction

Social media is a broad term that encompasses several types of new media and communication practices. It is difficult to create an exhaustive list of all types of social media, some of the most common social media include, weblogs, microblogs, social networks, Nikis and media sharing sites (Engler, 2019). Social media can be a great tool for researchers, academia, frontline extension workers, farmers, private sectors, and civil societies, etc., to share information and build relationships. Social media platforms such as blogs, Facebook and twitter are great tools for business, which can be easily used to share information about products and services.

More than ever, people want to know what is happening and go around (locally and globally,) where their food is coming from and want to get involved. Several social media are of importance in updating customers and knowledge sharing among the customers . For instance, blogs can be used to update customers about crop harvests and are also being used for sales. Social media also provides farmers a quick and easy way to seek information, build their capacity, relationships and interact with people in agriculture creating a much broader agriculture community, so obstacles like physical distance and isolation and poor informed decisions are issues of the past. However, it is pertinent that Agriculture and social media fit together, social media is the platform of engagement and agriculture is the content. Social media is giving farmers and rural businesses a voice and providing invaluable networking opportunities for continuous two-way communication with instant feedback.

The popularity of social media has grown as a result of the rapid changes in technology since computers are now more mobile and can be used virtually anywhere. Organisations are increasingly using social media as a new way to reach customers more effectively and to spread news of their activities more rapidly. The widespread use of social media has brought in its stead new challenges to the workplace. One of these is the apparent addiction that the millennial generation has to Facebook and other social media applications like Twitter and Instagram, among others. Emails and the Internet are more commonly used by organisations and many of them have enacted policies regarding their use or misuse at work. The use of social media during work hours, particularly when accessed via a personal cell phone or computers brings a new set of challenges to personnel across the globe (Amedie, 2017).

Social media are seen as a tremendous resource to academia (Choudhary *et. al.*, 2017). For example, it has been credited with helping trainers think outside the box. In the same vein, researchers who utilise social media have been reported to be more productive (Amedie., 2017). The use of social media has aided trainers to become more productive by getting them intimated with contemporary issues. Trainers are therefore better prepared to troubleshoot potential setbacks and are more likely to create good public relations through the work they do with the availability of social media.

The increasing popularity of social networks and their application in the workplace present major concerns for employers, but all indications are that employers cannot hope to prevent social network use during work hours (Engler, 2019). A dilemma therefore arises where employees spend more time on social media engaging in non-work related activities such as creating personal networks, checking on family and friends, streaming and downloading music and video, checking sports results, following social bookmarks among others. This comes at a time when organisations on a global scale have been faced with a multitude of challenges and are looking for different ways to remain competitive. The development of social media policies and internet use policies by most employers is at an early stage as most employers do not have proper policies while some practices have dictated use of arbitrary control and restrictions. It is against this background that this study was designed to specifically identify the various types of social media used by the trainers; analyse the purpose for the use of social media platforms; describe the various methods used by trainers to access social media; and examine the effect of social media on trainers' work performance.

Hypothesis

$H0_1$: There is no significant relationship between some selected personal characteristics of the trainers and the methods used by trainers to access social media.

Methodology

The study was carried out at the Agricultural and Rural Management Training Institute (ARMTI), Ilorin, Kwara State, Nigeria. The state which lies between latitudes 7° 45'N and 9° 30'N and longitudes 2° 30'E and 6° 25'E has two distinct seasons (the wet and dry seasons). Kwara state has 16 local government areas (LGAs). Kwara State is bounded in the North by Niger State and by River Niger; to the East is Kogi State, while it shares boundary with Oyo, Ondo and Osun States in the south.

The Agricultural and Rural Management Training Institute (ARMTI) was established in 1980 as a parastatal of the then Federal Ministry of Agriculture and Natural Resources (FMANR) now Federal Ministry of Agriculture and Rural Development (FMA&RD). The mission of the institute is to improve management training in the agricultural and rural sector, and ultimately improve the quality of rural life. The components of ARMTI's mandate towards achieving this are: provision of management training; provision of consultancy and advisory services; dissemination of management information; contribution to policy development; and conducting applied management research, special and diagnostic studies.

The population of the study was the total number of trainers in the various training departments in ARMTI, which totalled 138. A proportionate stratified random sampling technique was used to select Ninety-seven (97) respondents from all the training departments. Primary data were collected through the use of questionnaires to elicit information from the respondents in order to accomplish set study objectives. The data collected were analysed using descriptive and inferential statistics. The descriptive statistics includes; frequency, percentage, and mean scores while the hypothesis was tested using Chi-square.

Table 1: Sample frame of Trainers at ARMTI

Department	Population	Sample Size (70%)
Training Technology	32	22
Rural Development and Gender Issues	54	38
Agricultural Development Management	52	36
Total:	**138**	**97**

Results and Discussion

Types of social media used

Results in Table 2 reveal the types of social media used by trainers to include, email (100.0%), Whatsapp (97.2%), Facebook (94.1%), Youtube (73.4%), and Instagram (71.9%) accounted for the most accessed social media tools by the trainers in ARMTI. However, blogs (14.5%), Flickr (9.2), Tumblr (2.6%), and Pinterest (1.8%) accounted for the least used social media tools by the trainers. The high level use of email is very commendable and portends the trainers has been a group of overtly conscientious employees because this type of social media is not distractive (Perry, 2019). Also, it is not surprising that Youtube ranked high in the list of social media used by the trainers considering that Youtube offers trainers the ample opportunity to download relevant videos used for class discussion during training activities. However, the high rate of use of WhatsApp, Facebook and Instagram may be worrisome if not dedicated to work related purposes, especially during the office hours (Brown *et. al.*, 2018). The likes of blogs, flickr, tumblr and Pinterest were the least recognised social media in the organisation possibly because their advent into the social media family is more recent and the trainers are just getting to learn them, relative to the other media they were familiar with, which may have satisfied the social need of these trainers to a great extent.

Table 2: Types of social media used

Variables	**Yes (%)**
LinkedIn	39.2
Twitter	61.8
Youtube	73.4
Email	100.0
Whatsapp	97.2
Skype	22.7
Blog	14.5
Flickr	9.2
Facebook	94.1
Pinterest	1.8
Instagram	71.9
Tumblr	2.6
Snapchat	24.5
Tik tok	30.2
WeChat	19.6

Source: Field Survey, 2021

Reasons for Using Social Media

Table 3 shows the different reasons respondents use different social media platforms. Using mean score to rank the reasons according to their order of agreement as indicated by the information received, respondents have the following as their major reasons for using social media: “Connecting with family and friends (MS = 4.28)”, “Chatting and group discussion (MS = 3.82)”, “Download latest music, videos and comedy skits (MS = 3.71)”, “For collaborative efforts with other trainers (MS = 3.63)”, “Sourcing for journals (MS = 3.60)”, “Read electronic magazines/newspapers (MS = 3.58)”, “Networking with other management development institutes (MS = 3.57)”, and “Transfer files, text and make phone calls to colleagues (MS = 3.54)” as they ranked 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, and 8th respectively. The result from table 3 is rather worrisome considering that the first three ranked reasons for respondents’ use of social media were purely personal rather than professional. It can therefore be deduced from the result that the organization will not benefit maximally from their staff’s usage of social media considering their priorities in the usage of social media platforms. The result in table 3 further affirms the stands of Corcoran and Duane (2018) who disagreed that participating in social media at work allowed free sharing of ideas and thus makes employees achieve more as a team. Similarly, Mohamed (2019) argued that when the purpose for using social media during work hours is to socialize, then its usage does not contribute to work productivity.

Table 3: Reasons for using social media

Reasons	Mean	Rank
Knowledge sharing	3.51	10th
Online dating	2.19	15th
Video and picture uploads	2.11	16th
Platform for audio-visual information delivery	2.32	14th
Publish research findings	2.99	11th
Transfer files, text and make phone calls to colleagues	3.54	8th
Video conferencing	1.86	18th
Mobilize stakeholders in agriculture for scheduled meetings	2.11	16th
Attending online trainings	2.44	12th
Reading electronic magazines/newspapers	3.58	6th
Sourcing for research and training materials	3.53	9th
Connecting with family and friends	4.28	1st
Networking with other management development institutes	3.57	7th
Download latest music, videos and comedy skits	3.71	3rd
Chatting and group discussion	3.82	2nd
Online service consultation on social media	2.44	12th
Sourcing for journals	3.60	5th
For collaborative efforts with other trainers	3.63	4th

Source: Field Survey, 2021

Methods Used to Access Social Media

Table 4 shows the methods used by the respondents in accessing social media. Using mean score to rank the methods used to access social media in order of agreement as indicated by the information received, the majority of the respondents' access social media using personal GSM (MS = 4.02) and ranked 1st. Other methods used to access social media are: services from institution's library (MS = 2.39), Patronage of commercial cybercafé (MS = 2.24), and ICT department (MS = 2.21) as they ranked 2nd, 3rd, and 4th respectively.

This finding indicates that many of the respondents in the organisation deployed the use of social media at work mostly in their office using data subscription from their personal phones. This is indicative of the fact the institution has no adequate provision of an enabling environment in the use of social media for improved job disposition and efficiency. This will in turn affect negatively, the performance of these trainers who need to have access to some of these media in order to effectively and efficiently discharge their official duties. This view is in line with Kizgin *et. al.,* (2019) that institutions who create digital platforms to promote knowledge sharing and development through the use of social media are more likely to encourage their staff to achieve organisational goals.

Table 4: Methods used by respondents to access social media

Items	**Mean**	**Rank**
Personal office	1.99	6th
Institutional WIFI	2.02	5th
ICT department	2.21	4th
Services from institution's library	2.39	2nd
Patronage of commercial cybercafé	2.24	3rd
Departmental office	1.89	7th
Using personal GSM	4.02	1st

Source: Field Survey, 2021

Effect of Social Media on Work Performance

Results in table 5 show the perceptions of the trainers about social media. Findings showed that the majority (46.5%) of the trainers strongly agreed that social media was an essential tool used in an organisation to enhance work effectiveness while 50.2% of the trainers agreed that social media enhances their work. Furthermore, table 5 shows that 39.7% of the trainers agreed that Social media promotes moral decadence while about 33.9% strongly agreed that the use of social media gives a sense of fulfilment when used for work and socialisation purposes. Also, 27.1% of the trainers strongly disagreed that social media tends to be a means of distraction to trainers while 38.4% of the trainers strongly disagreed that social media lowers their productivity at work. Furthermore, table 5 shows that 19.2% of the trainers strongly disagreed that using social media for work and socialisation gives them a sense of fulfilment. The result in table 5 implies that respondents viewed social media as very important for their work and this may have positive effects on their work performance such as helping to improve efficiency, increase effectiveness, enhanced staff capacity and skills if managed properly for organisational workforce efficiency in the future. This agrees with the basic findings of scholars who further surmised that social media engenders formation of employees' social capital which further improve knowledge transfer (Cetinkaya & Rashid, 2018). Odoom *et. al.,* (2017) reported in their study that organisations that use social media in the workplace tended to report high satisfaction with their employees' job performance. This further underscores the fact that the importance of social media at the workplace cannot be over-emphasize so long organisations are able to put in a check and balance measure to check the abuse of social media during work hours. Also, Ali-Hassan *et. al.,* (2017) pointed out in their study that social and cognitive use of social media had a positive effect on an employee's routine and on innovative job performance while the hedonic use of social media had a negative effect on routine performance. Social media can therefore facilitate interactions which builds closer friendship and trust as well as commonality of opinion towards improvement of work attitude for organisational development.

Table 5: Effect of social media on respondents' work performance

Statements	Mean	SD
They distract trainers when at work	2.91	1.16
Social media usage can be frustrating	1.99	1.02
It enhances my work as a trainer	3.72	1.33
It is an essential tool in the organisation	4.36	0.89
It negatively influence my concentration at work	1.78	1.14
They lower productivity of trainers	2.69	0.99
I think social media should be blocked by ARMTI's ICT division	1.54	1.06
They give sense of fulfilment when used for work and socialization purpose	3.57	1.27
Improves one's efficiency in computer usage	3.51	1.15
Social media aid in research work	3.54	0.84
Social media promotes moral decadence	3.66	1.02

Field survey, 2021

Test of Hypothesis

The results from table 6 show that there is no significant relationship between sex ($\chi 2=10.22$) and the methods used by trainers in accessing social media. The implies that sex does not determine the usage of social media in the study area. Also, a significant relationship exists between religion (χ 2=7.992), marital status (χ 2=17.45) rank (χ 2=19.33) and the methods used by trainers in accessing social media. The result shows that marital status, religion and rank are highly related to the methods used by trainers in accessing social media in the study area. The rank of an individual has influence on the methods of accessing social media to accomplish organisational goals, lower cadre staff tend to use social media more for job accomplishments (Brown *et. al.*, 2017).

Also, an inversely significant relationship exists between Age (R = -0.266*) and work experience (R= -0.36*) of respondents relative to the methods used in accessing social media. Age and work experience have been adjudged as important factors affecting the methods used in accessing social media in academic organisations (Cetinkaya and Rashid, 2018).

Table 6: Relationship between personal characteristics of respondents and the methods used by trainers in accessing social media

Variable	Chi-square	df
Sex	10.22	4
Marital status	17.45*	8
Religion	7.992*	6
Rank	19.33*	14
	R	
Age	-0.266*	
Work experience	-0.36**	

Source: Field Survey, 2021
***p ≤ 0.05**

Conclusion and Recommendations

The study concluded that the use of social media is an essential tool that enhances the work performance of employees in the study area. Factors which affect methods used in accessing social media among trainers are marital status, religion and rank as well as age and work experience. The following suggestions for future undertakings were recommended in light of the study's results and conclusions:

- Policy makers and executives of organisations therefore, need to enhance the work environment with the use of social media to improve trainers' efficiency especially in the area of gathering training materials to training sessions while ensuring that distractions of workers arising from social media usage are reduced to the barest minimum, for improved effectiveness and efficiency of the workforce.
- Furthermore, owing to the importance of social media in the workspace as revealed in the study, it becomes imperative for the management of the institute to work at ensuring every staff of the institute own an official laptop with fully functional internet facility. This will no doubt help to enhance efficiency and improve the effectiveness of work carried out by the trainers.

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About the Journal

Ethiopian Journal of Agricultural Science (EJAS) is the flagship journal of agricultural science in Ethiopia published since 1979.

Aims and Scopes

The Ethiopian Journal of Agricultural Sciences (EJAS) publishes papers of original scientific work related to strategic, applied and interdisciplinary studies in all aspects of agricultural science as well as reviews of scientific topics of current agricultural relevance. Specific topics of interest may include all aspects of crop and animal production; farm animal welfare and behavior; soil science and soil health; plant and animal product quality; agricultural engineering solutions; decision support systems; land use; environmental impacts of agriculture; agroforestry systems relates to agriculture; impacts of climate change; climate change adaptation and mitigation; climate-smart agriculture; carbon sequestration; rural biodiversity; experimental design and statistical analysis; and the application of new analytical and study methods, including genetic diversity and molecular biology approaches. All manuscripts submitted will be judged from the standpoint of scientific originality and subject matter.

Manuscripts should not have been published in other professional journals or simultaneously submitted to another such journal with the exception of theses and research and development project reports.

Frequency of Publication

Since January 2020, four issues are published per year (January, April, July and October) by Ethiopian Institute of Agricultural Research (EIAR).

Information for Contributors

1. Manuscript types

1. Research articles

These papers treat both basic, applied, and action research findings related to Ethiopian agriculture. Articles from regional and international sources covering tropical and sub-tropical agriculture may also be considered for publication.

2. Review articles

Included here are scientific papers covering advances in various fields of agricultural research and development. Normally, review articles are prepared by experts in selected fields through communication with the Editor of the Journal. Review papers should be prepared based on a specific guideline.

3. Short communications

Short Communications are short papers that present original material for rapid dissemination. Short Communication may include a new finding that is expected to have a significant impact. Include development of new materials, new methods, etc.

4. Technology registration

Registration of agricultural technologies (varieties and prototypes) is also accepted for publication in *EJAS*. Technology registrations are details reports of the variety registration process and all the results.

2. Guidelines

1. General

Language

Manuscripts should be written in English, and all manuscripts submitted should be double checked for grammatical and spelling errors.

Peer review process

All articles submitted to EJAS will be subject to peer reviews by two qualified reviewers selected by the Editorial Team. Manuscripts which do not fully comply with the EJAS requirements will be **“desk rejected”.**

Reviewers shall be invited for a period of one month, and with request from the reviewer, an extra time might be provided. **“Reject” or “Revise”** decisions shall be made based on the assessments made by the reviewers and the Editorial Team. Revised manuscripts will be copy edited and “Proofs” will be sent to the author once. Proofs should be read carefully and returned to the Editorial Office within one month of receipt.

Additional note: Only manuscripts that have not been previously published can be accepted. A cover letter must state that the manuscript is new and original and not under consideration for publication elsewhere. Papers pending in other journals will not be considered. Co-authors should be individuals who have contributed substantially to the content of the paper.

2. Format for manuscripts

Layout of material in submitted manuscripts should conform to an acceptable standard editorial style. The manuscript should be written in double lines with Font: 12 points in Times New Roman.

1. **Title**

The title should clearly reflect the content of the manuscript. It should be concise, specific, and descriptive enough to contain keywords or phrases the contents of the article. Maximum 100 characters without space, or 120 characters including spaces.

2. **Author and institution/Affiliation.** The name(s) of the author(s) and the institution, with which they are affiliated, along with the addresses, should be provided. Names should include first name and surname or first name and father's name for Ethiopians.

3. **Abstract.** An abstract reflecting significant findings of the study is required. The abstract should not exceed 200 words and must be an informative type that includes the rationale, objectives, methods used, results, and conclusion. The abstract should be *italicized*. Abbreviations should be avoided in the abstract. Not more than five keywords, each word or phrase separated by semi-colon, should be included with the abstract.

4. **Introduction.** This part of the paper should state the context, justification or underlying hypothesis for doing the work and the major research objectives under investigation. The author should precisely present the problem statement and anchor it on a brief review of the literature, a summary of relevant, up-to-date publications in the field. The research gap and the contribution of the paper should be provided taking recent previous studies into account.

5. **Material and Methods.** A brief and concise description of the conditions under which the investigation was carried out and the procedures, techniques, and experimental designs used. Make sure that this section can convince the readers that your work is valid. Also make sure that other researchers can use your methodology to guide his or her own experiments.

6. **Results and Discussion**. The major findings and assessment of the significance of the results and possible practical implications are discussed with reference to the problems indicated in the introduction or stated as objectives. In this section you discuss important findings and compare your results with other published works. **Do not present your results and discussion in separate sections**.

7. **Conclusion:** In this section restate your hypothesis or research question; and restate your major findings. Briefly state what contribution your study has made to the body of knowledge. Clearly highlight strengths and limitations of the study. Future research questions/recommendations based on your findings. The author needs to present the objective, the key findings, the conclusions and finally policy and practical implications drawn from the conclusion.

8. **Acknowledgments**. Acknowledgments given in a separate section immediately following the results and discussion. The donors should be properly acknowledged and the grant numbers (or project codes) should be included in the acknowledgement.

Contributors to the research should be properly acknowledged if they are not entitled to the authorship.

9. **Contribution of Authors**. Authorship should be based on a substantial contribution to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; and drafting the work or revising it critically for important intellectual content; and agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Corresponding authors should present the contribution of each author in this subsection. Each author should sign on the cover letter before the manuscript is submitted.

3. References and citation

1. Inline citation

Single author: (Abbot, 1925)

Two authors: (Abdul Rahman and Ellis, 2019)

More than two authors: (Akpo *et al*. 2021)

2. Reference

Journal Article

Abbot, W. S. 1925. A method of computing the effectiveness of insecticides. J. Econ. Entomol. **18(2):265–267. (include "doi" if any)**

Abdul Rahman, S., and R. Ellis. 2019. Seed quality in rice is most sensitive to drought and high temperature in early seed development. Seed Sci. Res. **29(4):238–249. (include "doi" if any)**

Book

Akpo, E., C. O. Ojiewo, I. Kapran, L. O. Omoigui, A. Diama, and R. K. Varshney (eds.). 2021. Enhancing Smallholder Farmers ' Access to Seed of Improved Legume Varieties Through Multi-Stakeholder Platforms. Springer Nature Singapore Pte Ltd, Singapore.

Chapter in a book

Bernanke, J., and H. Köhler. 2008. The Impact of Environmental Chemicals on Wildlife Vertebrates. Pages 1–47. *In :* D. M. Whitacre(ed.) *Reviews of Environmental Contamination and Toxicology*. Springer Science + Business Media, LLC 2008.

Paper in a proceeding

Abebe, M. 2019. An investigation into the cause of wilt in cotton. p. 129-139. *In: Proceedings of Symposium on Cotton Production under Irrigation in Ethiopia*. Melka Werer, Ethiopia, 21-22 October 2019. Ethiopian Institute of Agricultural Research, Addis Abeba.

Unpublished and other source materials should not be included in the reference list but could be mentioned in parentheses in the text or as a footnote Abbreviate periodical names should be according to accepted standards.

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1. **Margins**: Leave margins of 2.5 cm at the top, bottom, and sides of each page.
2. **Lines**: All lines in the body text should be double spaced and should be numbered. **Manuscripts with unnumbered lines and pages will not be considered for further processing.**
3. **Word Counts:** Normally word counts should be between 5,000-12,000 words including, illustrations, tables, endnotes, and references.
4. **Pagination:** All pages should be numbered appropriately.

5. Headings and captions

Main text headings should be centered and typed in initial capitals. Sub-headings are typed in sentence style and placed on the left-hand margin.

6. Photographs and Illustrations

Photographs should be high resolution (600 dpi) graphical illustrations should not be less than 300 dpi. All artwork submissions should be in JPEG (for photographs) or PNG (for illustrations) formats. Captions for photographs and illustrations should be typed, separately and identified by inclusion of the figure numbers. All illustrations should be cited in the text**. Do not include deformed photographs.** Illustrations should be presented next to their initial citations.

7. Tables

Tables should facilitate comparisons, reveal relationships, and save space. Do not repeat information in the text presented in the tables or in charts or graphs. Tables should be numbered consecutively as Table 1, Table 2, etc., in the order in which they are first cited in the text. Each table, with its heading, should be typed on a word processing. Only plain tables (not Table Grids) are acceptable. Tables should be presented next to their first citations.

8. Units

All measurements are to be reported in SI units. For example, do not use quintal (q) but kg or t instead.

9. Thesis based papers

Papers based on the thesis should be presented with the thesis adviser as coauthor and should indicate the institution, the year the work was done, and the full title of the thesis.

3. Submission

Your submission should include a cover letter signed by the corresponding author and all co-authors. A submission that does not include the consent of all the co-authors shall not be considered for further processing. Your cover letter should clearly state that the manuscript is previously not published or being considered for publication in any academic journal.

Submit a single document in Microsoft word format, with all illustrations placed at their appropriate positions.

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