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Original Research Article||

Response of food barley (*Hordeum vulgare* L.) to split application of lime in acidic Nito-Soil at Gummer District, Southern highland of Ethiopia

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Abstract

Soil acidity is a barrier to agricultural production in areas with heavy rainfall, leading to reduced crop yields in acid soils. A fixed plot field investigation was conducted to evaluate the influence of split application of recommended lime rate, based on exchangeable acidity, on yield and yield attributes of barley in acidic soils over three cropping seasons (2018, 2019 and 2020). Four level splits of lime (full dose of required applied at onetime, split in to two applied 50% in 1st and 2nd year, 50% in first and third year, split in to three applied 33% in every year) laid in randomized complete block design with three replications. Over years mean of grain yield was not statistically significant ($p < 0.05$) by split application of recommended amount of lime compared to one time application of full dose. The results revealed that the highest yield was recorded in all plots treated with lime while the lowest yield was recorded in the un-limed treatment. The highest yield (5.67 ton ha^{-1}) was recorded from full lime dose plant while lowest yield (2.4 ton ha^{-1}) recorded from control. Resource poor farmers who cannot afford the full dose of lime can split it into two or three applications annually, achieving similar yields to single full dose application. The increased yield of limed treatments might be attributed to rising of soil pH and making supplied nutrients plant-available.

Key words: Barley, lime, soil acidity, yield

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INTRODUCTION

Soil acidity is a complex process caused by the excessive concentration of non-soluble and toxic ions in the soil solution, which acts as a barrier to agricultural production in areas where heavy rainfall causes nutrient losses through leaching and soil erosion. Crop yields are frequently reduced by 50% in acid soils and can drop to zero even with the application of the optimum rate of NP fertilizers (Haile and Boke, 2011). Increasing soil acidity trends may lead to reduced yields, stunted plant growth and development, poor nodulation of legumes, and increased incidence of diseases. It can also result in poor water use efficiency due to nutrient deficiencies and imbalances, as well as induced aluminum and manganese toxicity (Kisinyo et al., 2014). Soil acidity and exchangeable Al^{3+} in arable and abandoned lands are attributed to intensive cultivation and continuous use of acid-forming inorganic nitrogen fertilizers (Deressa, 2013). According to Haile, *et al*., (2009), the Guragie district areas are severely affected by soil acidity. The severity of acidity has induced farmers to shift to producing oats, a crop more tolerant to soil acidity than wheat and barley (Deressa, 2013). The poor performance of crops that induced by acidic soils might be due to acidity decreasing plant growth owing to the unavailability of nutrients (P, Ca and Mg) and toxicity of some trace elements (Caires, *et al.*, 2005). Application of lime in the form of $CaCO_3$, CaO, and Ca $(OH)_2$ is becoming an adequate practice to reclaim acid soils. The main effect of liming is the neutralization of exchangeable H^+ and Al^{3+} and increasing the degree of base saturation and pH values. The decrease in exchangeable Al^{3+} and Mn^{2+} and the high reduction in Al activity in the soil solution is believed to be the main reasons for the frequently observed crop yield improvements as a result of liming acid soils (Fageria and Baligar, 2008). Many small-scale farmers of the country depend on acid soil for their day today livelihoods, thereby liming is a vital and commonly used to be enhancement of acid soil productivity. However, lime is not obtained for free and it is not easily available. Large quantities may be required for highly affected areas, and its transportation is also difficult. Therefore, the present study has been initiated to determine the efficiency of split application of lime on yield and yield attributes of barley under rain-fed conditions in acidic soils at Gumer District, Southern Highlands of Ethiopia, over three consecutive main cropping seasons (2018, 2019, and 2020).

MATERIALS AND METHODS

Description of the Study Area

A field experiment was carried out consecutive main cropping seasons for three years (2018, 2019, and 2020) under rain fed conditions at Gumer Woreda, Guraghe Zone, Southern Nations Nationalities and Peoples' Regional State of Ethiopia. Experimental site is situated at 7°59'26.2"N and 38°05'28.3"E, and at altitude of 2952 meters above sea level with temperature of min 7.5% and max 20%. The area receives a bimodal rainfall with an annual average rainfall of 1200 mm. Rainfall is distributed between the short rainfall season (March to April) and the main rainy season (June to September). Mixed crop-livestock farming is the dominant economic activity in the rural areas.

Experimental design and treatments

An HB-1307 variety of barley was used in the experimentation and was sown by drilling seed rate of 150 kg·ha^{-1}; 20 cm spacing between rows and a plot size of 3mx3m. The experiment was laid out in randomized complete block design (RCBD) with three replications. Six levels of treatments (100% required amount of lime applied one time, 50% applied in 1st and 2nd year, 50% applied in 1st and 3rd year, 33% in every year, 92 Nitrogen 69 phosphorus kg ha-1, and Control). Good quality commercial grade agricultural lime ($CaCO_3$) with 98% neutralizing value and <250 µm in diameter was used. Lime requirement of the soil was calculated based on its exchangeable acidity (Al^{3+} and H^+) adapted from Kamprath, (1984). Lime was broadcasted uniformly and incorporated into the soil a month before planting (Mosissa, et al., 2019). Recommended rate of 92 Nitrogen, 69 phosphorus kg ha-1 were uniformly applied every year for all treatments except control. Urea was used as the source of N and its application was made in two splits: half at sowing and half at tillering stage while the entire rate of phosphorus was applied at sowing in a band. The experimental plots were kept permanent throughout the investigation.

Physicochemical Soil Characteristics

Before beginning experiment, experimental field was characterized for selected soil physical and chemical properties. Soil samples were collected from 0-15 cm depth for initial determination of soil fertility parameters. The soil samples were analyzed for pH, available phosphorus, exchangeable acidity, % Nitrogen, and % Organic carbon.

Table 1. Chemical and physical properties of soil prior to planting.

Descriptors	Levels
pH	4.8
EA	2.69
Ex H	1.6
BD	0.99
% OC	1.1
% TN	0.094
Ava. P (ppm)	1.28
CEC (cmol kg^{-1})	41.2
Textural Class	
Sand (%)	70
Clay (%)	14
Silt ((%))	16
Texture	Sandy loam

Agronomic data Collection

Different agronomic parameters such as plant height, spike length, tillers number was measured in (cm) from five plants sampled randomly from the central rows. Above ground dry biomass yield was weighed and grain yield was taken by threshing the harvested plants adjusted to 10% moisture.

Statistical data analysis

Data collected from the crop were subjected to analysis of variance using SAS version 9.0 software packages and mean separation was done using LSD (Gomez and Gomez, 1984) at 5% probability level.

RESULTS AND DISCUSSION

Physicochemical Properties of the Soil

Over the years, the mean data showed that split application of lime did not significantly affect barley grain yield at this study location ($p < 0.05$). Splitting the lime into three, two, or a full dose did not significantly affect barley grain yield throughout the entire experiment. Split application of lime into consecutive years gave similar grain yield with full rate application of lime. While compared to control, all split and full dose of lime application treatments gave significant yield in the consecutive years whereas the highest yield was recorded from full dose lime application in the first year. However, during the consecutive years, all split treatments resulted in similar grain yields compared to the full dose. The increased yield of barley treated with lime is due to the yearly application of lime, which increases nutrient availability and gradually increase pH and the buffering capacity of the soil, enhancing P release. Result revealed that splitting the required amount of lime into 33% and 50% is possible if to be grown on this soil. This result agrees with with those reported by Negese et al. (2022) and Dawid and Hailu (2017) who reported split application of lime in to 25%, 33%, and 50% was not significantly affected the yield of soybean compared with full dose application of lime. The finding of Anetor and Ezekiel (2007) also showed that lime increases pH and available P. Liming can increase soil pH and alter soil physical, chemical and biological properties. Therefore, resource poor farmers who cannot afford the full dose lime can split in to two, three and apply every year without yield loss significantly compared to one time application of full dose. Lime alone cannot boost crop production. Therefore, for increased production, the recommended amount of fertilization should be incorporated with lime. Induced declining the yield of plants that treated with only inorganic fertilizers might be phosphorus fixation nature of acidic soils.

Table 2. After treatment application or residual effects of lime on soil physicochemical properties

Treatments	pH	Ex. Acidity	Ava. P	%N	%OM
T1: Control	4.8	2.8	4.36	0.26	5.9
T2:92N 69P	4.75	2.85	4.4	0.27	6.0
T3: Full dose lime	5.4	1.6	5.5	0.29	5.8
T4: 50% (1st and 2nd year)	5.3	1.5	5.8	0.28	5.95
T5: 33% every year	5.35	1.3	6.1	0.26	6.1
T6: 50% (1st and 3rd year)	5.3	1.2	5.9	0.3	6.16

By the splitting application of lime above ground bio mass was not statistically affected ($p<0.05$) compared with full dose lime application in study area whereas limed treatments gave statistically highest biomass as compared to un-limed. Application of splitting lime i nto 33% and 50% and full dose treatments increased dry matter of barley. The increased biomass may be due to lime application release essential nutrients whi ch are un-available in acid soil and make it plant-avai lable nutrients. This finding agreement Dawid and H ailu (2017) who revealed that splitting application of lime was not statistically affected ($p<0.05$) yield and yield attributes of soy bean compared with full dose lime application.

Plant Height

Plant height was not significantly ($p < 0.05$) affected by the treatments during experimentation by splitting lime. But highest plant height was recorded from all limed plants whereas lowest plant height (cm) was recorded from un-limed treatment. The increased plant height of barley could be lime application attributed to rising of soils pH there by resulting vigor growth.

Tiler number and spike length

Tiller number and Spike Length also was not significantly ($p < 0.05$) affected by the split application of lime whereas significant difference was recorded from between limed and un-limed plants. The highest tillers and spike length was scored from all lime treatments. Similarly, Dawid and Hailu (2017) confirmed that application of splitting lime into 33% and 50% is and full dose treatments was not significantly ($p < 0.05$) increased growth parameters of soybean. While lime application was significantly ($p < 0.05$) affected growth parameters compared to un-limed due to applied lime ameliorate acid soil fertility status.

Table 3. Split application effect of lime affected yield and yield parameters of barley in 2018

Treatments	Plant height(cm)	Tiller Number	Spike Length (cm)	Biomass ton ha^{-1}	Grain yield ton ha^{-1}
T1: Control	76b	2.7c	4.6c	5.0c	1.66d
T2: 92N 69P kg/ha	115a	3.9b	5.6bc	8.6b	3.85c
T3: Full dose lime	123a	5.5a	7.2a	14.073a	6.28a
T4: 50% (1st and 2nd year)	112a	4.5b	6.8a	13.11a	5.72ab
T5: 33% every year	110a	3.9b	6.7a	12.77a	5.093b
T6: 50% (1st and 3rd year)	106a	4.6b	7.2a	12.223a	5.613ab
Mean	107	4.2	6.38	10.96	4.7
LSD (0.05)	17	0.83	1.36	3.23	0.75
CV (%)	9.18	10.77	11.72	16.23	8.85

Means with in a column with the same letter(s) are not significantly different at 0.05 probability level.

Table 4. Split application effect of lime on yield and yield parameters of barley in 2019

Treatments	Plant height(cm)	Tiller Number	Spike Length (cm)	Biomass ton ha^{-1}	Grain yield ton ha^{-1}
T1: Control	90b	3.6b	2c	10.24c	2.72c
T2: 92N 69P kg/ha	100ab	5.4a	3.9b	15.49b	5.0b
T3: Full dose lime	110ab	5.6a	5.4a	19.16a	6.57a
T4: 50% (1st and 2nd year)	120a	5.2a	4.4ab	18.13ab	6.24a
T5: 33% every year	110ab	5.2a	4.4ab	19.20a	6.57a
T6: 50% (1st and 3rd year)	100a	5.4a	4.5ab	17.64ab	6.42a
Mean	105	5.1	4.14	16.64	5.49
LSD (0.05)	24	1.12	1.2	2.82	0.82
CV (%)	12.3	12.1	16	9.33	8.7

Means with in a column with the same letter(s) are not significantly different at 0.05 probability level.

Table 5. Split application effect of lime on yield and yield parameters of barley in 2020

Treatments	Plant height(cm)	Tiller Number	Spike Length (cm)	Biomass ton ha^{-1}	Grain yield ton ha^{-1}
T1: Control	81b	3.1b	4.1b	7.48c	2.58c
T2: 92N 69P kg/ha	112a	5.2ab	5.5a	13.25b	3.85b
T3: Full dose lime	118a	5.6a	5.9a	16.17a	5.33a
T4: 50% (1st and 2nd year)	114a	5.8a	5.8a	16.03a	4.84a
T5: 33% every year	114a	6.4a	5.3a	16.14a	4.96a
T6: 50% (1st and 3rd year)	106a	6.3a	5.5a	15.92a	5.33a
Mean	107	5.4	5.3	14.06	4.44
LSD (0.05)	19	2.29	1.14	2.1	0.9
CV (%)	10.1	23	11.7	8.3	11.1

Means with in a column with the same letter(s) are not significantly different at 0.05 probability level.

Table 6. Combined Mean of barley affected by split application of lime on yield and yield parameters of barley

Treatments	Plant height(cm)	Tiller Number	Spike Length (cm)	Biomass ton ha^{-1}	Grain yield ton ha^{-1}
T1: Control	82c	3.1b	3.6d	7.57c	2.32c
T2: 92N 69P kg/ha	110ab	4.9a	4.9c	12.45b	4.23b
T3: Full dose lime	117a	5.6a	6.2a	16.47a	5.98a
T4: 50% (1st and 2nd year)	116ab	5.2a	5.7ab	15.75a	5.60a
T5: 33% every year	112ab	5.2a	5.5bc	16.04a	5.54a
T6: 50% (1st and 3rd year)	106b	5.4a	5.7ab	15.26a	5.79a
Mean	107	4.9	5.3	13.92	4.91
LSD (0.05)	10	0.95	0.66	1.41	0.69
CV (%)	10	20	13.18	10.68	14.9

Means with in a column with the same letter(s) are not significantly different at 0.05 probability level.

CONCLUSIONS

Application of lime over the years, at the rate determined by exchangeable acidity, combined with mineral NPS fertilizer, improves grain yields. Without significant yield loss, splitting lime into 33% and 50% and applying it over three and two consecutive years, respectively, resulted in similar yields to the full rate of lime applied once in the first year. Therefore, resource poor farmers who cannot afford full dose lime could split up to one-third and can cultivate crops under acid soil at study area and as well as similar agro-ecologies. These preliminary results recommend the use of lime split in combination with mineral fertilizers to increase barley yields. Furthermore, research needs to be conducted to investigate the residual effect of split and full-dose applications of lime on the physico-chemical properties of acidic soil.

CONFLICTS OF INTEREST

Authors declare that there are no conflicts of interest regarding the publication of this paper.

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REFERENCES

Anetor, Mercy Omogbohu and Ezekiel Akinkunmi Akinrinde(2007). Lime effectiveness of some fertilizers in a tropical acid alfiso. University of Ibadan, Ibadan, Nigeria.

Caires, E.F., Alleoni, L.R., Cambri, M.A. and Barth, G., 2005. Surface application of lime for crop grain production under a no-till system. Agronomy Journal, 97(3): 791-798.

Dawid, J. and Hailu, G., 2017. Application of lime for acid soil amelioration and better soybean performance in southwestern Ethiopia. J. Biol. Agri. and Healthcare, 7(5): 95-100.

Deressa, A., 2013. Evaluation of soil acidity in agricultural soils of smallholder farmers in South Western Ethiopia. Science, Technology and Arts Research Journal, 2(2): 01-06.

Fageria, N.K. and Baligar, V.C., 2008. Ameliorating soil acidity of tropical Oxisols by liming for sustainable crop production. Advances in agronomy, 99: 345-399.

Haile, W. and Boke, S., 2011. On-Farm verification of lime and NPK fertilizers effects on the tuber yield of Irish potato (Solanum tuberosum) on some acidic soils of Southern Ethiopia. Journal of Drylands, 4: 283-288

Haile, W., Boke, S. and Box, P., 2009. Mitigation of soil acidity and fertility decline challenges for sustainable livelihood improvement: research findings from southern region of Ethiopia and its policy implications. Awassa Agricultural Research Institute.

Gomez K. A. and Gomez A. A., 1984. Statistical procedures for agricultural research. John Wiley & Sons.

Kamprath, E.J., 1984. Crop response to lime on soils in the tropics. Soil acidity and liming, 12: 349-368.

Kisinyo, P.O., Othieno, C.O., Gudu, S.O., Okalebo, J.R., Opala, P.A., Ng'Etich, W.K., Nyambati, R.O., Ouma, E.O., Agalo, J.J., Kebeney, S.J. and Too, E.J., 2014. Immediate and residual effects of lime and phosphorus fertilizer on soil acidity and maize production in western Kenya. *Experimental agriculture*, *50*(1), pp.128-143).

Mosisa, F., Balemi, T. and Keneni, G., 2019. Effect of lime rates and incubation periods on the amelioration of acidic nitisols of Bedi area in Ethiopia. *Journal of Agricultural Science and Soil Sciences*, *7*(7), pp.087-093.

Negese, W., Mosisa, T. and Mulugeta, G., 2022. Split Application of Lime for Acid Soil Amelioration and Better Maize Yield at Yubdo Districts West Wollega Zone, Oromia, Ethiopia. population, 77.

Original Research Article||

Performance evaluation of improved maize (*Zea mays* L.) varieties in Debub Ari District, Southwestern Ethiopia

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Abstract

A field experiment involving seven improved and one local maize variety was carried out in Debub Ari District during the 2018 to 2020 main cropping seasons to identify the best-performing variety for the midland areas of the South Omo Zone. The midland maize varieties included in the field experiment were seven improved varieties (SBRH, SPRH, Gibe-2, Gibe-3, BH546, BH547, BH548) and a local check. Growth parameters and yield and yield components were recorded and analyzed. The analysis of variance results showed significant variations among the maize varieties for all the tested traits. The longest plant height (258.67 cm) was observed for the variety SBRH but is at par with all the other varieties except the shortest (203.5) for GIBE-2. The highest ear length (26.5 cm) obtained from the variety BH548, while the lowest (21.5 cm) was from the local check. The highest hundred seed weight (39.85g) was obtained from the variety BH547, whereas the SPRH variety with 32 (g) is the least. The highest grain yield (8428.2 kg ha^{-1}) was recorded for the improved variety BH546 whereas, 6064 (kg ha^{-1}) for the local check was the least. In this study, yield advantages of 28.05% and 19.21% were obtained from the improved maize varieties BH546 and BH547, respectively, performing way better than the local check. Therefore, it can be concluded that the use of improved maize varieties, such as BH546 or BH547, is recommended and could be suitable for midland maize production in the study area, although further testing is needed to support the recommendation.

Key words: Growth parameters, grain yield, mid land maize, variety

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INTRODUCTION

Cereal production is the livelihood for millions of households in Ethiopia and is the largest sub-sector within the country's agriculture, far surpassing all others in terms of rural employment, agricultural land use, calorie intake, and contribution to national income (Shahidur, 2010). Maize (*Zea mays* L., 2n=20) is an important cereal crop belonging to the tribe *Maydeae*, of the grass family, *Poaceae*, genus *Zea* and species *mays* (Piperno and Flannery, 2001). Maize accounts for 15-56% of the total daily calories of people in developing countries in sub-Saharan Africa. Maize is currently produced on nearly 100 million hectares in 125 developing sub-Saharan African countries and is among the three most widely grown crops in 75% of those countries (FAOSTAT, 2010). The crop is largely produced in Western, Central, Southern and Eastern parts of Ethiopia. In 2014/2015, cropping seasons 2,114,876 hectares of land was covered with maize with an estimated production not less than 72350 ton (CSA, 2015). In Ethiopia, maize is produced primarily for food, especially in major maize-producing regions, and is a staple food for low-income groups. Maize is consumed as injera' porridge, bread and *nefro*. It is also consumed roasted or boiled as vegetables at sweet stage. In addition, it is used to prepare *Tella* and *Arekie* (local beverages). The leaf and stalk are used for animal feed and dried stalk and cob are major fuels for the rural community. Maize is also used as industrial raw material for oil and glucose production (MARD, 2014). Maize holds a unique and exceptional position in world agriculture as food, feed for livestock, and as a source of diverse, industrially important products. Maize grains have great nutritional value as they contain 72% starch, 10% protein, 4.8% oil, 8.5% fiber, 3.0% sugar and 1.7% ash. It is also used in the manufacturing of starch, corn flakes, alcohol, salad oil, soap, varnishes, paints, printing, and similar products (Ahmed, 2000). Maize is one of the most important cereal crops in midland areas of the southern region in general and in midland areas of the South Omo zonal administration in particular. Its production is common in midland areas of South Omo zone, especially in Debub Ari district. Even though the crop is important in the target area, some factors constrained the productivity of maize in the target areas. Advancing the improvement of crop productivity in different localities can be achieved, through testing the adaptability of crop technologies. Keeping this in view; the present study was conducted to evaluate the performance of recently released midland maize varieties for their adaptability.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at Aykamer kebele in Debub Ari District during the main cropping seasons (July to November 2018 to 2020) under rained conditions. The study site is located at an altitude of 1645 meters above sea level (masl) with geographical coordinates of longitude 036°34' 35.0'' E and latitude 05°54' 97.4" N. The location is found north at eastern direction 18 km from Jinka town (principal city of the south Omo Zone). The study site has a bi-modal rainfall pattern with the shorter rainy season from March-May and the longest rainy season from August through November. The total annual rainfall is 1852.2± 250.7 mm. The annual mean minimum and maximum temperatures are 15.5±0.9°C and 18.7 ± 1.4°C, respectively.

Treatments and Experimental Design

The experiment was executed by using seven improved and one local maize variety. Field experiment was laid out in a randomized complete block design (RCBD) with three replications. The experimental field was well prepared by plowing three times as conventional tillage practice. Sowing was done by row with two seeds per hole at 0.75 m between rows and 0.25 cm between plants within rows. The seeds were planted immediately after the onset of the main rainy season ensuring an adequate soil moisture level for good germination and seedling development. NPS and urea fertilizers were applied at the rate of 100 kg ha^{-1} and 200 kg ha^{-1}, respectively. NPS fertilizer was applied once at planting time, while urea was applied in split, half at planting and the remaining half at knee height. Weed management practices were done three times based on the recommendations. Pests were controlled using recommended chemicals, harvesting was manually done. Hundred seed count was done by seed counter machine (grain seed counter machine) and grain yield and hundred seed weight were measured by sensitive weighing balance.

Data Collection

Data was recorded on five plants from each plot for yield related traits viz; plant height (cm), ear height (cm) and ear length. The grain yield (kg ha^{-1}) and 100 grains weight (g) were calculated for the entire plot.

Data Analysis

The collected data (plant height, ear height, ear length, grain yield and hundred seed weight) were subjected to Analysis of variances (ANOVA) using the General Linear Model (GLM) procedure of Statistical Analysis System (SAS) software (SAS Institute 2002). Significant differences between and among treatment means were delineated by using LSD (least significance difference at 5% level of significance)

RESULTS AND DISCUSSION

The result showed that there were significant differences among the tested varieties for all the studied traits (Table 1). Among the tested varieties, the maximum plant height was recorded for SBRC (258.67 cm) and the minimum plant height was corresponded to Gibe -2 (203.5 cm). The result from the present study agreed with the report of Tahir et al. (2008), who reported that plant height is genetically as well as environmentally controlled. The maximum and the minimum ear height were recorded for BH547 and BH548, respectively. These results get sufficient validation from the findings of Nazir, (2010) and Sahibzada, (2011). Moreover, the maximum and the minimum ear length were recorded for BH546 and local check, respectively. As presented in Table 1, significant differences were observed for grain yield among different varieties used in this study. BH546 and BH547 showed higher grain yield (8428 kg ha^{-1} and 7506 kg ha^{-1}), respectively. The local variety produced lower grain yield (6064 kg ha^{-1}) than the other tested varieties. Grain yield ranged from 6064 (kg ha^{-1}) for the local check to 8428 (kg ha^{-1}) for the improved variety - BH546. In this study, yield advantages of 28.05% and 19.21% were obtained from the improved maize varieties: BH546 and BH547, respectively over the local check. It was noted that the improved midland maize varieties: BH546 and BH547were the best performing cultivars than the other varieties under study in the study area.

Table 1. The combined mean square value for growth parameters, yield and yield components of maize affected by variety at Ayikamer Keble in Debube Ari District during 2018 and 2019

SOV	DF	PH	EL	EL	HSW	GY
Variety (v)	7	1730**	578.559***	10.559***	39.35***	293425***
Replication (R)	2	ns	ns	ns	ns	ns
Year (Yr)	1	29205***	ns	ns	ns	ns
Variety X Year (VxYr)	7	ns	9.2837	ns	ns	ns

Note: DF =degree of freedom, SOV = source of variation, PH= plant height, EL = ear length, EH= ear height, HSW = hundred seed weight, GY= grain yield, ns = non- significant. significant at 0.05, ** significant at 0.01 and *** significant at 0.001 level of significance*

Table 2. The combined mean value of yield and yield components of maize varieties at Ayikamer Kebele, in Debub Ari district, during 2018 to 2020.

Variety	PH (cm)	EH (cm)	EL (cm)	GY (kg/ha)	HSW (g)
SBRH	258.7[a]	126.16[a]	24.66[b]	6710[bc]	39.00[a]
GIBE-2	203.5[c]	104.5[bc]	23.00[c]	64510[c]	37.00[abc]
BH547	239.8[ab]	130.83[a]	22.33[cd]	7506[b]	39.85[a]
GIBE-3	239.7[ab]	122.16[ab]	22.83[cd]	6167[c]	36.25[bc]
BH546	245.2[a]	120.5[ab]	25.50[ab]	8428[a]	37.91[ab]
BH548	222.6[bc]	101.83[c]	26.50[a]	6424[c]	34.16[cd]
G-3	239.7[ab]	122.16[ab]	22.83[cd]	67617[c]	36.25[bc]
Local	248.8[ab]	125.50[a]	21.50[d]	6064[c]	38.00[ab]
CV	7.86	12.94	5.17	10.59	7.26
LSD (5%)	21.97	18.03	1.43	849.5	3.15

Note: Means with the same letters within the columns are not significantly different at $p<0.05$; PH = plant height (cm), EH = ear height (cm), EL = ear length (cm), HSW = hundred seed weight (g), GY = grain yield (kg ha^{-1})

The significant differences among varieties indicates the presence of variability for grain yield among the tested entries. This finding is in agreement with the reports of Wedajo and Hussein (2015), who indicated that there were significant differences observed among the maize varieties for grain yield. Similar results were reported by Ahmed et al. (2000), who evaluated and identified high yielding maize varieties among different genotypes tested. From the tested varieties in the present study, higher hundred seeds weight (37.91 g) and (39.85 g) were recorded for the improved midland maize varieties (BH546 and BH547, respectively). On the other hand, the minimum hundred seed weight (32g) was noted for the SPRH line.

CONCLUSIONS

The experiment was carried out using seven improved midland maize varieties and one local check in randomized complete block design (RCBD) with three replications during 2018 to 2020 main cropping seasons. According to the study results, all the studied growth parameters, yield components and grain yield were significantly affected by varieties. Higher performances in terms of seeds weight were exhibited by the improved midland maize varieties: BH547 and BH546. Similarly higher grain yields (kg ha^{-1}), were recorded for BH546 and BH547 Based on the combined mean performances the two varieties (BH546 and BH547) were significantly higher than that of the standard local check (BH140). Therefore, it can be concluded that use of the improved maize varieties of BH546 and BH547 would be recommended for demonstration and popularization for production in the target area and other places with similar agroecology.

CONFLICTS OF INTEREST

Authors declare that there are no conflicts of interest regarding the publication of this paper.

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REFERENCES

Ahmed, N., Waheed, A. and Hamid, F. S. 2000. Performance of maize cultivar under late sowing conditions. Pakistan J. Biol. Sci., 3(12): 2098-2100.

CSA (Central Statistical Agency of the Federal Democratic Republic of Ethiopia). 2015. Agricultural Sample Survey, 2014/15. Report on Area and production of major crops (Private Peasant Holdings, meher season). Statistical Bulletin 278. Vol. I, Addis Ababa, Ethiopia

FAOSTAT. 2010. Food and Agricultural Organization of the United Nations [online].

MARD (Ministry of Agriculture and Rural Development). 2014. Animal and Plant Health Regulatory Directorate. Crop Variety Registry issue no.17. Addis Ababa, Ethiopia.

Nazir, H., Zaman, Q., Amjad, M. and Aziz, N.A. 2010. Response of maize varieties under agro ecological conditions of Dera Ismail khan. J. Agric. Res., 48(1): 59-63.

Piperno, D. R. and Flannery, K. V. 2001. The earliest archaeological maize (Zea mays L.) from High land Mexico: new acceleration mass spectrometry dates and their implications. Proceedings of national academy of sciences, 98: 2101-2103. Pakistan. Pak J Life Soc Sci, 2008, 6:

Shahidur, R. 2010. Staple Food Prices in Ethiopia. International Food Policy Research Institute, Addis Ababa, Ethiopia.

Sahibzada, Q. A., Khan S., Ghaffar M., and Ahmad F. 2011. Agricultural Research Station,Baffa, Mansehra, KPK, Pakistan. Genetic Diversity Analysis for Yield and Other Parameters in Maize (*Zea mays* L.) Genotypes.Asian Journal of Agricultural Sciences, 3(5): 385-388.

Tahir, M., Tanveer, A., Ali, A., Abbas, M. and Wasaya, A. 2008. Comparative yield performance of different maize (Zea mays L.) hybrids under local conditions of Faisalabad-Pakistan. Pak J Life Soc Sci., 6(2): 118-120.

Wedajo, G., and Hussein M. 2015, July). Study on adaptability and stability of drought tolerant maize varieties in drought prone areas of South Omo Zone, SNNPRS. International Journal of Research in Agriculture and Forestry, 2(I7).

Original Research Article||

Performance evaluation and yield stability of maize (*Zea mays* L.) hybrid genotypes in southern Ethiopia

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Abstract

Improved Maize varieties were released by different agricultural research centers at different times in Ethiopia. However, the productivity of these varieties was not evaluated under wider environmental ranges. The variety choice of most farmers in Ethiopia is not suitable for their farm due to lack of awareness about varieties, their adaptability to various conditions and field conditions. The objective of this study was to evaluate the stability and yield potential of hybrid maize genotypes across locations. Seven maize hybrid varieties were evaluated at Sankura, Meskan, and Sodo in Ethiopia during the 2019 and 2020 main cropping seasons. The varieties were assigned in randomized complete block design with three replications. The major agronomic data were collected for each genotype for all locations. The combined analysis of variance showed that the effects of genotypes (G), environments (E) and their interaction (GEI) on grain yield were found to be highly significant. The highest grain yield recoded was 6674 kg ha^{-1} for BH546 while the lowest yield was 4330 kg ha^{-1} for SBRH. The first two principal component axis (IPCA1 and IPCA2) were significant ($p < 0.01$) and cumulatively contributed 95.12% of the total variations of GEI. The selection of one trait would influence the grain yield of variety. BH546 and PHB30G19 were most stable genotypes with better mean performance across testing locations. Thus, these two varieties were recommended for the study areas, although further studies will be required in multiple environments to confirm consistency in yield performance and stability across more environments.

Key words: AMMI, grain yield, hybrid, stability

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INTRODUCTION

Maize is one of the most important cereal crops grown in Ethiopia, with total annual production and productivity exceeding that of all other cereal crops. In terms of area coverage, it is only super passed by tef [*Eragrostis tef* (Zucc.) Trotter] (Mosisa *et al*., 2011; CSA, 2014). In Ethiopia, maize is one of the major cereals widely cultivated across diverse ecologies. These include lowland moist, lowland and highland moisture stress, mid altitude and highland sub-humid moist agroecology. As each of the agroecology is differing in altitudes, rainfall and soil properties, they possess their own characteristic limitations and opportunities revealed in production and productivity of maize varieties under the influence of prevailing weather conditions (Legesse *et al.*, 2012). Ethiopia's current average national maize yield is 3.43 metric tons per hectare whereas the developing and developed countries average yields are 2.5 and 6.2 metric tons per hectare, respectively (CSA, 2015).

Lower yields have been attributed to the use of low-yielding varieties, use of self-produced seed, poor soil fertility and limited use of fertilizers, low plant population, and inappropriate weed control methods. Hence, significant potential improvements in yields could be achieved through the use of hybrid maize varieties.

Cultivar performance is a function of the genotype and the environment. Environmental factors have a great influence on both qualitative and quantitative traits, and genotype-by-environment interaction makes it difficult to select the best-performing and most stable genotypes. It is an important consideration in plant breeding programs because it impedes progress from selection in any given environment (Yau, 1995).

Under these heterogeneous environments, allocating a variety that can successfully adapted to a certain location or across locations is difficult due to the interaction effects of genotypes with the environment. In order to solve this problem, experimental research need to be carried out in multi-environment variety trials to identify and analyze the major factors that are responsible for genotype adaptation (De Lacy *et al*., 1996). In multi-location experiments the influence of environment is basically attached to the expression of complex characteristics and reveals in high influence of environment. Genotype by environment interaction occurring due to differential response of genotypes to different growing conditions (Bernardo, 2002). The objective of this study was to evaluate the stability and yield potential of hybrid maize genotypes and to assess the effect of genotype-by-environment interaction on yield.

MATERIALS AND METHODS

Experimental Materials and Design

Seven hybrid maize (BH546, BH547, SBRH, SPRH MHQ138, MH140 and PHBG30) varieties were used for the experiment. The varieties were released at different times from the Bako and Melkasa Agricultural Research Centers for mid-altitude areas. They were evaluated at three different locations in the Gurage and Siliti Zones (Sankura, Meskan, and Sodo districts). The experiment was conducted using a randomized complete block design with three replications in the two main cropping seasons (2019 and 2020). The experimental plot size was 4.8 m x 3 m (14.4 m2) with inter and intra-row spacing of 80 x 20 cm for all locations over the crop years. The recommended field management practices were followed uniformly with 150 kg ha-1 NPS and 200 kg ha-1 Urea fertilizers used in the experiment.

Data Collections

The data were recorded on plant height, cob length, seed per cob, number of rows per cobs, 100 seed weight (g) and grain yield. The grain yield in kilograms per plot recorded was converted to grain yield in kg per hectare at 12.5% grain moisture.

Statistical Analysis

Analysis of variance was performed using the GLM procedure of SAS statistical software version 9.4. Effects were considered significant in all statistical calculations if the p-values were ≤ 0.05. Means were separated following the procedures of Fisher's least significant difference (LSD). Genotype-by-environment interaction was quantified using pooled analysis of variance, which partitions the total variance into its component parts: genotype, environment, genotype × environment interaction, and pooled error.

The method of Eberhart and Russell (1966) was used to calculate the regression coefficient (bi), deviation from regression (S^2di) and coefficient of determination (R^2i). It was calculated by regressing mean grain yield of individual genotypes/ environments on environmental/ genotypic index. The genotype with value of regression coefficient (bi ~1) and smaller value deviation from regression (S^2di) value are thus more stable. Ecovalence measure (Wi) suggested by Wricke (1962) was also computed to further describe stability. The Ecovalence (Wi) or stability of the i^{th} genotype is its interaction with the environments, squared and summed across environments.

It is important that not only the IPCA scores be used for stability analysis to judge whether a given variety is stable across environments; other stability parameters would also provide information on the response of varieties across locations.

RESULTS AND DISCUSSION

Mean Performance of Hybrid Maize Genotypes

All the characters considered showed significant differences ($p<0.05$) among the evaluated genotypes indicating the presence of competent variability (Table 1). Among the tested cultivars, MH-140 and PHB30G19 had the highest plant height (2.5 m) while short statured plant height was recorded (2.2 m) was for MHQ-138 variety. On similar studies Hussain et al. (2011) reported differential pattern of maize varieties for plant height.

The highest cob length (20.4 cm) was recorded for PHB30G19, followed by BH546 (20.3 cm), while the shortest cob length corresponded to MHQ-138 (16.2 cm) (Table 1). The results obtained were comparable with the ranges reported in earlier studies by Hussain et al. (2011) and Nazir et al. (2010).

The highest number of seeds per cob was recorded for BH547 (629.6) followed by PHB30G19 (587.5) while the least corresponded to MHQ-138 (493.9). The number of rows per cob contributes to maximum grain yield. In the present study, the maximum number of rows recorded was 16.4 for PHB30G19, and the smallest, 13.3, corresponded to SPRH. Hundred seed weight (HSW) is an important yield component and varies among varieties. The maximum value for HSW was obtained for MH-140 (37.7 g) and the minimum value was obtained from cultivar MHQ-138 (25.9 g).

The BH546 variety recorded the highest average grain yield (6674 kg ha^{-1}), while the lowest average grain yield (4330 kg ha^{-1}) corresponded to SBRH.

Table 1. Mean performance of yield and yield components of maize varieties

Variety	PH (m)	EL (cm)	SE	NR	HSW (g)	GY (kg ha^{-1})
BH546	2.4^{ab}	20.3^{a}	$556.9a^{bc}$	15.1^{cd}	30.6^{c}	6674^{a}
BH-547	2.3^{bc}	19.8^{ab}	629.6^{a}	16.0^{ab}	37.2^{a}	6087^{b}
SBRH	2.4^{a}	19.4^{b}	495.2^{c}	15.6^{bc}	33.9^{b}	4330^{d}
SPRH	$2.4a^{b}$	18.0^{c}	511.9^{b}	13.3^{e}	30.0^{c}	5688^{bc}
MHQ-138	2.2^{c}	16.2^{d}	493.9c	14.9^{cd}	25.9^{d}	5448^{C}
MH-140	2.5^{a}	19.3^{b}	495.0^{c}	14.7^{d}	37.7^{a}	6051^{b}
PHB30G19	2.5^{a}	20.4^{a}	587.5^{ab}	16.4^{a}	36.7^{a}	6178^{ab}
Mean	2.4	19.1	538.6	15.1	33.1	5780
LSD (0.05)	0.1	0.7	79.3	0.7	2	553
CV (%)	5.9	4.4	15.5	5.4	6.5	10.1

Similar letters within a column were non-significant. LSD= Least significant difference, CV = coefficient of variation, PH = plant height (m), EL = Ear length (cm), SE = seeds per ear, NR = number of rows, HSW = hundred seed weight (g), GY = grain yield (kg ha^{-1})

Additive Main Effects and Multiplicative Interaction (AMMI)

The grain yields were significantly affected by the environment, which explained 41.1% of the total variation, whereas the genotype and genotype-by-environment interaction were significant and accounted for 30.96% and 27.94% of the variation, respectively (Table 2). A large yield variation attributed to environments indicating a significant role in the expression of traits being considered.

The genotypes perform better at Sankura compared to Sodo and Meskan. MH-140 gave the highest yield (8056 kg ha^{-1}) at Sankura and the smallest yield was recorded for MH-140 (3460 kg ha^{-1}) at Meskan (Table 3). Genotype-by-environment interaction effects were further partitioned into interaction principal components (IPCA) using the AMMI model.

Table 2. AMMI analysis of variance for grain yield of hybrid maize genotypes grown at three environments

Source of Variation	DF	SS	MS	F	%SS
Environment®	2	39975405	19987703	57.19	41.10
Genotype (G)	6	30114658	5019110	14.36	30.96
G x E	12	27180744	2265062	6.48	27.94
PC1	7	21741749	3105964	9.23	79.99
PC2	5	5438994	1087799	3.23	20.01
Residual	42	14679160	349503.8		

DF = degrees of freedom; SS = sum of squares; MS = means squares; F = Fischer's F-ratio as cut off point for significant variations

The principal component (PC1) explained 57.28% of total variation; while PC2 explained 37.84%, the two accounting for 95.12% of the total GEI variation for grain yield (Figure 1). The result from the present experiment was in agreement with the reports of Mohammadi *et al*. (2010), where the largest proportion of total variation in multi-environment trials is attributed to environment. Genotype SBRH was low yielder and unstable far from the origin. The greater the absolute length of the projection of a genotype, the less stable it is (Yan *et al*., 2000; Yan and Holland, 2010).

Stability Analysis

The responses of genotypes across the three locations were significantly different, indicating the sensitivity of genotypes to the environment. Six stability parameters were measured to evaluate the stability of genotypes across locations (Table 4). Genotype BH546 with the lowest (Sd = 310.58, CVi = 4.65, bi = 0.12, S^2di = 60268, Wi = 1629822) was more adapted to wider environments and stable, whereas MH-140 genotype with the highest (Sd = 2353, CVi = 38.89, bi = 2.41, S^2di = -103664, Wi = 3796700) was sensitive and adapted to ideal environments for selecting varieties with specific adaptation and unstable.

Table 3. Mean grain yield and rank (R) of 7 maize genotypes tested across three locations in southern Ethiopia

Variety	Sodo		Sankura		Meskan	
	GY (kg ha^{-1})	R	GY (kg ha^{-1})	R	GY (kg ha^{-1})	R
BH546	7027	1	6554	6	6441	1
BH-547	7000	2	6500	3	4762	3
SBRH	3889	7	5196	7	3906	6
SPRH	6250	4	6610	2	4204	4
MHQ-138	5417	6	6806	4	4121	5
MH-140	6638	3	8056	1	3460	7
PHB30G19	5893	5	6583	5	6057	2
Mean	6016		6615		4707	

GY = grain yield, R = rank Tiler number and spike length

Table 4. Mean grain yield and stability parameters for maize hybrid genotypes tested at 3 environments

Genotype	GY	Sd	CV (%)	bi	S^2di	R^2	Wi
BH546	6674	310.58	4.65	0.12	60268	0.15	1629822
BH-547	6087	1174.74	19.30	1.04	592510	0.75	699783
SBRH	4330	749.44	17.31	0.56	414405	0.54	880825
SPRH	5688	1297.80	22.82	1.31	-45320	0.97	282998
MHQ-138	5448	1342.34	24.64	1.34	86229	0.95	409160
MH-140	6051	2353.38	38.89	2.41	-103664	1.00	3796700
PHB30G19	6178	360.59	5.84	0.21	71384.29	0.33	1360960

Key: GY = grain yield, SD = standard deviation, CV = Coefficient Variability, bi = Eberhart & Russell coefficient, S^2d = deviation from regression, R = coefficient of determination, W_i = Wricke's Ecovalence,

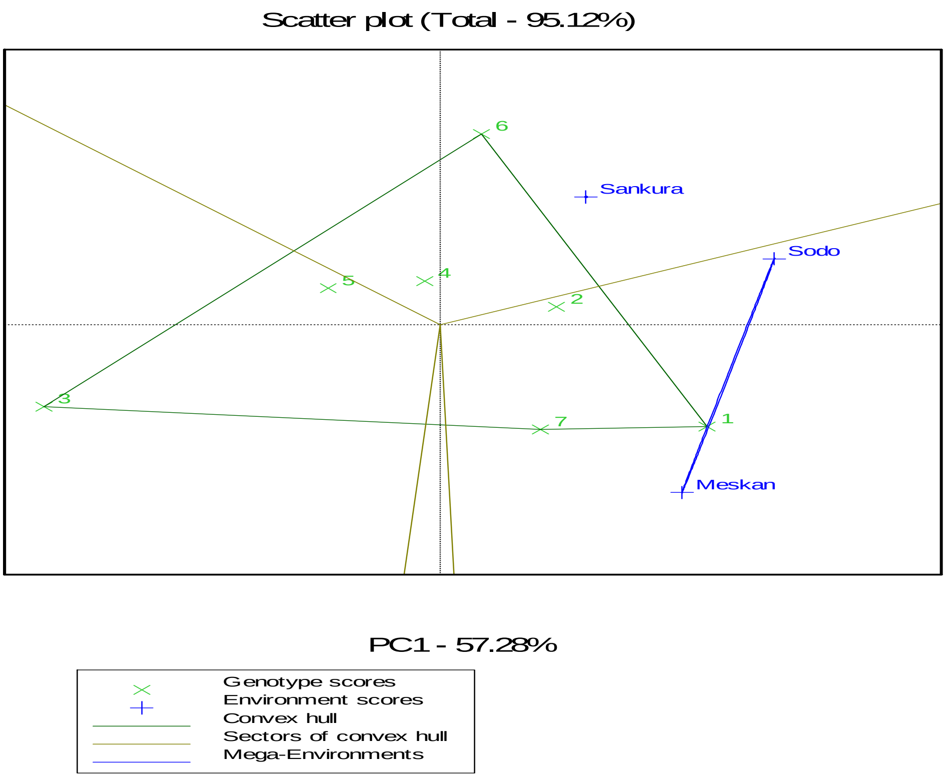

Figure 1. Biplot of PCA1 against PCA2 for both environments and genotypes

CONCLUSIONS

Based on the results of the multi-location analysis, genotypes BH546 and PHB30G19 were relatively stable, exhibiting yield performances above the mean across test environments. From this experiment, it is concluded that the genotypes BH546 and PHB30G19 were superior in their yield during the experimental years. Therefore, these varieties were recommended for Sodo and Meskan areas and other locations with similar agroecologies. MH-140 was found to be highly sensitive to environment and recommended for Sankura and other areas with similar agroecologies. The results of this study revealed a considerable degree of differences among the varieties that could be explored for further improvement in maize breeding.

CONFLICTS OF INTEREST

Author declares that there is no conflict of interest regarding the publication of this article.

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REFERENCES

Bernardo R. 2002. Genotype x environment interaction. In: Bernardo, R. (ed.) Breeding for quantitative traits in plants. Stemma Press. Woodbury, MN. pp 147-171.

CSA (Central Statistical Agency), 2014. Report on area and production of crops: Agricultural Sample Survey on Private peasant holdings of 2013/2014 Meher season. Central Statistical Agency, Addis Ababa, Ethiopia

CSA (Central Statistical Agency), 2015. Agricultural Sample Survey for 2014/2015. Vol. I, Report on Area and production of Major Crops (Private Peasant Holdings, Meher Season). Statistical Bulletin, Addis Ababa, Ethiopia.

De Lacy I. H., Cooper M., and Basford K. E. 1996. Relationships among analytical methods used to study genotype-by-environment interactions and evaluation of their impact on response to selection. In: Kang, M.S. and Gauch, Jr. H.G. (eds.). Genotype-by- Environment Interaction, CRC press: Boca Raton, New York. pp. 51-84.

Eberhart S. A. and Russell W. A., 1966. Stability parameter for comparing varieties. Crop sci., 6: 6-40.

Hussain M. M. Y. Khan M. S. Baloch M. S. 2011. Screening of Maize Varieties for Grain Yield at

Dera Ismail Khan. J. Anim. Plant Sci., 21(3): 626-628.

Legesse W. Mosisa W., Berhanu T., Girma D. Girum A., Wende A. and Getachew W., 2012. Genetic Improvement of Maize for Mid-altitude and Lowland Sub-humid Agro- ecologies of Ethiopia,"Meeting the Challenges of Global Climate Change and Food Security through Innovative Maize Research", pp. 24-34.

Mohammadi, R., Roostaei, M., Ansari, Y., Aghaee, M. and Amri, A., 2010. Relationships of phenotypic stability measures for genotypes of three cereal crops. Canadian Journal of Plant Science, 90(6): 819-830.

Mosisa W, Twumasi-Afriyie S., Legesse W., Prasana M. B., ed., 2011. Proceedings of the 3rd National Maize Workshop of Ethiopia, April 18-20, Addis Ababa, Ethiopia

Nazir H., Zaman Q., Amjad M., Nadeeman A., 2010. Response of maize varieties under agro ecological conditions of Dera Ismail khan. J. Agric. Res., 48(1): 59-63.

Wricke G., 1962. Uber eine methode zur erfassung der okologischen streubreite in feldversuchen. Z. Pflanzenzuecht, 47: 92-96.

Yan W. and Holland K. J. B., 2010. A heritability-adjusted GGE bi-plot for test environment evaluation. Euphytica, 171: 355-369.

Yan W., Hunt L. A., Sheng Q., and Szlavnics Z., 2000. Cultivar Evaluation and Mega-environment Investigation Based on the GGE Bi-plot. Crop Sci., 40: 597-605.

Yau S. K. 1995. 'Regression and AMMI analyses of genotype x environment interactions: An empirical comparison'. Agronomy Journal 87(1): 121-126.

Original Research Article||

Assessment on indigenous chicken incubation, brooding hen and chicks' husbandry practice of farmers at different agroecological zones of Sidama Region, Ethiopia

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Abstract

This study was conducted to assess the indigenous chicken incubation, brooding hen, and chick husbandry practices of farmers in Hulla, Aleta Wondo, and Dale districts, representing highland, midland, and lowland agro-ecologies, respectively. From each agroecology, two kebeles were purposively selected based on potential poultry production and road availability. About 256 households were purposively selected from six kebeles for survey interview. The collected data were analyzed using SPSS version 20 and SAS version 9.0 software packages. The results indicated that all the respondents in the study areas incubate only eggs laid at home. The majority (75.8%) of the respondents in all agroecology did not select eggs for incubation. Majority of the respondents (61.3%) in all agroecological zones stored incubated eggs for two weeks before the incubation. Another majority of respondents (66.8%) in all agroecological zones provided water to brooder hen in the afternoon only. All of the respondents in the study areas incubated eggs and rear their chicks naturally using broody hen. About 62.4, 51.0, and 52.0 % of respondents in highland, midland, and lowland agroecological zones, respectively, responded that the handling problem was the main cause of the failure to hatchability. Almost all of the respondents in the study areas provided free access to water to their chicks. The average number of eggs set per hen was 12.46±1.50 (mean±SD) with no significant difference between agroecological zones. The hatchability of the eggs in the study areas was 83.55% and there was no significant difference between agroecological zones In conclusion, regardless of the agroecological differences, farmers incubated eggs and brooded chicks naturally using broody hens, and they stored incubating eggs for long periods without considering storage conditions. Therefore, promoting incubation and brooding technologies (mini-hatcheries, sandwich incubators, hay box brooders) is necessary to improve the productivity of local chickens.

Key words: Agro-ecology, Brooder hen, Chicks' husbandry, incubation practices, indigenous chicken, Sidama Region

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INTRODUCTION

The total chicken population of Ethiopia is about 49 million, which are kept for egg and meat production, as well as for cash income purposes (CSA, 2020). Even though Ethiopia has a large number of chicken flocks, there are various factors, such as diseases, predators, lack of proper healthcare, feed shortages, and poor marketing information, that hinder the productivity of chickens in most areas of the country (Bayesa, 2021).

Among the above obstacles, poultry diseases are the main constraints incriminated for reduction of total numbers and compromised productivity (Natnael, 2015). The poultry population growth is very low due to the disease and the number is even in a decreasing trend (Fenet and Alemayehu 2019). Local chicken flocks are slow in growth rates and very poor in productivity. Mean body weights at 8 and 16 weeks of age could be as low as 242 and 621 g, respectively (Nigussie, 2011). The mean annual egg production does not exceed 60 egg/hen with an average egg weight of 40 g (Halima, 2007). Due to this, poultry meat and egg consumption in Ethiopia is extremely low (Matawork 2016). In 2013, the per capita consumption of poultry meat was about 0.66 kg. During the same year, the per capita annual poultry meat consumption of East Africa and Africa were estimated at 1.64 and 6.73 kg, respectively, while the global average stood at 14.99 kg (FAOSTAT, 2018). The per capita consumption of eggs was also low, accounting for around 0.36 kg in 2013 (FAO, 2019).

Despite their lower productivity, local birds are still the major suppliers of poultry products in Ethiopia. They are well adapted to their environments, resistant to diseases, can scavenge for food, and can avoid predators as they are agile and fast, with the color and patterns of their feathers providing natural camouflage (Abdelqader et al., 2007; Mammo, 2012). The incubation period for chicken eggs is 20 to 21 days and increases up to 30 days for other poultry chicks. Proper incubation requires the right combination of temperature, humidity and time (Olsen, 2000). The broody hen chosen for natural incubation should be large (to cover and thus keep more eggs warm), healthy and preferably vaccinated, with a good brooding and mothering record (King'or, 2011). Few researches were conducted on natural incubation practices of local chicken under farmer's management conditions (Shishay et al., 2014). These researches do not provide full information on farmers' practices of incubation and brooding of chicks, management of broody hen and brooding hen selection across different agroecological zones. Agro-ecologically based developmental interventions on improving local chicken need this information. The objective of this study was to assess indigenous chicken incubation practices, as well as brooding hen and chick husbandry practices of farmers in different agroecological areas of Sidama Region, Ethiopia.

MATERIALS AND METHODS

Description of the Study Area

This study was conducted at three districts of Sidama Regional State namely, Hula, Aleta Wondo and Dale representing highland, midland and lowland agroecological zones, respectively. Hula district is located at a distance of 91 km from Hawassa and 366 kms from Addis Ababa. The district is located at longitude and latitude of 6°.41'-6°.61' N and 38°.44'-38°.70' E, respectively and l201 to 3000 masl elevation. Hula is bordered on the south by the Oromia Region, on the west by Dara, on the northwest by Aleta Wondo, on the north by Bursa, and on the east by Bona Zuria districts. It received annual rainfall ranges of 700-1200 mm with annual temperature ranges of 11-18℃. According to the information obtained from the Hula district, the total population of the district is 80,464. The total livestock population of Hula district is 15,456 cattle, 2,215 sheep, 1,056 goats, 769 horses, 456 donkeys, 3,422 poultry. The main agricultural activities of the district are livestock production, enset plantation and cereal crop production.

Aleta Wondo district is one of the 36 districts in Sidama Regional State, located about 64 km from Hawassa and 339 km from the capital city of Ethiopia, Addis Ababa. It is situated in the coordinates of 60 35′ to 60 40′ N latitude and 380 25′ to 380 30′ E longitudes. The annual temperature of the district ranged between 10℃ to 24℃. Elevation ranges from 1700 to 2500 masl. As per the information gotten from the district reports, annual rainfall of the district ranges from 900 mm to 1400 mm. Aleta Wondo district is bordered with Dare in the south, Chuko in the west, Dale and Wonsho on the west and Bursa and Hulla in the east directions. The livestock population was estimated to be 138,251 cattle, 39,211 sheep, 22,421 goat, 3918 horses, 8586 donkeys, 168 mules and 169, 256 poultry The main agricultural practices in the area include coffee plantation, inset plantation, maize and cereal crop production, cattle fattening, apiculture, as well as fruit and vegetable production.

Dale district is one of the 36 districts of Sidama Regional State. The district is located on the highway from Hawassa to Moyale at 45 km from Hawassa and 320 km from the capital, Addis Ababa, and situated with latitude of 6° 39' 20"- 6° 50' 28" N and longitude of 38°18'12" - 39°31'30" E. Dale is bordered on the south by Aleta Wendo and Chuko, in the west by Loka Abaya, in the northwest by Boricha, in the north by Shebedino, and on the east by Wonsho. Its elevation ranges from 1200-3200 masl. The annual rainfall in Dale district ranges from 1,300 to 1,900 mm, and the annual temperature varies from 18°C to 20°C.The main agricultural activity of the district is livestock production, enset plantation, coffee plantation and cereal crops production.

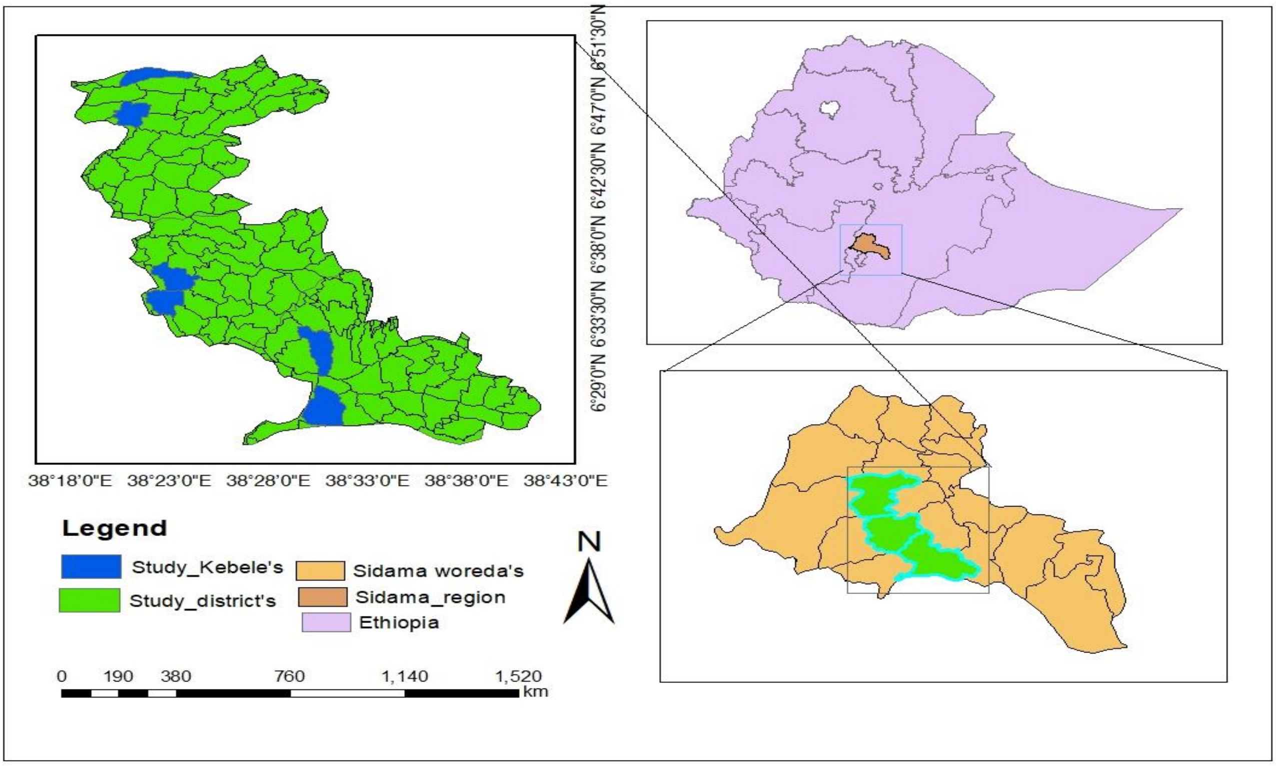

Figure 1. Administrative map of Sidama region and the study areas

Selection of the Study Area and Sampling Technique

A multi-stage sampling technique was used to select both the study area and the study households. The districts were purposively selected primarily based on agro-ecology, their potential for chicken production, and transportation accessibility. Then, two kebeles (the smallest administrative unit) from each district representing one agro-ecology were purposively selected (based on in-depth discussion with districts' office of livestock and fishery), where exotic breeds were less distributed. Households who possessed at least 5 local adult chickens were purposely selected for questionnaire survey. Preliminary data was collected using focus group discussion. One FGD containing six to twenty discussants was established and used in each kebele. Each farmer and key informants were interviewed individually. Proportional samples were taken using the formula by (Yamane, 1967) for kebeles having a different number of households. Accordingly, a total of 256 HHs (85 from highland, 96 from midland and 75 from lowland) were selected for the survey.

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

n = where: n is sample size, N= is population size, e = is level of precision

Assumption: - 95% confidence level p = 0.05

Survey Data Collection

Data were collected for demographic characteristics, chicken flock structure, egg selection and handling practices, broody hen selection and management, methods of interrupting broodiness, incubation season of local chicken, methods of chick management, number of chicks hatched per hen, chick hatchability and number of chicks survived to the age of sexual maturity.

Statistical Analysis

Collected qualitative data were analyzed using crosstabs among agroecology in descriptive statistics using statistical package for social science (SPSS) for Windows, version 20.0. Quantitative data was analyzed using general linear model (GLM) procedure of SAS (version 9.0). Mean comparisons were conducted using Duncan's multiple range test. Values were considered as significant at 5% level of significance.

RESULTS AND DISCUSSION

Demographic Characteristics of Respondents

The demographic characteristic of the respondents is shown in Table 1. The results revealed that 55.5% of respondents were male and the rest (44.5%) were female. The number of male respondents was higher at highland agro-ecology than midland and lowland, which might be due to the presence of market days (Hulla and Aberra markets) during survey work of highland agro-ecological zones. Women are more likely to go to the markets to buy goods for the households' consumption, but men and children remain at homestead and they were available during present survey work. The percentage of female respondents involved in the current study was higher than those reported earlier by Demissu (2020) and Mekonnen (2007) where 87.45% male and 12.55% female and 86.3% male and 13.7% female, respectively participated. Age classification was done according to Meseret (2010). Most of the respondents (73.4%) were categorized under the age group between 31 -45 years and 20.3% of respondents were categorized under the age group between 15 and 30 and only 5.9% were above 45 years of aged. This result was in line with the findings of Meseret (2010), where most of respondents were categorized under the age group between 31-60 years.

The result indicated that 37.5% of the respondents were illiterate and only 6.2% of the responds were categorized under the educational status of college and above. This report showed higher number of illiterate respondents than that reported by Mieraf (2020) where 23.1% and 4.4% of respondents were illiterate and College/University graduate, respectively. Regarding the educational status of surveyed households, there were no clear differences between the different agroecological zones. The average family size of respondents was 5.71±1.69 regardless of the considered agroecological zones. The result from the current study was in agreement witn that reported by Ermias (2015).

Table 1. Demographic characteristic of respondents

Variable	Agro-ecology			Overall	χ^2
	Highland	Midland	Lowland		
Sex (%)					
Male	62(72.9)^a	43(44.8)^b	37(49.3)^b	142(55.5)	16.079
Female	23(27.1)^b	53(55.2)^a	38(50.7)^a	114(44.5)	
Age					
15-30	4(4.7)^b	27(28.1)^a	22(29.3)^a	53(20.7)	136.144
31-45	78(89.4)	62(64.6)	50(66.7)	188(73.4)	
Above 45	5(5.9)	7(7.3)	3(4.0)	15(5.9)	
Educational status					
Illiterate	27(31.8)	40(41.7)	29(38.7)	96(37.5)	10.625
Primary	21(24.7)	22(22.9)	20(26.7)	63(24.6)	
Elementary	26(30.6)	13(13.5)	14(18.7)	53(20.7)	
High school	6(7.1)	14(14.6)	8(10.7)	28(10.9)	
College or above	5(5.9)	7(7.3)	4(5.3)	16(6.2)	
Family size (mean±SD)	5.98±1.41	5.51±1.78	5.67±1.83	5.71±1.69	24.26

Figures outside and inside parenthesis represents frequency and percentiles respectively; SD= standard deviation; values within row with different superscript letters are significantly different at $p<0.05$

Chicken Flock Structure

The flock structure of chicken with the surveyed households is presented in Table 2, which indicates that the overall mean of hen and cocks in the flock were 3.82±0.96 and 1.12±0.35, respectively. The result of current study shows that there is no significant difference on the mean value of hen and cock in the flock composition between all study ago-ecological zones ($p>0.05$). This result was in line with the findings of Welelaw *et al.* (2018), who reported 3.6±1.4 and 1.2±0.9 for hens and cocks, respectively. However, pullets and cockerels were statistically higher at highland areas. However, there is no significant difference between midland and lowland agroecological on the number of pullets and cockerels per household. The overall mean number of pullets and cockerels in the current study were 3.42±1.32 and 1.63±0.78, respectively. Lower value on pullets and higher value of cockerels were reported in the findings of a study by Mekonnen, (2007) who reported 2.35±1.33 and 2.15±1.29 for pullets and cockerels respectively. The total average number of birds was statistically higher at lowland and lower at highland areas ($p<0.05$). The possible reason for this difference might be due to the highest survival rate of chicks in lowland than in the highland areas. The average flock size of the respondent households at study areas was 9.16±2.70. The average flock size of the current study was in line with findings of Welelaw *et al.* (2018), who reported 9.2±3.5 chicken per household in Sheko district, Bench Maji Zone of Southern Ethiopia. But the results reported by Halima (2007) and Meseret, (2010) were lower with an average flock size of 7.13 and 6.23, respectively at different regions of Ethiopia.

Table 2. Chicken flock structure by sex and age group

Chicken type	Agroecology			Overall	p-value
	Highland	Midland	Lowland		
Hen	3.76±0.83	3.91±0.99	3.78±1.06	3.82±0.96	0.567
Cocks	1.06±0.31	1.12±0.33	1.19±0.39	1.12±0.35	0.201
Pullets	$3.09±1.09^a$	$3.56±1.43^b$	$3.59±1.34^b$	3.42±1.32	0.021
Cockerels	$1.41±0.67^a$	$1.69±0.79^b$	$1.86±0.83^b$	1.63±0.78	0.005
Chicks	-	10±2.65	9.33±3.51	9.67±2.80	0.806
Total	$8.47±1.98^a$	$9.43±2.77^b$	$9.45±3.17^b$	9.16±2.70	0.024

Values are Mean ± SD and those within row with different superscript letters are significantly different at p<0.05; SD= standard deviation. Means

Egg Selection Practices of Farmers in the Study Area

The source of eggs to be incubated and egg selection practices of farmers are presented in Table 3. As the result indicate, all respondents in the study incubate only eggs laid at home. During the survey period respondents explained that farmers assume that, eggs purchased from the market or collected from neighbors may not be fertile. All farmers rear cocks with their hens before incubation or they take a hen assumed to hatch eggs to neighbor for mating with cock. This will be done just before the hen start laying incubating eggs. The current study was in line with study by Mekonnen (2007), who reported that 98.13% of the respondents incubate eggs laid at home. Most of the respondents in all studied areas (72.9% from highland, 78.1% from midland and 76.0% from lowland) did not have a practice of selecting eggs for incubation. The study by Demissu (2020) reported that 63.87% of the respondents did not select eggs for incubation, which was lower than the result of the present study. The result in the present study also was in line with the study by Adissu (2013), who reported that 88.24% of respondents did not select eggs for incubation. From respondents, who have practiced egg selection for incubation, 52.2% select eggs with its size, 47.8% for cleanliness at highland, 57.1% for egg size and 42.9% select for cleanliness at midland and 58.1% select for egg size and rest (41.9%) select egg for cleanliness at lowland areas.

Egg Handling before and after Incubation

Egg handling practices of respondents before and during incubation are presented in Table 4. The result indicates that majority (61.3%) of the respondents in all agroecology store eggs for two weeks before incubation. About 25% and 13.7% of the respondents in the study districts store eggs before incubation for one and three weeks, respectively. The difference observed for duration of storing eggs before incubation might be due to differences in the waiting time until the hen shows broody behavior. In general, there is no significant difference between agroecology on the duration of egg storage before incubation. In contradiction with the current study, Demissu, (2020) reported that 72.73% of respondents store eggs till hens show broody behavior and sit on eggs. Similar materials mentioned in a report by Mekonnen (2007), Demissu (2020), Shishay (2014) and Melesse (2012) at different parts of the country, were used for egg setting during incubation.

Table 3. Egg selection practices of farmers

Variables	Agroecology			Overall	χ^2
	Highland (n=85)	Midland (n=96)	Lowland (n=75)		
Source of eggs to be incubated					
Laid at home	100	100	100	100	0.00
Egg selection for incubation					
Yes	27.1	21.9	24.0	24.2	0.663
No	72.9	78.1	76.0	75.8	
Egg selection criteria					
Egg size	52.2	57.1	66.7	58.1	0.882
Cleanliness of the eggs	47.8	42.9	33.3	41.9	
Preferable egg size for incubation					
Medium to large egg size	17.6	12.5	12.0	14.1	1.362
Any size (no considerations)	82.4	87.5	88.0	85.9	

χ^2: Chi-square

Table 4. Egg handling before and during incubation

Parameters	Agroecology			Overall	p-value
	Highland (n=85)	Midland (n=96)	Lowland (n=75)		
Egg storage before incubation					
One week	18(21.1)	22(22.9)	24(32.0)	64(25.0)	
Two weeks	48(56.5)	64(66.7)	45(60.0)	157(61.3)	0.038
Above two weeks	19(22.4)	10(10.4)	6(8.0)	35(13.7)	
Setting materials					
Clay pot	20(23.5)^{ab}	36(37.5)^{b}	13(17.3)^{a}	69(27.0)	
Bamboo made basket	40(47.1)^{b}	26(27.1)^{a}	12(16.0)^{a}	78(30.5)	<0.001
Ground	8(9.4)^{a}	10(10.4)^{a}	32(42.7)^{b}	50(19.5)	
Cartoon	17(20.0)	24(25)	18(24.0)	59(23.0)	
Egg storage materials before incubation					
Clay pot	34(40)	39(40.6)	24(32.0)	97(37.9)	
Cartoon	9(10.6)	17(17.7)	13(17.3)	39(15.3)	
Bamboo basket	26(30.6)	36(37.5)	24(32.0)	86(33.6)	<0.001
Gerry cane	4(4.7)	2(2.1)	2(2.7)	8(3.1)	
Plastic bucket	12(14.1)^{b}	2(2.1)^{a}	3(4.0)^{ab}	17(6.6)	
Ground with soil	0(0.0)^{a}	0(0.0)^{a}	9(12)^{b}	9(3.5)	

Figures outside the parenthesis represent frequency and numbers inside the parenthesis represent percentage values. Values within row with different superscript letters are statistically different at $p<0.05$

Broody Hen Selection and Management

Broody hen selection and management practices are summarized in Table 7. The result of the current study revealed that all (100%) of the respondents at all study agroecologies hatch eggs using natural incubation, which is in agreement with the report of Hailu (2016), where eggs were incubated using broody hen at Sheka Zone of South Western Ethiopia. In the current study all respondents have a habit of selecting the best hen before incubation. It was indicated that, farmers select a hen with a bigger size due to an assumption that the bigger hens are able to incubate and hatch many eggs than smaller ones. This finding was in agreement with the report of FAO (2004) where maximum of 14 to 16 eggs were brooded in one nest, but hatchability often declines with more than ten eggs, depending on the size of the hen. At all agroecology with no significant difference, farmers select breeding hen depending on ample plumage, productivity, mothering ability, hatching history and also combination of two or more criteria mentioned above. This report was consistent with that of Nigussie (2011), who indicated that farmers select breeding hen based on plumage color, body weight, reproductive performances and mothering ability. The majority of respondents (66.8%) provide water to brooder hen in the afternoon only. The rest of the respondents (23.4%) provide water to the broody hen in the morning and afternoon, while 9.8% provide free access to water. The results of the current study differ from those reported by Fisseha et al. (2010), where all respondents provided free access to water for their chickens.

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Table 5. Broody hen selection and management

Variables	Agroecology			Overall	χ^2
	Highland (n=85)	Midland (n=96)	Lowland (n=75)		
Incubation methods used					
Naturally by a broody hen	85(100)	96(100)	75(100)	256(100)	0.00
Do you select broody hen for incubation?					
Yes	85(100)	96(100)	75(100)	256(100)	0.00
Broody hen selection criteria					18.704
Size	20(23.5)	18(18.8)	16(21.3)	54(21.1)	
Ample plumage	15(17.6)	19(19.8)	11(14.7)	45(17.6)	
Productivity	5(5.9)	12(12.5)	6(8.0)	23(9.0)	
Mothering ability	2(2.4)	7(7.3)	4(5.3)	13(5.1)	
Hatching history	1(1.2)	0(0.0)	5(6.7)	6(2.3)	
Size and mothering ability	10(11.8)	8(8.3)	7(9.3)	25(9.8)	
Productivity and mothering ability	28(32.9)	23(24.0)	23(30.7)	74(28.9)	
Size, plumage, productivity and mothering ability	4(4.7)	9(9.4)	3(4.0)	16(6.2)	
Broody hen supplementation					
Yes	85(100)	96(100)	75(100)	256(100)	0.00
Broody hen watering					15.659
Free access	4(4.7)	11(11.5)	10(13.3)	25(9.8)	
Morning and afternoon	14(16.5)^{a}	19(19.8)^{ab}	27(36.0)^{b}	60(23.4)	
Afternoon only	67(78.8)^{a}	66(68.8)^{a}	38(50.7)^{b}	171(66.8)	

Numbers outside brackets are frequency and inside brackets are percentage values. The row with different superscript letters is statistically different at $p<0.05$. χ^2: chi-square.

Incubation Season and Failure to Hatchability

Incubation season and causes of hatchability failure are presented in Table 6. There is no significant difference between the different agroecologies of the study areas in the season of incubation of chickens. Most of the respondents (98.8%) in all agroecology incubate their chickens during dry season. Regarding the hatchability of chicks 90.2% of the respondents said that they achieve best hatchability during dry season. In this study from all agroecological zones the incubation season preferred by respondents was from September to February due to feed availability and favorable temperature for hatchability and chick survival. Halima (2007) reported that 95.6% respondent look for season to incubate their chicken. The present study was in agreement with the study by Meseret (2010), where respondents chose the time between October and January as the best season to get better hatchability. Ermias (2015) also reported that farmers do not incubate eggs during rainy seasons due to the reason that incubated eggs do not get enough warmth from broody hen and eggs would rot and chicks die due to cold stress. In the study by Ermias (2015) respondents indicated that the sound of thunder storm cause eggs to rot and chicks will die due to the fear of thunder storm. The result indicated that, 55.1% of the respondents believed that the handling problem was main reason for failure of hatchability. Another 28.5% of the respondents said that the problem of brooding hen was main issue for the failure of hatchability. The rest of the respondents (16.4%) did not know the reason for the failure in hatchability. King'or (2011) reported in the review that the size, age, and management of broody hens, as well as the storage conditions of incubating eggs, affect the hatchability of eggs.

Table 6. Incubation season and failure to hatchability

Variables	Agroecology			Overall	p-value
	Highland (n=85)	Midland (n=96)	Lowland (n=75)		
When to incubate chicken					
Dry season	84(98.8)	94(97.9)	75(100)	253(98.8)	0.252
Year-round	1(1.2)	2(2.1)	0(0.00)	3(1.2)	
Season to achieve best hatchability					
Dry season	80(94.1)	84(87.5)	67(89.3)	231(90.2)	0.311
No variation	5(5.9)	12(12.5)	8(10.7)	25(9.8)	
Months of achieving worst hatchability					
Rainy season	80(94.1)	84(87.5)	67(89.3)	231(90.2)	0.311
No variation	5(5.9)	12(12.5)	8(10.7)	25(9.8)	
Causes to failure of hatchability					
Handling problem	53(62.4)	49(51)	39(52.0)	141(55.1)	0.268
Broody hen problem	23(27.1)	26(27.1)	24(32.9)	73(28.5)	
Unknown reason	9(10.6)	21(21.9)	12(16)	42(16.4)	

Numbers outside parenthesis represents number of respondents and inside the parenthesis are percentage values. Row values with different superscript letters are significantly different at $p<0.05$.

Chick Management Practices of Farmers

Chicks rearing and management practices of respondents are summarized above in Table 7. The results indicated that all respondents in the study areas rear chicks naturally using the mother hen (p=1.00). Respondents said that they never know chick rearing methods other than natural brooding. The current study was in agreement with that reported by Shishay *et al.,* (2014), where 100% of respondents brooded chicks by broody hen in western part of Tigray Region. The result indicated that 57.4% of the respondents provide chicks with free access to feeding. The rest of the respondents (24.6%) provides feed in the morning, mid-day and afternoon and 18.0% of the respondents provided locally available feed to chicks in the morning and afternoon. Consistent with the present study, poultry owners supplement their baby chicks frequently at different districts of Sheka Zone of Western Ethiopia (Hailu, 2016). The result in the current study indicates that, there is no significant difference between agroecological zones in terms of the frequency of feed provision to baby chicks. Most of the respondents (96.5%) provide free access of water for their chicks. There is no significant difference on watering of chicks between different study agroecological areas ($p>0.05$). The current study revealed higher number of respondents offering water to their chicken than the report (53.8%) of Gamo Gofa Zone by Etalem (2019). About 51.3% of respondents said that highest mortality occurs at first weeks of age and 37.5% and

9.4% answered that highest mortality of chicks occurs at the age of first two weeks and first three weeks, respectively.

Table 7. Methods of chick management

Variables	Agroecology			Overall	p-value
	Highland (n=85)	Midland (n=96)	Lowland (n=75)		
Chick rearing methods					
Broody hen	85(100)	96(100)	75(100)	256(100)	1.00
Chick feeding frequency					
Ad lib	44(51.8)	58(60.4)	45(60.0)	147(57.4)	0.558
Morning, mid-day and afternoon	22(25.9)	21(21.9)	20(26.7)	63(24.6)	
Morning and afternoon	19(22.4)	17(17.7)	10(13.3)	46(18.0)	
Free access water provision to chicks					
Yes	85(100)	90(93.8)	72(96.0)	247(96.5)	0.072
No	0(0.0)	6(6.2)	3(4.0)	9(3.5)	
Age of highest mortality (weeks)					
First week	22(25.9)^{a}	64(66.7)^{b}	50(66.7)^{b}	136(53.1)	<0.001
First two weeks	39(45.9)	32(33.3)	25(33.3)	96(37.5)	
First three weeks	24(28.2)	0(0.0)	0(0.0)	24(9.4)	

$^{a-b}$ row values with different superscript letters are significantly different at $p<0.05$. Figures outside parenthesis represent frequency and inside the parenthesis are percentage values.

Hatchability and chicks survived to sexual maturity

The hatchability and the number of chicks survived to the age of sexual maturity at different agroecological zones are shown in Table 8. The result indicated that the number of eggs incubated by a single broody hen was 12.46±1.50. It is statistically higher at highland and midland agroecology than lowland counterpart ($p<0.05$). In agreement with the current result Melesse (2012) reported that the number of eggs incubated per hen to be 12.80±2.30. Similarly, Ermias (2015) reported that an average of 12.2 eggs are incubated by a single broody hen in Central Oromia Region. Similarly, Etalem (2019) reported 12.4±2.4 eggs incubated per broody hen at Gamo Gofa Zone. Hatchability of eggs obtained in this study was 83.55% and there is no significant difference between agroecological areas ($p>0.05$). This result agrees with the reports of Welelaw *et al.* (2018) and Azanaw (2017), where 82.2 and 82.7% hatchability, respectively were reported for indigenous Ethiopian chicken breeds. This research also indicated that the average number of chicks survived to the age of sexual maturity was 4.70±1.13, which was significantly higher for the lowland and the lower for highland areas; the difference likely attributed to the difference of management and environmental conditions. The result of the current research was in line with the report of Welelaw *et al.* (2018), in that 48.8% of chicks survived at different districts of Bench Maji Zone. Higher survival rate (58.25%) was reported by Melesse (2012) in different agro-ecological zones of Ethiopia. Contrarily, lower chick survival rate (2.82 ± 0.92) was reported by Meseret (2010) at Gomma district of Jimma Zone. It is assumed that this variation might be attributed to variation of management system, disease prevalence and veterinary services (Melesse, 2014). The average period on which hen spend on rearing chicks was 2.45±1.99 months, which is not statistically different among the agroecological zones of interest ($p>0.05$). In agreement with current result Meseret (2010) reported weaning age of chicks being around 2.61± 0.4 months in Gomma district of Jimma Zone. Length of brooding period reported by Welelaw *et al.* (2018) (2.90±1.0 for Bench Maji Zone, Southern Ethiopia) was higher than the that indicated in the present study.

Table 8. Chicks' hatchability and number of chicks survived to the age of sexual maturity

Variables	Agroecology			Overall	p-value
	Highland	Midland	Lowland		
	n=85	n=96	n=75	n=256	
Number of eggs set per hen (Mean±SD)	12.71±1.68 [a]	12.61±1.31[a]	11.97±1.37 [b]	12.46±1.50	0.0031
Hatchability (%)	83	83.27	84.63	83.55	0.1176
Number of chicks survived to sexual maturity per hen (Mean±SD)	4.33±0.89[c]	4.71±0.96[b]	5.12±1.42[a]	4.70±1.13	0.000
Period of hen waiting on rearing chicks (months) (Mean±SD)	2.65±0.46[a]	2.46±3.04[a]	2.19±0.30[a]	2.45±1.99	0.2816

Means with in row with different superscript letters are significantly different at p<0.05. SD= standard deviation

CONCLUSION

In conclusion, in all agroecological zones, farmers incubated eggs and brood chicks naturally by using a broody hen, and they store incubating eggs for long time (until the hen shows broody behavior) without considering storage conditions. Therefore, promoting incubation and brooding technologies (mini-hatcheries, sandwich incubator, hay box brooder) is necessary to improve the productivity of local chicken.

CONFLICTS OF INTEREST

Author declares that there is no conflict of interest in the publication of this article.

REFERENCES

Abdelqader A.; Wollny B. A. and Gauly M. 2007. Characterization of local chicken production systems and their potential under different levels of management practice in Jordan. Tropical Animal Health and Production.

Adissu H., Hailu M. and Zewdu W. 2013. Local Chicken Production System and Breeding Practice in North Wollo, Amhara Region, Ethiopia. Poultry, Fishery and Wildlife Sciences. 1: 108

CSA (Central Statistical Authority, Ethiopia). 2020. Report on livestock and livestock characteristics, Agricultural Sample Survey 2016/17 (2009 E.C.). Statistical Bulletin No.585, Vol. II. Addis Ababa.

Azanaw W. 2017. Assessment of Poultry Production Practices in Tegede District, North Gondar Zone, North West Ethiopia. International Journal of Advanced Research and Publications, 1(5): 386-394

Bayesa T. 2021. Current Status of Indigenous and Highly Productive Chicken Breeds in Ethiopia. Advances in Agriculture 1-5.

Demissu H. S. 2020. Evaluation of productive and reproductive performances of different strains of chickens under varied management systems in western Ethiopia. PhD Dissertation. Addis Ababa University. Addis Ababa, Ethiopia. Ref no. 052/01/2020.

Ermias T. D. 2015. Characterization of husbandry practices, adoption and impact of village poultry technology packages in the Central Oromia Region, Ethiopia. PhD dissertation. Addis Ababa Univeristy. Bishofitu, Ethiopia. Ref. No. 017/11/2015

Etalem G. M. 2019. Assessment of the local chicken production systems and hatchability of chicks and growth performance of chicks hatched using small scale electric incubator in two districts of Gamo Gofa Zone. MSc. Thesis, Hawassa University. Hawassa, Ethiopia.

FAO. 2019. Poultry Sector Ethiopia. FAO Animal Production and Health Livestock Country Reviews. No. 11. Rome.

FAO. 2004. Improving farmyard poultry production in Africa: Interventions and their economic assessment Proceedings of a final research coordination meeting organized by the Joint /IAEA Division of Nuclear Techniques in Food and Agriculture and held in Vienna, 24-28 May 2004

FAOSTAT 2018. FAO online database. Rome, https://www.fao.org/faostat/en/#data/SCL accessed on 29/03/2022

Fenet B. and Alemayehu O. 2019. Socioeconomic importance and production characteristics of village poultry production in Ethiopia: A review. Nigerian J. Anim. Sci. 21 (2): 112-122

Fisseha M., Azage T. and Tadelle D. 2010. Local chicken production and marketing systems in Ethiopia: Characteristics and opportunities for market-oriented development. IPMS (Improving Productivity and Market Success) of Ethiopian Farmers Project Working Paper 24. Nairobi, Kenya, ILRI.

Hailu A., Melesse, A., Mestawet T. 2019. Characterization of local chicken production systems in Sheka zone, south western Ethiopia. International Journal for Research In Agricultural And Food Science 5(2):1-19.

Halima H. M. 2007. Phenotypic and genetic characterization of local chicken populations in Northwest Ethiopia. PhD dissertation, University of the Free State, Bloemfontein, South Africa.

King'or A. M. 2011. Review of the factors that influence egg fertility and hatchability on poultry. International journal of poultry science. 6(1): 483-492.

Mammo M. 2012. The local chicken production and innate characteristics. Asian journal of poultry science 6.

Matawork M., 2016. Chicken meat production, consumption and constraints in Ethiopia. Food Science and Quality Management 52:1-12.

Mieraf A. 2020. Assessing egg production, egg quality and some morphometric traits of local and exotic chicken reared in two agroecology of Gamo Zone. MSc. thesis, Hawassa University. Hawassa, Ethiopia.

Mekonnen G. 2007. Characterization of the small holder poultry production and marketing system of dale, Wonsho and Loka abaya weredas of SNNPRS. MSc Thesis. Hawassa University.

Melesse, A. 2014. Significance of scavenging chicken production in the rural community of Africa for enhanced food security. World's Poultry Journal Science Journal 70:593-606

Melesse, A., Worku, Z., and Teklegiorgis, Y. 2012. Assessment of prevailing handling and egg quality from scavenging local chicken reared in different agro-ecological zones of Ethiopia. Research Journal of Poultry Sciences 5(4-6):64-70.

Meseret M. B. 2010. Characterization of village chicken production and marketing system in Gomma wereda, Jimma Zone, Ethiopia. MSc thesis. Jimma, Ethiopia.

Natnael T. 2015. Pathological and seroprevalence studies on infectious bursal disease in chickens in and around Bahir Dar, North West, Ethiopia. M.Sc. Thesis, Addis Ababa University, College of Veterinary Medicine and Agriculture, Department of Pathology and Parasitology, Bishoftu, Ethiopia

Nigussie D. 2011. Breeding programs for local chicken in Ethiopia. Analysis of diversity in production systems and chicken population. PhD thesis, Wageningen University, The Netherlands. ISBN: 978-90-8585-872-0

Olsen M. 2000. Influence of turning and other factors on the hatching power of hens' eggs. Thesis, Iowa State College.

SAS, 2002. Statistical Analysis System, version 9, Institute, Inc., Cary, NC, USA.

Shishay M., Berhanu B. and Tadelle D. 2014. Incubation and Brooding Practices of Local Chicken Producers in Ethiopia: The Case of Western Zone of Tigray. Journal of Biology, Agriculture and Healthcare. 4.

SPSS. 2011. Statistical package for the social sciences. Vision 20. IBM Corporation, SPSS Inc., Chicago IL.

Welelaw E., Melesse, A., Mohammed B. and Mestawet T. 2018. Assessing the Performance, Egg Quality, and Carcass Characteristics of Local Chickens Reared Under Traditional Management System" International Journal of Research Studies in Agricultural Sciences (IJRSAS). 4(10): 27-35.

Yamane T. 1967. Statistics: An Introductory Analysis, 2nd Ed., New York: Harper and Row.

Original Research Article||

Performance evaluation of Debre Birhan based plywood manufacturing company, North Shewa Zone, Ethiopia

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Abstract

The demand for building wood material in Ethiopia is increasing at alarming rate, resulting in increases in product prices. To overcome wood shortage, Ethiopian government has opened an opportunity for foreign investors to establish different types of wood product factories in the country. However, efficiency of these enterprises needs to be study to find out any irregularities which needs to be improve in the future for better performance of these companies. So the initiative was started from one of such plywood based factory, Debre Birhan plywood processing company with the objective to assess the operational performance of the company. A multi-stage sampling technique was used to select representative respondents. The data were collected through questionnaire surveys, interviews, observation records, and document review. Non-financial perspectives were explored using key indicators of operational performance associated with resource utilization, quality management, and operational practices. Data collected were analyzed using descriptive statistics of SPSS Version 20. Results show that Debre Birhan Wood Processing Company produces three categories of plywood (5-ply, 7-ply, and 9-ply) but lacks veneer thickness standards. The operational processes are categorized as log storage, debarking, bucking/trimming, peeling, green-clipping, drying, grading, gluing, panel layup, pressing, trimming, sanding, packaging, and processing activities. Performance indicates needs for improvement to quality management standards. The mean value of quality management criteria implementation using variable characteristics of log such as log form, dimension, and defects were 3.26, which shows intermediate achievement. The average performance of the company's production capacity over the four years was 81.53%. It is recommended that the company use the available resources efficiently to grow in a competitive market and keep up with modern information.

Key words: Performance, plywood, quality criteria, veneer, wood processing

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INTRODUCTION

The world's trade in wood is predominantly in primary or secondary products, and their contributions, such as construction materials, electrical poles, paper manufacturing, furniture making, and other building materials, are vital to the economic growth of society (EFAP, 1994; FSR, 2015; Brack, 2018). The sustainable production of wood has the most important to role in fulfilling the diverse outputs and services values (MEFCC, 2018). Forestry-related products are in great demand and increasing actively in Ethiopia (Rawat and Tekleyohannes, 2021). FAO (2016) reports strong growth in the production and consumption of wood-based panels and sawn timber; the global production in 2013 was increased by 8% and 5%, wood-based panel products, and sawn timber, respectively. A very modest growth (<1%/year) was quantified for pulp and paper production. Rawat and Tekleyohannes (2021) found primary and secondary forest products manufacturing is expected to increase from the current 112 million m^3 to 158 million m^3 by 2033. Infrastructural expansion and remarkable building activities are responsible for rapid increase of wood-based products in construction materials (MEFCC, 2018). Expanding the production potential of wood product companies to succeed with rapidly growing construction activities is essential (Bekele, 2011).

Industrial wood products are sawn wood, wood-based panels (plywood, fiberboard, chipboard), and paper (Bekele, 2000). The two types of plywood are structural or non-structural (APA, 2012), where structural plywood is used for construction purposes and non-structural plywood is purchased for aesthetics value and have high-quality face and paint. To supplement the limited supply of plywood products from domestic sources, the country is importing the product from abroad (Lemenih and Kassa, 2014; Alem, 2016; Rawat and Tekleyohannes, 2021). On the contrary, Debre Birhan wood processing company is a top company established for manufacturing structural plywood utilized in the domestic market. Besides, wood processing company has shown growths to process highly demanded wood products in the country, yet gaps exist. Bottlenecks to the expansion of industrial wood processing were not clearly described and the processing limitations and wood processing performances were not well-documented in the wood processing industry (FSR, 2015). Validation should be forwarded as production planning and scheduling and that they are efficiently utilizing the available resource.

Limited research has been conducted on quality standards, productivity, and production capacity of wood processing companies. Additionally, there is a limited identification standard used for log selection in utilization for face, back and interior veneer of plywood work. Therefore, this research has been conducted to respond to the company's veneer and plywood product processing and quality performances. In addition, the finding also focused on log supply efficiency, processing performance, and production success at Debre Birhan wood processing company.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted at Debre Birhan wood processing company, located in the Amhara regional state, North Shewa zone which is approximately 120 kilometers northeast of Addis Ababa, the capital city of Ethiopia. The study site is located between 9°41' N latitude and 39°32′ E longitude at an elevation of 2,840 meters above sea level. The average annual temperature and rainfall ranges between 20.7ºC and 8.2ºC and 814-1080 mm, respectively. The company is a principal construction plywood manufacturer in Ethiopia. It is a share company between Amhara Forest Enterprise and a Chinese investor with a proportion of 51% and 49% shares, respectively. Now the company is running with fully covered Ethiopian experts after four years of aggressive effort of knowledge transfer from the Chinese experts.

Sampling Procedure and Sample Size

A multi-stage sampling procedure was employed to select representative respondents. In the first stage, as par discussion with human resource department all company staff members were classified as management staff members and production operation staff members. The target populations were the employees of Debre Birhan wood processing, primarily those from management and senior production professionals. As per identification based on their job position 13 permanent employees in management staff and 125 Production operations staff were listed, which 138 of total population was quantified for sampling. Secondly, respondents were selected using random sampling for production operations staff. Sample size was determined according to the formula described by Gill and Johnson (2002). Equation (1) is used to compute the initial sample size. Since the initial sample size (eq-1) is above the population, their equation (2) is used to compute the new sample size.

In the third stage, the sample respondents were selected proportionally. All management staff (13 individuals) and 89 production staff were interviewed.

$$n_0 = \frac{Z^2 \times P(1-P)}{e^2} \qquad \textit{Eq. 1}$$

$$n_f = \frac{n_0}{1+\frac{n_0-1}{N}} \qquad \textit{Eq. 2}$$

Where; n_o = initial sample size, n_f = target sample size, Z= Z-value for Confidence level (i.e., 1.96 for 95% confidence level used in this research), P= percentage picking choice (i.e., 0.5 used for this research), e = confidence interval (i.e., 0.05 used), N = Total population

$$n_0 = \frac{1.96^2 \times 0.5(1-0.5)}{0.05^2} = \underline{384.16}$$

$$n_f = \frac{384.16}{1+\frac{384.16-1}{138}} = \underline{102}$$

Data Source and Methods of Collection

Both primary and secondary data were collected. Primary data included annual volume of material processed, marketed, wood raw material input-output relationship, the operational performance, and challenges affecting the operational performance. Primary data were collected using questionnaire, interviews, and physical/technical observations. Multi-stage interviews were held with unit and middle-level management divisions, and professional employees were also included in a face-to-face interview. Interviewees were purposely selected from department leaders including heads of the production with technical teams and administrative authorities within the company. Respondents for the interview were selected and arranged from departmental management, production workers and machinery technical heads, human resource department, procurement department, and property and logistics case team. Physical/technical observations were used to assess the manufacturing techniques in the production processes as well as the raw material supply quantity, and quality in the company.

Secondary data sources were collected from the company's various reports, production documents and data, and website of Amhara Forest enterprise (AFE) to validate the data collected from primary sources. Secondary data included the annual volume of wood utilized and the output produced, and identification of season for less output produced.

Veneer and Plywood Production System Model

Log allocation**:** The section is concerned with optimizing the supply of logs needed for the company considering the log length (straight over 2.7 m), diameter (as per sort of machine intake capacity), and defects free as suitability indicators for use. The model is used to outline the appropriate method and type of wood with the company requirement. Veneer and plywood operation represented one of the utilization centers to evaluate the proper allocation strategy of log for the production.

Generally, component manufacturing consists of a series of connected processes that convert the input material into the final product. Thus, the performance of the manufacturing process depends on how well the resource is balanced between the process and within each operation. A generic model for the evaluation of the performance of manufacturing was presented in Figure 1.

Production and Quality Performance

There are four specifications that are used in veneer grading operations. These are represented by A_1, A_2, B, and C grades assigned by the quality management team in the company. In data collection the criteria for each grading were assessed using interview and physical observations. Data collection were based on veneers length and width; quality, full-sized, surface smoothness, knot, surface hole use as the back and face of plywood products. A_2-grade is smaller veneer; veneers having some defect but small size and easily repairable. Quality parameters on plywood products were classified based on their back and face surface sheet quality. Plywood grades are classified into two: A-grade and B-grade type plywood. Data was collected using interview with store managers on time and criteria for plywood grading to be A-grade plywood products or B-grade.

The production capacity of the company was assessed using the trends from four consecutive years, and the performance results were calculated using the following equation.

$$PP\ (\%) = \frac{Actual\ annua\ production}{Planned\ annual\ production} \times 100$$

Where PP = production performance

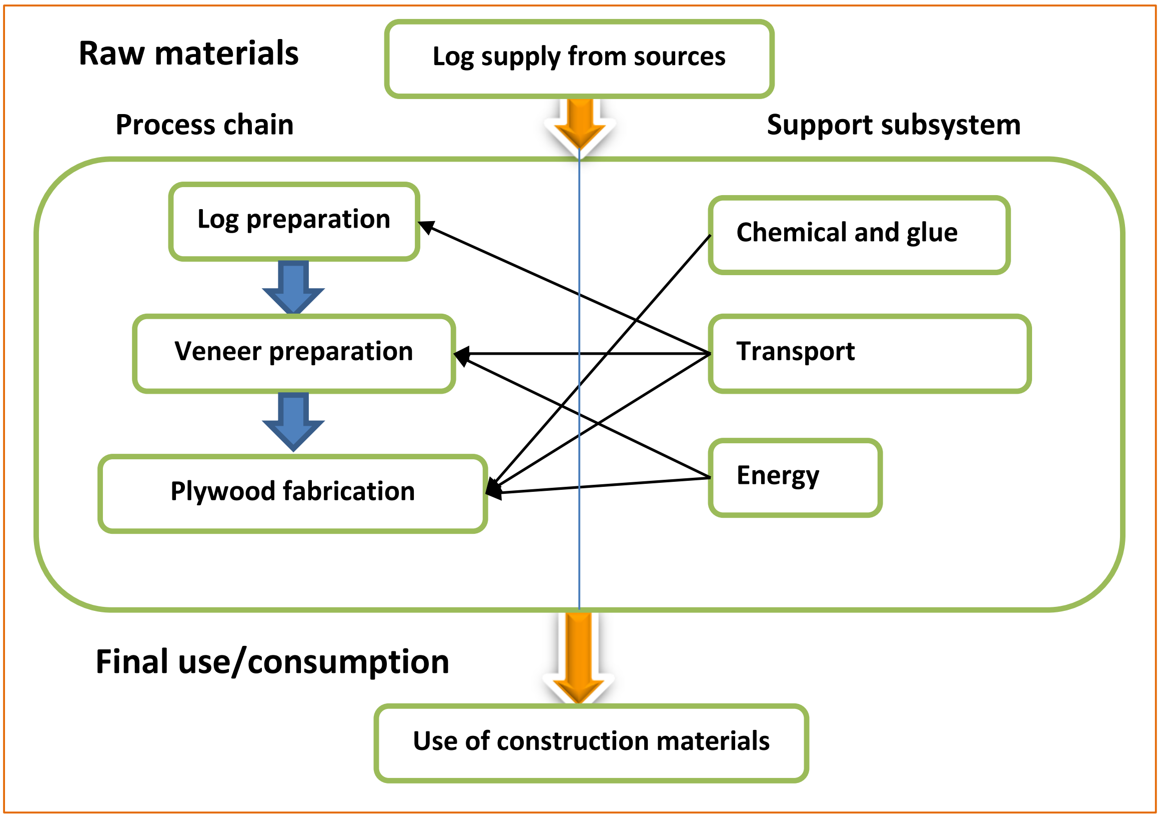


Figure 1. Veneer and plywood processing systems model

Data Analysis

The collected data were analyzed using the qualitative and quantitative data analysis methods. Before analyzing the data, raw data were processed (coded, edited, ordered, and organized) to generate relevant information. Descriptive statistics were used to analyze and understand the issue covered with production performance and current challenges that influence company performance improvement. The collected data were analyzed using each qualitative and quantitative evaluation methods. Qualitative evaluation methods were held with data collected in the form of descriptions while the quantitative analysis method was related to the numerical form of data. The Statistical Package for Social Science (SPSS version-20) and Microsoft Excel were used for analyzing data. Mean, frequencies, and percentiles analysis were used.

RESULTS AND DISCUSSION

Company Product Description

Veneer and plywood are produced at Debre Birhan wood processing company (Table 1). The veneer products were categorized based on the length and width for the two veneer types and the number of laminated veneer sheets for plywood products. Result indicates that the differences in veneer products were the length and width but the same thickness were manufactured. In the manufacturing process at the company the actual thickness desired was 2 mm and the considered value for shrinkage after drying and the machining lathe adjustment error was 0.2 mm. Similarly, Barbara (2014) stated that Australian Standard veneer drying shrinkage and machining distortion from Eucalyptus was +/-0.2 mm. The plywood products fabricated in the company were classified based on their number of plies/sheets and represented as 9-ply, 7-ply, and 5-ply with an estimated thickness (mm) of 18, 14, and 10, respectively. The most quantitatively produced plywood type was 9-ply type due to dominance in the market demand. The other two types (7- and 5-ply) plywood products are manufactured only on order by customers. APA (2012) stated that plywood thickness varied with the variability in exit moisture content, the pressure used for pressing, and a difference in thickness of veneer used for exterior and interior parts of the product than layer quantity.

Table 1. Dimensional description of veneer and plywood product types produced by Debre Birhan Wood Processing Company

Product type		Length (m)	Width (m)	Thickness (mm)
Veneer	Face veneer	2.50	1.45	2.2
	Interior veneer	1.30	0.70	2.2
Plywood	5-ply	2.44	1.22	10
	7-ply	2.44	1.22	14
	9-ply	2.44	1.22	18

Log Thickness Preference

Log thickness preference was measured and assessed using the survey questionnaires. The company's standard log thickness range was 13-45 cm. The discussion with log supply and quality managers indicated that the minimum and maximum thickness of logs were not continuously implemented for the scarcity of log supply at the rainy season. The thickness limitation to the maximum of 45 cm was restricted based on the intake capacity of the peeling machine, where logs thicker than the given ranges in diameters cannot be peeled. In general, with the specified thickness and machining capacity the professionals' preferences were obtained (Table 2).

Table 2. Log preference on the basis of diameter (large as >25 cm and small diameter were 13-25 cm Eucalyptus globulus log)

Log types	Frequency	Percentage (%)
Larger diameter log	81	82.65
Small-diameter log	3	3.06
Both	14	14.29
Total	98	100.0

Implementations of Log Quality Selection

The selection criteria of the company on five-point Likert scale and all these criteria were considered for a face veneer log (Table 3). The result indicated that the highest consideration in log selection was straightness (minimum of 2.7 m) and followed by knot-free, and then log with required diameter measure (13-45 cm) which are highly achieved for acceptance. On the other hand, characteristics of stump-pull/felling split, log handling damage, fungal decayed wood, and large-sized knot were among the criteria with high achievement to reject. Intermediately achieved selection criteria was shape, and growth defects. Finally, the least consideration was given to taper ratio measurement, lengthwise curvature/bend, check/shake, and logs with insect damage. A similar study by Barbara (2014) also indicated that the selection of quality logs used for veneers also needs proper management of logs during transport and supply handling. Furthermore, the overall mean result of the log quality implementation (3.26) indicated that the performance of the company is intermediate. According to Barbour (2001), the three most important criteria in specifications used by buyers and sellers with at least good implementation as criteria to determine the value were log grade, scale, and species. Bennett (2014) also confirmed that there was a strong negative relationship between lumber recovery percentages and log taper. Contrary to the literature, the consideration of log taper ratio as a criterion by Debre Birhan Wood Processing Company was very poor.

Table 3. Extent of implementation of various log quality practices for the company

Group	Variables measures	Min	Max	Mean	Std. Dev.
Criteria to receive	Straightness of log along 2.7 m	2	5	4.22	0.806
	Log diameter require as per machine capacity to peeling processes	1	5	3.93	0.933
	Cylindrical in shape	1	5	3.39	1.232
	Knots free log	1	5	4.19	0.713

	Minimum taper ratio	1	4	2.42	0.884
Criteria to remove	Lengthwise curve/sweep of log	1	5	2.09	0.838
	Log of abnormal/growth stressed	2	5	2.72	0.928
	Stump pull and felling split	2	5	4.00	0.812
	Log handling damage	1	5	4.07	0.828
	Sized holes on a log	1	5	2.96	0.994
	Log with the bumpy surface	1	4	2.98	1.184
	Log with shake/check	3	5	2.11	0.884
	Frequent but small-sized knot	2	5	3.34	0.849
	Large-sized knot	2	5	3.97	0.779
	Insects damaged	1	4	1.79	0.763
	Decayed wood	3	5	4.01	0.711
Average of mean and SD of criteria achievement				**3.26**	**0.88**

Veneer and Plywood Processing

The company's veneer and plywood production operation process with their supportive processes chains under the study is shown in Figure 2. The process includes bucking, debarking, peeling, green clipping, drying, grading followed by gluing, layering, cold pressing, hot pressing, trimming, defect sanding, and plywood grading.

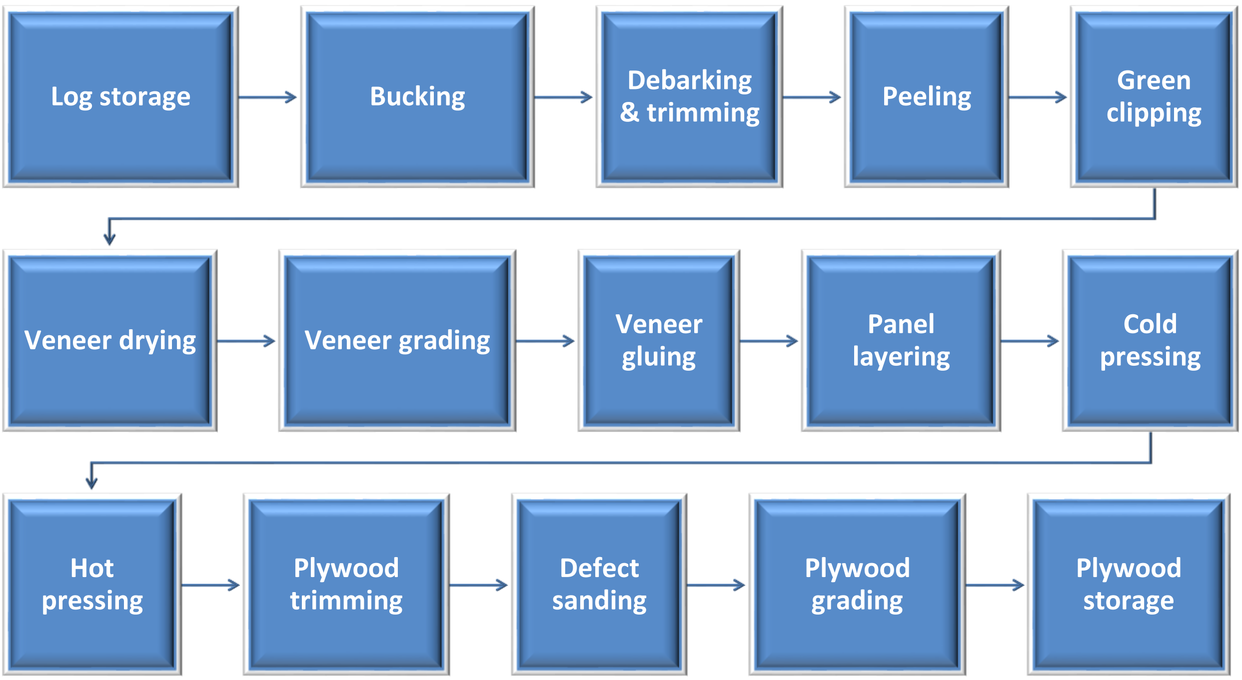


Figure 2. The complete operational activities for plywood fabrications

Log Preparation Processes

The preparation process includes log handling/storage, bucking, debarking, and trimming activities (Figure 2). The company's cut-length were 2.5 m for a face veneer and 1.3 m for interior veneer parts. Similarly, Irle et al. (2010) stated that the common cut lengths used by the majority of veneer manufacturing companies are 2.7 m for face veneer logs and 1.3 m for interior veneer logs, respectively. Bark removal was applied using the log debarking Spindles of Lathe technology through manual mounting which conveys good skinning effect. Similarly, Leggate et al. (2017) stated that using Spindles of Lathe debarking machine is usually with a more basic design, and is well suited to small operations and small-diameter logs. The problem in preparation phases is lack of log conditioning (heating/soaking) processes due to short time storage of logs. This short time storage date was indicative of high log utilization capacity relative to the supply of logs. Moreover, the company doesn't have log dipping pond. Contrary to this Emmanuel (1993) indicated that logs of especially hardwood species need to be conditioned to soften the wood to facilitate peeling and to produce an acceptable quality of veneer through soaking in hot water, exposed to live steam or hot water sprays. Figure 3 indicate the most basically applied log preparation processes exercised in the Debre Birhan Wood Processing company.

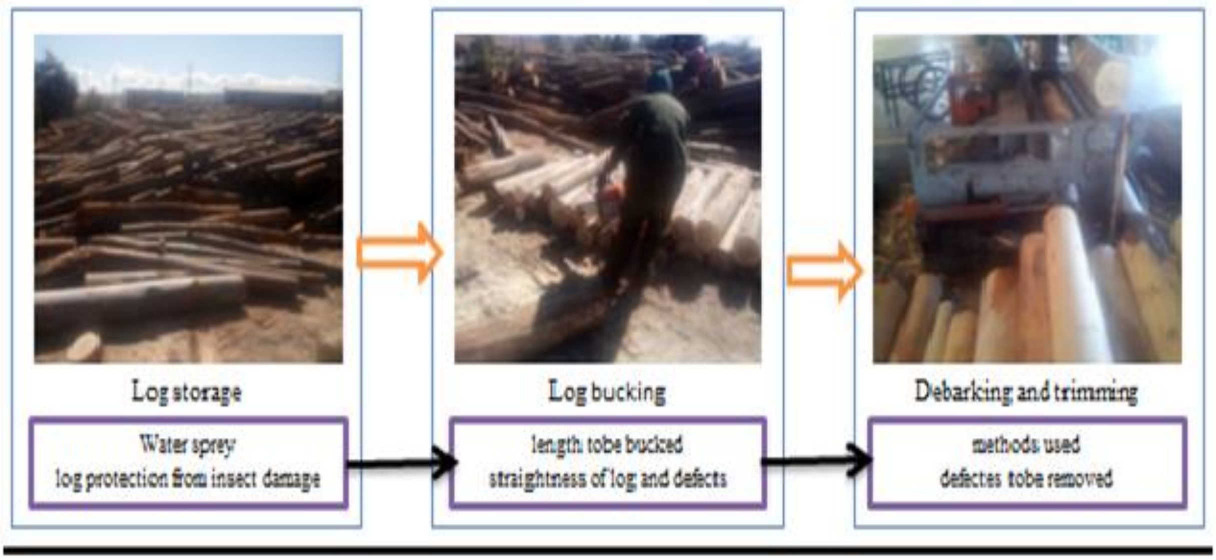


Figure 3. Log preparation activities of the first work-flow for the company

Veneer Preparation Processes

The second comprehensive class of time-intensive operations in the company is the veneer processing class, which starts with log peeling and ends with veneer grading. Figure 4 indicates the peeling operation in the company that is done using rotary peeling methods with a Spindles of Lathe veneer peeling machine. The method is the best for effectively utilizing small-diameter logs to recover more veneer from low-grade logs for manufacturing interior veneer and producing a more uniform cut. The performance report from Debre Birhan Wood Processing company was supported by Leggate et al. (2017) from Australia, where the majority (>90%) of the veneer companies use rotary peeling for a maximum yield. The rotary peeling method is preferable as it results in the widest sheets; with knots cut to show the smallest cross-section, where most small-sized wood and splits are left in the core. As reported by McGavin (2016), rotary veneer processing using Spindles of Lathe methods can efficiently process young fast grown hardwood plantation trees with resulting veneers containing visual grade qualities and mechanical properties suitable for the manufacture of structural veneer-based products. The veneer was conveyed from a peeling machine with a cut-width adjusted to 1.45 m for the face and 0.7 m for interior veneer). The veneers were clipped manually with pressure acting from two sides, applying critical care for quality.

Veneers are dried using solar- and air-drying systems for the summer/dry and winter/rainy periods, respectively. There is difficulty of regulating the standard moisture content due to unavailability of drying machine. The moisture ranges of 10-12% for the face and 7-9% for the interior veneers are tolerated after drying, which is in line with the report of Walker (2006) for plywood manufacturing having 6% to 12% range of moisture for the veneers. Furthermore, Zhang et al. (2006) described the need for veneer sheets to be dry before peeling/clipping to prevent the glue from over penetrating the wood, a phenomenon known as bleed-through. The adequate drying will help to avoid steam-induced blows during the hot-press. The drying temperatures of 90 -160°C may be considered normal with higher temperatures up to 175°C being used on certain tree species to reduce the overall drying time. Contrary to the recommended practices of regulating drying conditions, the Debre Birhan Wood Processing company lacks mechanical-drying machines and does not exercise the regulated drying conditions. In addition, infrastructure (electricity) is a bottleneck to efficient production settings.

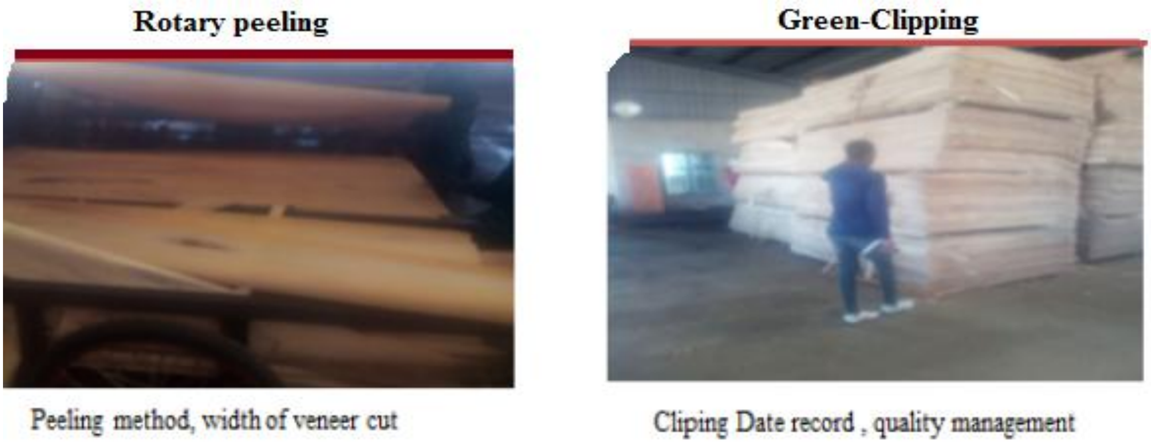


Figure 4. Rotary peeling and green clipping operation and main information flow

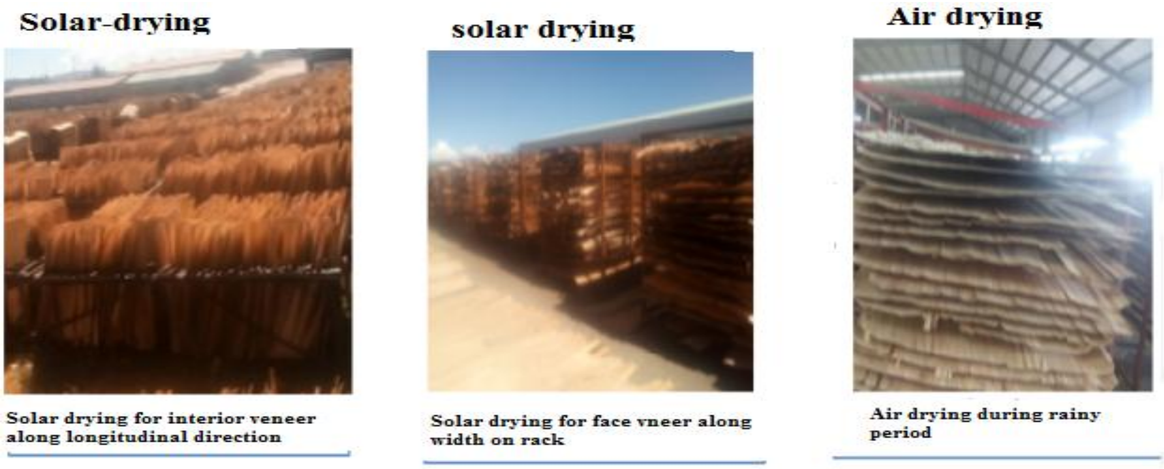


Figure 5. Veneer drying system and information

The moisture content of veneers and substrate is a critical factor in manufacturing of high quality and high-performance veneered products. However, the veneer produced in Debre Birhan Wood Processing company has a lot of drying defects like split, cracks shrinkage, waviness, and collapses. These defects were noted to be partly caused by low care during transportation to drying and during drying (manner of veneer set up on a rack), as well as lathe operation during peeling. The poor management results in fairly high veneer waste in the company, with the lack of a veneer jointing machine after drying, further affecting the standard and quality of the final product.

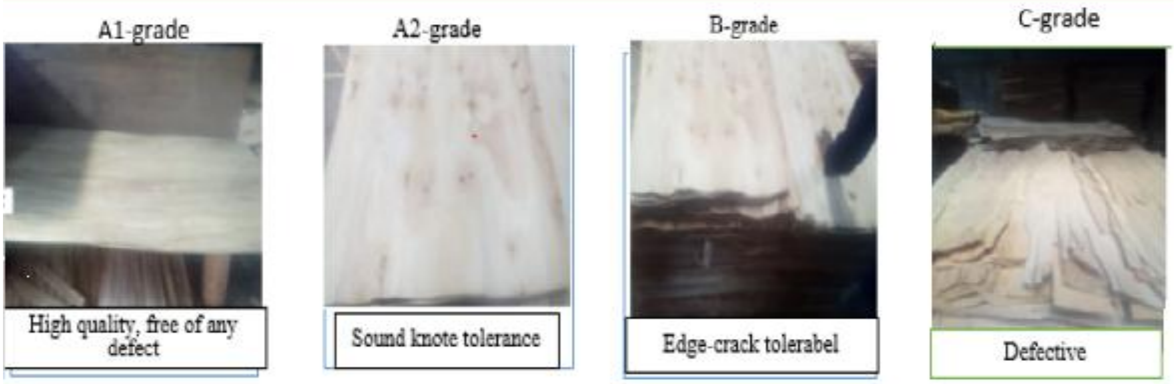


Figure 6. Criteria used for veneer grading in the company

Plywood Fabrication Process

In the fabrication process, the appropriateness of time, layering set-up and orders were assessed (Table 4). The time interval between layering and cold-press was not quantitatively specified. After the lay-up process, the wet laminated material goes into cold-press to flatten veneers. After the cold-press, the product is shifted into hot-press, where it is held for 8-15 minutes under pressure. The pressing time varies depending on the electric power. The minimum time of hot-press was needed for 5-ply type plywood whereas the maximum time requirement was for 9-ply type plywood products. This is in agreement with the reports of Irle et al. (2010) where the length of cycle specification is calculated as 'rule of thumb' is 1.5 min. for each mm of panel thickness.

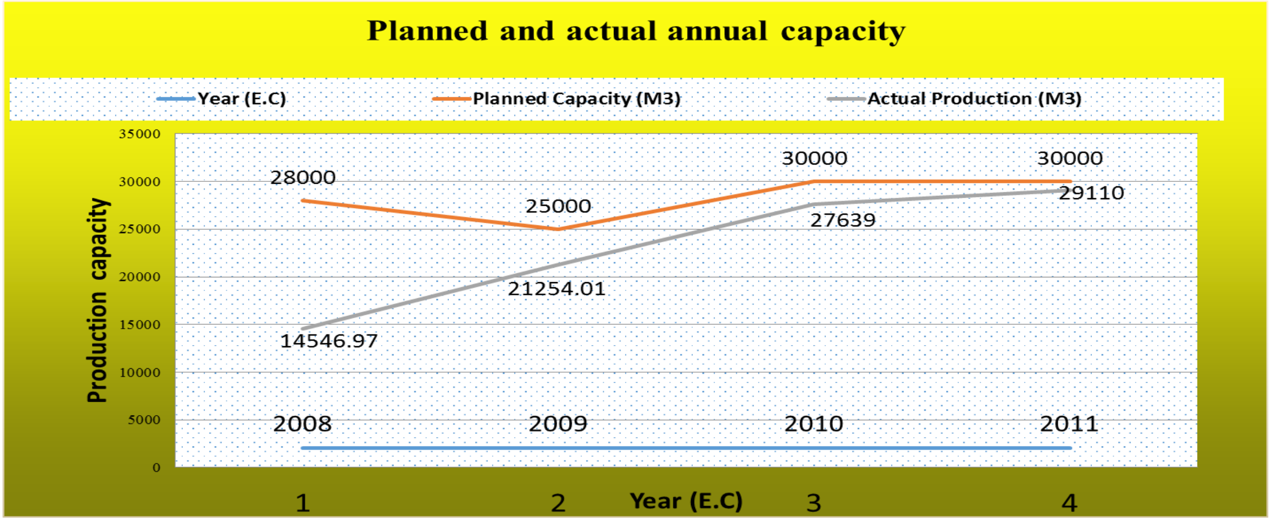
Table 4. Parameters for veneer layer operations

Layer no.	Layers set-up	Layer part with adhesive coated veneer	Veneer quantity (minimum)
5-layer	**L'**-T-L-T-**L'**	2nd, and 4th	2 face and 12 interior veneer sheets
7-layer	***L'**-T-L-T -L-T-**L'***	2nd, 4th, and 6th	2 face and 20 interior veneer sheets
9-layer	***L'**-T-L-T- ($L_{(f)}$) -T-L-T-**L'***	2nd, 4th, 6th, and 8th	3 face and 24 interior veneer sheets

***L'**= longitudinal, $L_{(f)}$ = longitudinal B-grade larger veneer, T = transverse (interior veneer), L= longitudinal (interior veneer)*

Production Capacity of the Company

In the analysis of the production performance of the company, the working hours, shifts per day, and machine availability were stated, and the company has a working time of eight hours and one shift per day. The production capacity was also assessed using intake capacity of plywood into the storehouse using current manufacturing performance and the recorded result indicates quantity was fluctuating over seasons of the year depending also on the input materials. Finally, the planned and the actual capacity of the wood processing company regarding the production capacity of the four years of plywood products were revised from the prevailed. Figure 7 shows the four years (2008-2011 EC) trend of the company's actual versus planned annual production. The average capacity utilization and the actual output of the company potentially increased in consecutive years. The result of the production performance of the company compared to its yearly plan of total production was 81.53%. In addition to the production performance, the trend of four years plan to actual production indicates there was a high improvement in balancing the plan according to their capacity. As seen from the start, the planned capacity was decreased, whereas the actual capacity increased, although there was a limitation on increasing planned production towards the end of the assessment years.



Performance (%)	**51.95**	**85.02**	**92.13**	**97.03**
Average				**81.53**

Figure 7. Production capacity of the company (source: document review)

CONCLUSION

The performance of Debre Birhan Wood Processing Company was evaluated in terms of quality management, production processes, capacity utilization, and challenges to performance improvement. The result indicates that log utilization was a function of quality implementation but, the specified quality criteria in log selection depends on log shape, diameter and knot. Regarding the plywood production, the company has three main phases of manufacture: log preparation phase (log storage to log trimming), veneer processing phase (veneer peeling to grading), and plywood manufacturing (veneer gluing to plywood packaging). Moreover, a veneer grading (A1, A2, B, and C) process follows only observable defects with the poorest quality veneer being grade C, in which defects such as cracks, knots, small-sized holes, and edge-scratches were acceptedFinally, the research findings indicate that the operating performance of the company concerning processing and quality standards was achieved at an intermediate level.

CONFLICTS OF INTEREST

Authors declare that there is no conflict of interest in the publication of this article.

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REFERENCES

Alem, S., 2016. Status and trends of the processed wood products trade in Ethiopia. Journal of Sustainable Forestry, 35(4): 251-260.

APA (American Plywood Association - The Engineered Wood Association). 2012. Panel design specification. Tacoma, WA: APA—The Engineered Wood Association: Wood the natural choice. Pg 36.

Barbara, O. 2014. A Manual for Decorative Wood Veneering Technology, The University of Melbourne Forest and wood product Australia, 2nd Edition. Editor Dr. Joely Taylor.

Barbour, R. J. 2001. Log and lumber grades as indicators of wood quality in 20-to 100-year-old Douglas-fir trees from thinned and unthinned stands (Vol. 510). US Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Bekele, M. 2000. Review and improvement of data Related to wood Products. EC-FAO Mineralization Rates and spatial Variability. Journal of Soil Science, 36:585-591.

Bekele, M. 2011. Forest plantations and woodlots in Ethiopia. In African Forest Forum 12(1):11-15.

Bennett, N. 2014. Sawing methods for improving lumber yield recovery of out-of-shape hardwood saw logs. Gen. Tech. Rep. NRS-130. Newtown Square, PA: US Department of Agriculture, Forest Service, Northern Research Station. 130: 1-8.
Brack, D. 2018. Sustainable consumption and production of forest products. In Proceedings of the Thirteenth Session of the United Nations Forum on Forests, New York, NY, USA (pp. 7-11).
EFAP. 1994. Forest industries and forest product development plan for Ethiopia. Taskforce main report number 7. Addis Ababa, Ethiopia.
Emmanuel, S. N. B. 1993. Decision Support System for Veneer and Plywood Production and Marketing: A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Forestry in the University of Canterbury (Doctoral dissertation, University of Canterbury).
FAO. 2016. 2015 global forest products facts and figures.
FSR (Forest Sector Review). 2015. Forest sector review focus on commercial forestry and industrialization, Addis Ababa, Ethiopia
Gill, J. and Johnson, P. 2002. Research methods for managers. Sage.
Irle, M., Barbu, M., Thoeman, H., Inggris, G. B., Irle M. and Sernek M. 2010. Wood baed panels: an introduction for specialists. Cost Action E49, p.1.
Leggate, W., McGavin, R. L. and Bailleres, H. 2017. A guide to manufacturing rotary veneer and products from small logs.
Lemenih M. and Kassa H. 2014. Re-greening Ethiopia: history, challenges and lessons. Forests, 5(8):1896-1909.
McGavin R. L. 2016. Analysis of small-log processing to achieve structural veneer from juvenile hardwood plantations (Doctoral dissertation).
MEFCC (Ministry of Environment, Forestry, and Climate Change). 2018. National Forest Sector Development Program, Ethiopia. Volume II: Program Pillars, Action Areas and Targets. Ministry of Environment, Forestry, and Climate Change, Addis Ababa, Ethiopia:
Rawat, Y. S. and Tekleyohannes, A. T. 2021. Sustainable forest management and forest products industry development in Ethiopia. International Forestry Review, 23(2): 197-218.
Walker, J. C. 2006. Primary wood processing: principles and practice. Springer Science & Business Media.
Zhang, D. Y., Sun, L. P. and Cao, J. 2006. Modeling of temperature-humidity for wood drying based on time-delay neural network. Journal of Forestry Research, 17(2): 141-144.

Original Research Article||

Assessment and evaluation of enset landraces to bacterial wilt (*Xanthamonas campestris* pv. musacearum) disease at Gedio Zone, Southern Ethiopia

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Abstract

Enset is an important food crop produced in Ethiopia with great role in food security especially for millions of people living in the southern and south western parts of the country. However, its production has been threatened by a devastating bacterial disease caused by *Xanthomonas campestris* pv. musacearum Field surveys in Gedio Zone and a pot experiment at Dilla University were conducted during the 2018/2019 cropping season. A total of 90 enset farms were observed at about 5 km apart. Observations of disease symptoms on farms were performed using a simple random sampling technique in a diagonal fashion within a sampling area of 10 m × 10 m. Numbers of infected and disease free enset plants in each sample were recorded. The results showed that 65% of enset farms were infected with the disease, with a mean incidence of 34.96%. Twenty Enset landraces collected from Gedeo zone were evaluated for their reaction to Enset bacterial wilt through artificial inoculation. The experiment was laid out in a Randomized Complete Design with twenty treatments assigned to experimental units in three replications. Except Maziya, all enset landraces showed wilt symptom but at varying levels of the disease incidence during the first 35 days after inoculation. Maziya was resistant enset landrace while Ganticho, Torame, Filila, Ado, Werabesa, Mindame, and Gakira were moderately resistant. Therefore, the resistant and tolerant landraces should be multiplied, demonstrated, and incorporated into farming practices. However, these should be further evaluated for a large number of Xcm isolates under both pot experiments and field conditions.

Key words: Enset, inoculums, resistance, tolerance

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INTRODUCTION

Enset (*Ensete ventricosum*) supports more than 20% of Ethiopia's population as stable and co-stable food (Tadesse, 2002; Spring et al., 1997). According to CSA (2016), enset is grown in south-western part of the country and covers considerable land area within the private holdings. The number of estimated enset trees harvested, in that agricultural year, from all over the country is 112,522,152. Thus, the total produce in the form of Amicho, Kocho, and Bula is 23,821,849.47 quintals, 28,329,103.94 quintals and 950,414.35 quintals respectively. From these next to Sidama Zone, Gedeo Zone has the second lion share accounting for 7,776,231 enset trees. Its product in the form of Amicho, Kocho, and Bula in quintals were 3,003,975.22, 3,421,855.40 and 61,909.36 quintals, respectively in 2015/2016.

Farmers use different clones for different uses like for kocho, bulla and fiber productivity, medicinal values, and rate clones based on their reaction to bacterial wilt diseases. Farmers conserve a number of enset clones ranging from 3 to 28, on average 9 clones per family farm in southern Ethiopia. The highest number of enset clones (66) was recorded in Dauro zone and the lowest number (26) in Gedeo zone. Enset contributes 23.36 % of the total gross farm income in these areas (McKnight Foundation Collaborative Crop Research Program Project., 2013). The majority of enset production is consumed by the producers as a main dish in their daily lives.

Gedeo is one of the major enset (*Ensete ventricosum*) producing zones of the Southern Nations, nationalities and People's region. Coffee and enset are the dominant perennials in the Gedeo Zone, with enset is growing over all altitudes (Gebrehiwot and Maryo, 2015). In addition, Gedeo zone is characterized by its enset based agro-forestry system and such system is also found in Sidama, Gurage, Hadiya and Kembata zones of the country (Tadesse, 2002).

The production and productivity of enset is threatened by different biotic and abiotic factors. Among the biotic constraints, diseases caused by bacteria, fungi, nematodes, viruses as well as mammalian and insect pests have been identified as serious problems. Of all the biotic constraints, the bacterial wilt disease is the major impediment for enset production. Enset Bacterial Wilt (EBW) particularly *Xathomonas vasicola pv. musacearum* is known to cause severe damage, as it attacks and kills the plants at any growth stages, including fully matured (ready for harvest). Both the areas and the productivity of enset is declining continuously due to this disease (Endale et al., 2003; Tsegaye et al., 2007; Anita et al., 1996). The losses due to this disease can reach up to 100% under favorable condition. The disease is also the major constraint for enset production in Gedeo zone.

Host plant resistance is believed to be the most effective and economical control measures for the disease. Yet, there is no bactericide control agent recommended for the disease, hence use of EBW resistant cultivars remain to be the only practical and effective method of controlling the disease. However, the development of resistant enset clone has remained difficult, available reports related to clonal screening against bacterial wilt have indicated the possibilities of using host plant resistance. The reactions of enset clones to EBW disease was evaluated at different regions of Ethiopia and variable levels of reactions were observed (Mekuria et al., 2016, Mengistu et al., 2014; Welde-Michael et al., 2008). Gedeo zone is one of the potential areas for enset production and high diversity of enset landraces. Despite the importance of enset crops in Gedeo and the significant diversity of enset clones in the zone, the identification of enset clones' resistance to EBW disease is essential. Therefore, the objectives of this study were to determine the distribution and incidence of enset bacterial wilt disease in the study area and to evaluate the resistance of enset clones to EBW disease.

MATERIALS AND METHODS

Description of the Study Area

This study was conducted in the Gedeo zone during the 2018/2019 cropping season. The area is located about 365 km south of Addis Ababa along the main highway that connects Ethiopia and Kenya, and about 90 km south of Hawassa, the capital city of SNNPRS. The zone shares boundaries in the East, West and South with Oromia regional state, and in the North with Sidama Region. The total area of the zone is 134,708 hectares. The study area lies at elevation ranging between 1501 and 3000 masl. The major crops grown in the area are enset, maize, soya bean, cabbage, fruit trees (avocado, mango), root and tuber crops, coffee and onion. Enset -Coffee based agroforestry is the leading farming system in the area. Enset is the major crop grown in the zone; it is the most frequently and widely grown crop used for household consumption, and it is becoming one of the most valuable cash crops and a source of livelihood support for the rural community.

Field Survey and Sampling Procedures

The status of EBW at each field was assessed and recorded through direct field observations. Three districts of the zone namely: Dilla Zuriya, Bule and Gedeb were purposefully selected for their high enset production potentials. A total of 9 kebeles (three in each district) were selected based on road access and importance of the disease. A total of 90 enset farms were observed (10 in each kebele) at about 3-5 km apart. Observation for disease symptom in farms was performed with a simple random sampling technique in a diagonal fashion in a sampling area of 100 m (10 m × 10 m). The number of samples observed from each farm ranged from three to five, depending on the size of the farm. Numbers of infected and disease free enset plants in each sample were recorded. Disease incidence was calculated as the number of plants showing wilting symptoms divided by the total number of plants assessed, multiplied by 100.

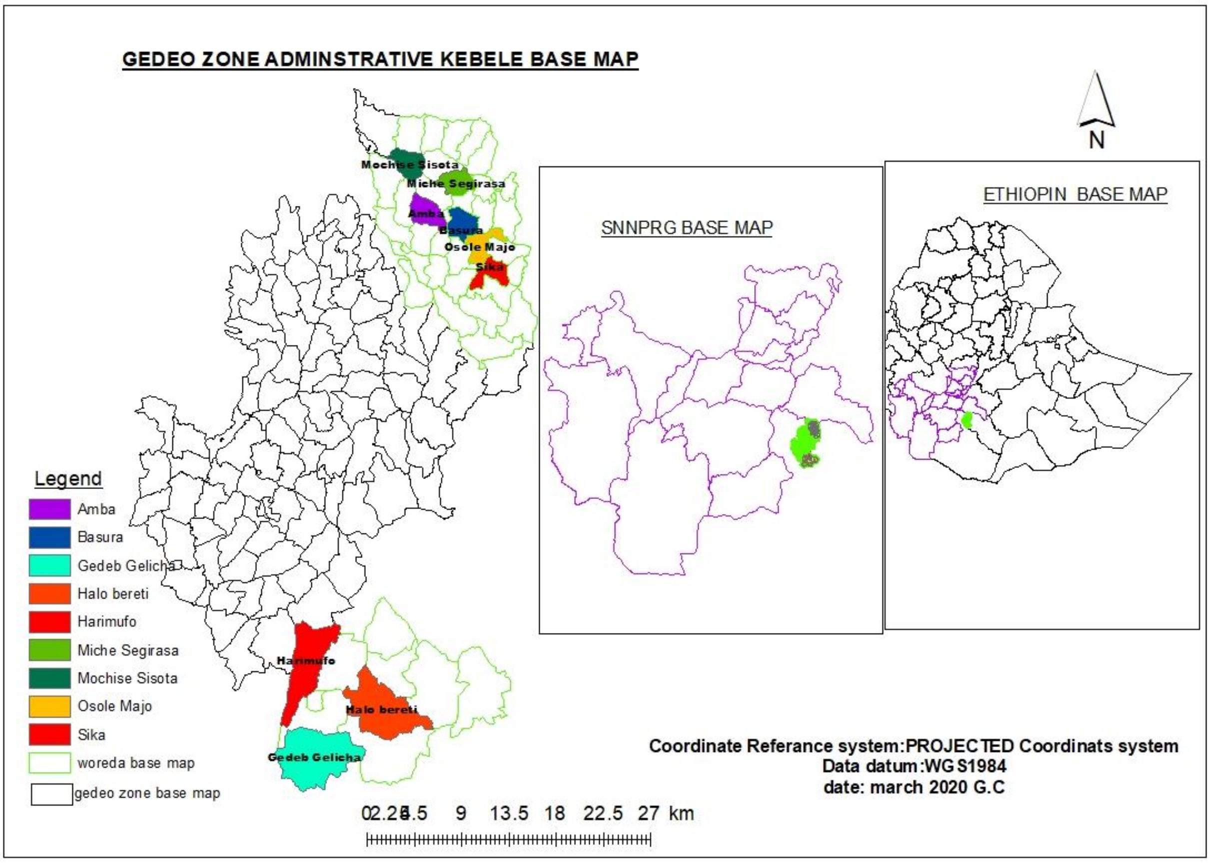

Figure 1. Maps of study sites surveyed for EBW disease

Average wilt incidence for the field was obtained. Prevalence of the disease was calculated using percentage of fields encountered with bacterial wilt disease. Disease severity was calculated based on percentage of damage observed and followed by the procedure of Horsfall and Barratt, 1945.

$$\text{Prevalence} = \frac{NWF}{NTF} X100$$

Where, NWF = the number of fields with bacterial wilt symptom and; NTF = the total number of surveyed fields.

$$\text{Wilt Incidence} = \frac{NWP}{TNP} X100$$

Where, NWP = the number of plants infected by bacterial wilt symptom and; TNP = the total number of plants assessed.

Figure 2. Identification of infected plants during field survey at Amba kebele

Isolation and Preparation of Bacterial Suspension for Inoculation

Xanthomonas campestris (Xcm) samples were collected from a disease hot spot in the Gedeb area, Gedeo Zone, southern Ethiopia. Xcm bacterial ooze from young leaves and/or pseudo stem of diseased enset plants were collected into sterile distilled water and preserved at 4℃ until use. The samples were cut into smaller pieces using sterile scalpel. Then after, the cut pieces were placed in a test tube containing 5 mL of distilled water and allowed to steam for 5 minutes until the bacterial population diffuses out of the cut tissue into the distilled water. Serial dilutions of the bacterial suspension were prepared, and a loopful of the 10^{-3} dilution was streaked onto a sterilized semi-selective growth medium (Tripathi et al., 2007).

Pathogenicity and Hypersensitivity Test

A pathogenicity test was conducted by using a susceptible enset landrace. Xcm suspension (10 mL) of 24 hrs old were tested for hypersensitivity and pathogenicity on two-month-old tobacco (*Nicotiana tabacum*) or the susceptible control enset landrace. In hypersensitivity test conducted on *N. tabacum* (Bobosha, 2003) using cultured and uncultured inoculum types independently, 2 mL of a bacterial suspension containing ~10^8 colony forming units (CFU) per mL (approximately OD600 = 0.5) was used for inoculation. A positive hypersensitive response was scored if tissue exhibited yellow clearing chlorosis limited to around the point of injection. For the initial assessment of pathogenicity tests, disease-free enset suckers of the susceptible landrace 'Astara' were infected, as described by Bobosha (2003) for 'Arkia,' which is a susceptible landrace of enset.

Inoculum Preparation

Bacterial ooze was collected from the inoculated plants used in pathogenicity test. The exudates were collected aseptically from the cut ends of petioles and leaf sheaths of freshly infected plants with the help of a toothpick and suspended in sterilized distilled water.

Inoculum of EBW and Disease Assessment

The pot experiment was organized in three replicates of 20 landraces, each landrace containing 10 plants and landraces within each replication were randomized. Thus, the entire experiment comprised a total of 600 plants. This included a total of 30 individuals of the 20 enset landraces inoculated with uncultured Xcm suspension and the remaining 10 individuals of the 20 plants comprising negative controls inoculated with sterile distilled water. Suckers of three-month-old of the landraces generated from corms of 2 years old were collected from major enset growing areas of Gedeo Zone and Areka enset clones' maintenance and multiplication site. Enset clones of Maziya were used as a resistant check. Uncultured Xcm suspensions preserved at 4℃ were used as inoculum for landrace evaluation. Suckers of enset landraces (two months after transplanting in potted soil mix) were inoculated with a 4 mL aliquot of the bacterial suspension, adjusted to ~10^8 CFUmL^{-1} as described above, by infiltration with a hypodermic sterile syringe into the youngest innermost leaf petiole (Figure 3). A new sterile hypodermic syringe was used for inoculating each sucker of every landrace. The control plants were infiltrated with the same volume of sterile distilled water.

Disease evaluation was conducted at seven days interval for one and half month as suggested by Welde-Michael et al. (2008) for number of diseased plants and severity after artificial infection. Disease assessment will be done at 7, 14, 21, 28 and 35 days after inoculation. The number of infected plants per clone at each disease assessment period was recorded**.** Disease severity was calculated based on the percentage of damage observed, following the procedure of Horsfall and Barratt, 1945.

Data Analysis

The disease prevalence and incidence were analyzed from the collected data by descriptive statistics. The experimental data was subjected to analysis of variance using SAS version 9.2. Means were compared by using least significant difference (LSD) at 1% level of significance.

Figure 3. Inoculation of landraces with uncultured *Xanthomonas campustris* pv. musacearum (Xcm) suspension

RESULTS AND DISCUSSIONS

Prevalence and Incidence

Bacterial wilt disease symptoms were observed in the majority (65% and 34.96%) of the observed enset farms with disease prevalence and incidence percentage, respectively (Table 1). Disease prevalence and incidence varied among the three districts and also among kebeles within a district. The obtained disease incidence in the surveyed farms ranges from 10-66.7% with mean of 34.96%.

Table 1. Prevalence and incidence of EBW in different production locations of Gedeo Zone

District	Keble	Number of farms			Prev. (%)	Incidence%	Severity%
			*NF	*IF			
Dilla Zuria	Anba	10	4	6	60	18.8	100
	Girsa	10	6	4	40	16	100
	M/ Sisota	10	8	2	20	10	100
Bule	Basura	10	3	7	70	30	100
	Oselemajo	10	1	9	90	53.4	100
	Sicka	10	6	4	40	24.2	100
Gedebe	Gubeta	10	0	10	100	66.7	100
	Harmufo	10	1	9	90	58	100
	Hallo Berte	10	2	8	80	37.5	100
Total		90	31	59			
Average					65.6	34.96	

*NF=Non-infected; *IF =Infected; Prev =prevalence

Wilt Incidence for Landraces

The disease was mostly observed on plantations of older than four years. The farmers in the survey area were growing many different clones of enset, with variations among cultivars in their reaction to the disease. However, there was no completely resistant enset landrace. Most of the farmers were aware about the disease. Inter cropping with cactus, rouging out of the diseased plant was the common management practice followed by farmers in controlling the dispersal of the disease. But the assessed farmer's practices on the management of EBW disease were mainly related to sanitary measurements, where most farmers also believed that disease transmission is by farming tools and browsing animals. that are the most important factor, play major role in dissemination of the pathogen in their fields. Generally, the phytosanitary measures minimize the EBW disease severity.

Table 2. Wilt incidence at various days after inoculation (DAI) and disease rating for the 20 enset landraces

No.	Clone name	EL	Disease incidence (%), DAI				DI
			7	14	21	28	
1.	Maziya	10	0	0	0	0	0.00^{h}
2.	Ganticha	10	0	0	0	10	10.00^{gh}
3.	Torame	10	0	0	0	10	10.00^{gh}
4.	Filila	10	0	0	10	20	40.00^{ef}
5.	Ado	10	0	0	20	20	40.00^{ef}
6.	Werabesa	10	0	0	10	20	30.00^{fg}
7.	Mundame	10	0	0	20	30	40.00^{ef}
8.	Gakira	10	0	0	10	20	26.67^{fg}
9.	Korkoro	10	0	10	20	30	56.67^{de}
10	Shagna	10	0	20	30	50	60.00^{cde}
11.	Kake	10	0	10	30	40	70.00^{bcd}
12.	Harame	10	0	10	20	40	60.00^{cde}
13.	Bufe	10	0	20	40	60	70.00^{bcd}
14.	Miqe	10	0	20	30	30	60.00^{cde}
15.	Dinke	10	0	30	50	60	80.00^{abc}
16.	Karase	10	0	20	40	60	80.00^{abc}
17.	Dimoye	10	10	30	50	70	80.00^{abc}
18.	Dambale	10	0	30	40	80	90.00^{ab}
19.	Astara	10	10	30	70	80	100.00^{a}
20.	Nifo	10	10	40	60	90	100.00^{a}
LSD							20.08
CV%							22.02

DI = disease incidence, DAI = days after inoculation; EL =

Symptom development after the artificial inoculation was similar to those observed in young plants affected by natural infection in the field. A range of symptoms was observed during the course of infection and subsequent disease development on Xcm-challenged enset landraces. At early stages of infection, up to 28 DAI, landraces showed a varying range of symptoms (Table 2), which included twisting with slight leaf curling, and drooping of the blade and tip of the inoculated leaf. The leaf blade around the Xcm inoculated area often became deformed, twisted or curved inwards. These symptoms were replaced by severe curling of the leaf edge, drooping and folding back of leaf blade from 28 DAI, were consistently observed in all landraces. Gradually, drooping from the leaf apex and folding back or collapsing of leaves became the most prominent symptom as the disease developed. All tested enset landraces showed one or more of the symptoms.

Significant differences ($p < 0.0001$) were observed in the incubation period, wilt incidence, and complete wilting period among the 20 enset landraces evaluated for their resistance to Xcm pathogen (Table 3). The various enset plants showed significant differences in susceptibility to Xcm with wilt incidence at the 35th DAI ranging from 0 to 100%. Maziya was resistant to Xcm with no wilt incidence at 35 DAI, and with mean incubation period of 50 days and complete wilting of 67.67 days. Seven enset landraces, were moderately resistant to Xcm. These ensest landraces showed wilt incidence of less than 40% at 35 DAI and an incubation period of 56-30 days. On the other hand, a complete wilting for these landraces ranged from 64-40 DAI (Table 2). Six enset landraces, were susceptible to the pathogen with an incidence at 35 DAI of 56.67-60%, incubation period of 26-25 days and a complete wilting from 38-36 DAI. The other eleven landraces were found to be highly susceptible to Xcm pathogen with wilt incidence of 70-100% at 35 DAI, incubation period of 16-36 days and complete wilting period of 48-64 days (Table 2).

Resistance Rating

Many reports indicate that there was no completely resistant enset clone to Xcm pathogen (Handora and

Michael, 2007; Gizachew et al., 2008), except for Mezya, which had a high resistance to the pathogen (Dereje, 1985).

Table 3. Mean incubation period, complete wilting and disease rating for the 20 enset landraces

No.	Clone name	EL	MIP	CW	CR*
1.	Maziya	10	50.00[b]	67.67[a]	R
2.	Ganticha	10	56.00[a]	64.00[b]	MR
3.	Torame	10	44.00[c]	62.00[b]	MR
4.	Filila	10	38.00[d]	52.00[c]	MR
5.	Ado	10	39.00[d]	54.00[c]	MR
6.	Werabesa	10	36.00[de]	50.00[d]	MR
7.	Mundame	10	33.33[ef]	52.67[cd]	MR
8.	Gakira	10	30.00[fg]	40.00[e]	MR
9.	Korkoro	10	26.00[ghi]	38.00[efg]	S
10	Shagna	10	25.00[hi]	38.00[efg]	S
11.	Kake	10	27.00[gh]	38.00e[fg]	S
12.	Harame	10	26.67[ghi]	36.00[fg]	S
13.	Bufe	10	26.00[ghi]	39.33[fg]	S
14.	Miqe	10	25.00[hi]	36.00[fg]	S
15.	Dinke	10	24.00[hij]	35.00[fgh]	HS
16.	Karase	10	23.00[hij]	35.00[fgh]	HS
17.	Dimoye	10	23.00[hij]	34.00[gh]	HS
18.	Dambale	10	22.00[ij]	32.00[h]	HS
19.	Astara	10	20.00[j]	25.00[i]	HS
20.	Nifo	10	20.00[j]	25.00[i]	HS
LSD			4.23	3.09	
CV%			8.33	4.39	

*MIP = Mean incubation period; CW = Complete wilting; R = resistant; MR = moderate resistant; S = susceptible; HS = highly susceptible.

The resistance rating was based on average wilt incidences at 35 DAI (days after inoculation): as highly susceptible (HS): 70-100% plants wilted, susceptible (S): 40-69% plants wilted, moderately resistant (MR): less than 40% plants wilted and resistant (R): none of the plants completely wilted. Means with different superscripts within the same column and class are statistically different at 1% level of significance.

Similarly, no banana cultivar was found to be completely resistant to Xcm (Tariku et al., 2015; Smith et al., 2008; Tripathi et al., 2007). None of the inoculated enset clones were recovered from Xcm infection. Fikre and Gizachew (2007) reported enset clones are not consistent for their resistance/tolerance across locations and time. Both the susceptible (Astara) and the tolerant (Nifo) checks used in the present study were all found to be susceptible to the pathogen. Tariku et al. (2015) also reported that Astara was a susceptible clone. This study shows that enset landraces vary in their reaction to enset bacterial wilt. Landraces like Ganticha, Torame (Toricho) and Filila were recovered after initial disease symptom development. In the present experiment, tolerant land races were identified.

CONCLUSIONS

Generally, all the enset landraces except maziya showed symptoms of chlorosis and/or necrosis on leaves of the inoculated plants in varying periods, whereas the control plants (inoculated with water only) did not show any kind of symptoms. However, the landraces varied in their reaction to the pathogen, including incubation period, wilt incidence, and complete wilting days. Among the evaluated 20 enset landraces, only Maziya was resistant and that of Ganticha was moderately resistant, while six enset landraces, were categorized as susceptible ones. The other 11 enset clones were found to be highly susceptible to Xcm pathogen. Considering the rich diversity of enset plants, it was anticipated that screening and evaluation of enset clones might provide a good source for effective management strategies of the disease. The present study identified one resistant and seven moderately tolerant enset clones to the pathogen. Therefore, farmers should be encouraged to incorporate these clones in combination with other effective control measures into their farming systems. On the other hand, this study considered only 20 enset landraces. However, enset plant is genetically diverse in different locations and zones. Therefore, it is recommended that all enset landraces be collected and evaluated for their reaction to the pathogen at the farm level across the country. It is also recommended that all genetic resources are further evaluated against a large number of Xcm isolates after being well-characterized into races or biotypes. The tolerant landraces should also be further evaluated for their agronomic performance.

CONFLICTS OF INTEREST

Authors declare that there is no conflict of interest regarding the publication of this article.

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REFERENCES

Anita, S., Clifton, H., Endale, T. and Gizachew W. M. 1996. Enset need assessment project Phase 1 Report. Awassa, Ethiopia.

Bobosha, K. 2003. Characterisation of Xanthomonas campestris pv. Musacearum isolates: Causal agent of enset bacterial wilt disease. M.Sc. Thesis. Addis Ababa, Ethiopia. 95pp.

Spring, A., Diro, M., A Brandt, S., Tabogie, E., Wolde-Michael, G., McCabe, J.T., Shigeta, M., Hiebsch, C., Tesfaye, S. and Yntiso, G. 1997. Tree against hunger: enset-based agricultural systems in Ethiopia. American Association for the Advancement of Science.

CSA (Central Statistical Agency). 2016. The Federal Democratic Republic of Ethiopia Agricultural Sample Survey 2015/2016. Volume I. Addis Ababa, Ethiopia. Ethiopia Climate-Smart Agriculture Scoping Study.

Dereje, A. 1985. Studies on the bacterial wilt of enset (*Ensete ventricosum*) and prospects for its control. Ethiopian Journal of Agricultural Science, 7(1): 1-14.

Endale, T., Million T. and Gizachew W. 2003. Enset-based farming system of Kucha Woreda of Gamo Goffa Zone. Research Report No. 52. EARO. SNNPRS, SARI, p. 48.

Fikre, H. and Gizachew W. M. 2007. Evaluation of enset clone meziya against enset bacterial wilt. Proceeding of Africa Crop Science Conference. 8: 887-890. El-Minia, Egypt. African Crop Science Society.

Gebrehiwot, B. and Maryo, M. 2015. 'Evaluation of land use patterns across agro-ecological and slope classes using gis and remote sensing: The Case of Gedeo Zone, Southern Ethiopia', International Journal of Advanced Remote Sensing and GIS., 4(1): 1385-1399.

Gizachew, W. M., Kidist ,B., Blomme, G., Addis, T. A., Mengesha, T. and Mekonnen, S. 2008. Evaluation of enset clones against enset bacterial wilt. African Crop Sci. J., 16: 89-95.

Handora, F. and Michael, G. W. 2007. Evaluation of enset clone meziya against enset bacterial 531 wilt. 8th African Crop Science Society Conference, El-Minia, Egypt, 27-31 October, 2007.

Horsfall, J. G. and Barratt, R. W. 1945. An Improved Grading System for Measuring Plant Diseases. Phytopathology 35.

McKnight Foundation Collaborative Crop Research Program Project. 2013. "Integrated Management of Bacterial Wilt of Enset (Ensete ventricosum (Welw.) Cheesman) caused by Xanthomonas campestris pv. musacearum in Ethiopia"

Mekuria, W., Amare, A. and Chala, A. 2016. Evaluation of Enset Clones for their Reaction to Bacterial Wilt of Enset (*Xanthomonas campestris pv. musacearum*) in Gurage Zone, Southern Ethiopia. Jordan Journal of Biological Sciences, 9(2): 109–115.

Mengistu, O., Kassahun, S., Tariku, H. and Selvaraj, T. 2014. Assessment of Disease Intensity and Evaluation of Enset Clones Against Bacterial Wilt (Xanthomonas campestris pv. musacearum) in Tikur Inchini and Jibat Districts of West Shewa, Ethiopia. International Journal of Research in Science. 1(2): 83–97.

Smith, J. J., Jones, D. R., Karamura, E., Blomme, G. and Turyagyenda, F. L. 2008. An analysis of the risk from Xanthomonas campestris pv. musaceurum to banana cultivation in Eastern, Central and Southern Africa. Biodiversity International, Montpellier, France. 1-29

Tadesse, K. K. 2002. 'Five thousand years of sustainability: A case study on Gedeo land use, Southern Ethiopia', Treemail publishers, Heelsum, the Netherlands, pp. 147-169.

Tariku, H., Kassahun, S., Endale, H. and Mengistu, O. 2015. Evaluation of enset clones' resistance against enset bacterial wilt disease (*Xanthomonas campestris* pv. musacearum). J. Vet. Sci. Technol. 6.

Tripathi, L., Odipio, J., Tripathi, J. N. and Tusiime, G. 2007. A rapid technique for screening banana cultivars for resistance to Xanthomonas wilt. European J. Plant Pathol., 121: 9-19.

Tsegaye, B., Tesfaye, G., Kidist, B., Shiferaw, M. and Bola, F. 1998. Study on Coffee and Enset Production Constraints in Kucha Woreda, Kucha KHC Integrated Development project, Ethiopia.

Welde-Michael, G. K., Bobosha, G., Blomme, A., Temesgen, T. M. and Mekonnen, S. 2008. Evaluation of Enset Clones against Enset Bacterial Wilt. African Crop Science Journal, 16(1): 89-95.

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Review articles cover recent advances in an area in which an author has been actively engaged. Maximum permissible length is 6000 words, including title, abstract and bibliography, or proportionately shorter if the review includes illustrations.

Short communications

Short communications contain news of interest to researchers, including progress reports on ongoing research, records of observations, short comments, correction and reinterpretation of articles previously published in JSD, etc. Maximum permissible length is 1500 words, including title, abstract and references; they may contain no more than two figures and/or two tables.

Book reviews

A critical evaluation of a recently published book in all areas of science and development will be published under this column. The maximum permissible length of a book review is 1500 words, including any references.

Format of manuscripts

Research articles intended for submission to the Journal of Science and Development (*JSD*) should have the following basic structure.

Research articles

Title: The title of the paper, the name (s) and affiliated institutions. Full postal, telephone and email address of the corresponding author should be clearly indicated.

Abstract: The abstract must contain (a) the author's or authors' name(s), (b) the full title of the manuscript, (c) an abstract of not more than 250 words indicating the major aims and findings of the paper.

Keywords: 3-6 keywords should be set below the abstract, arranged in alphabetical order and separated by commas.

Introduction: A brief background of the subject, statement of the problem and the aims of the paper.

Materials and methods: Describe the materials and sites used in the study, the procedures, methods or tools used in data collection and analysis.

Results: Describe the results obtained, cross-referencing between text, tables and figures. When applicable, describe the statistical significance of the results.

Discussion: Give interpretations and implications of the results obtained. Compare your findings with related previous studies. The results and discussion sections may be presented together or separately.

Conclusions: Describe the contribution of the study to knowledge, and indicate future research needs (if any). The conclusion may also be included in the discussion.

References: All literature referred to in the text should be cited as exemplified below.

Acknowledgements: (if required). These should be brief, *e.g.* five lines of text.

Short communications

Short communications should essentially follow the structure given for research articles.

Review articles, book reviews

The structure of these articles will largely be determined by their subject-matter. However, they should be clearly divided into sections by an appropriate choice of headings.

Methods of submission

1. Electronic submission

Manuscripts should be prepared by means of Microsoft Word or an equivalent word-processing program. They should preferably be submitted electronically, by means of the style sheet ***JSD*-stylesheet.doc**, which can be downloaded from the Journal webpage. This style sheet consists of two sections:

(1) an *Input section*, into which your final manuscript is pasted from another Word document, and

(2) a *Help section*.

The Help section contains detailed instructions for preparing a manuscript for *JSD*. Please read it before you begin to prepare your manuscript.

Electronic files containing manuscripts should be named according to the following convention:

Authorname_Brief_title.doc, *e.g.* Bloggs_Podocarps_in_southern_Ethiopia.doc, Where Brief_title is the first 4-5 words of the manuscript's title.

Diagrams should be lettered in a sans-serif font (Arial or Helvetica-at least 12-point), for final reduction to single- column (6.9 cm) or double-column (14.3 cm) width. Single column figures are preferred. Black-and-white diagrams should be submitted as uncompressed TIFF (.tif) files or as .jpg files, at a resolution of 300 dpi. Diagrams created in the default mode of Microsoft Excel (frame, colored background, *etc*.) are not acceptable for publication in *JSD.*

Files containing diagrams should be named according to the following convention: Author name _Figure No xxx.tif,
e.g. Bloggs_Figure 006.tif

Photographs should be submitted as high-resolution (at least 600 dpi) greyscale (8-bit).jpg or uncompressed .tif files. The desired final size ('1-col', '2-col' or 'landscape') should be indicated. Always send photographs as separate files, using the same filename convention as above.

Photographs as described above are preferred, but clear, glossy black and white photographs (100×70 mm) on photographic paper may also be submitted. They should be clearly numbered on the back in **soft** pencil.

Tables should be prepared in MS Word's Table Editor, using (as far as possible) 'Simple1' as the model: (Table … Insert … Table … Auto format …Simple 1),
(see JSD_stylesheet.doc for illustration). Tables taken directly from Microsoft Excel are not generally acceptable for publication in *JSD*.

Use Arabic (1, 2, 3 …), not Roman (I, II, III …), numerals for tables. Footnotes in tables should be indicated by superscript letters beginning with 'a' in each table. Descriptive material not designated as a footnote maybe placed under a table as a Note.

Footnotes should be avoided. Wherever possible, incorporate such material in the text, within parentheses.

2. Submission in paper form

Manuscripts may also be submitted on A4paper, subject to the same limits regarding number of words, tables and
figures as above. Separate the manuscript into three sections: (1) **text section**, with figure and table texts at the end;

(2) **figure section** (one figure per page, for reduction to 6.9-cm and 14.3-cmcolumn width); and

(3) **table section** (one table per page). Type the text itself at double line-spacing on one side of the paper only, with top, left and bottom margins set at 2.5 cm. The right margin should, however, be set at 7.5cm, to leave space for reviewers' and editors' comments. Number all pages in sequence, including figures and tables.

The order of headings and sub-headings should be indicated as shown in the style sheet JSD_stylesheet.doc. Keep all levels of heading as short as possible.

Tables, figures and illustrations should be submitted each on a separate page. When a manuscript is submitted in paper form, a CD containing all sections of the paper, including diagrams, is also required. Diskettes ('floppy disks') are not admissible.

Conventions
Scientific names must be italicized. At first mention, the author (*e.g.* (L.)) should be given, but must not be italicized.
Use single quotation marks '', unless you are giving a quotation within a quotation, in which case use "".
Insert … Symbol … Special characters
All data should be given in the metric system, using SI units of measurement.
Use '.' (point) as the decimal symbol. Thousands are shown spaced, thus: 1 000 000.Use a leading zero with all numbers <1, including probability values (*e.g*., *p*< 0.001).
Numbers from one to nine should be written out in the text, except when used with units or in percentages (*e.g*., two occasions, 10 samples, 5 seconds, 3.5%). At the beginning of a sentence, always spell out numbers (*e.g*., 'Twenty-one
trees were sampled...').

Use the 24-hour time format, with a colon '**:**' as separator (*e.g*., 12:15 h). Use day/month/year as the full date format (*e.g*., 12 August2001, or 12/08/01 for brevity in tables or figures). Give years in full (*e.g*. '1994–2001', never '94–01'). Use the form '1990s', not '1990's' or '1990ies'.
Use the en-dash – for ranges, as in '1994–2001'
(Insert … Symbol … Special characters En dash).
In stating temperatures, use the degree symbol 'º', thus 'ºC', **not** a superscript zero '0'. (Insert … Symbol …
Normal text),
Define all symbols, abbreviations and acronyms the first time they are used, *e.g*., diameter at breast height (DBH), meters above sea-level (m asl). In the text, use negative exponents, *e.g*., g m-2, g m-2 sec-1, m3 ha-1 as appropriate.
Use 'h' for hours; do not abbreviate 'day'.

If possible, format mathematical expressions in their final version (*e.g.*, by means of Equation Editor in MS Word or its equivalent in Word Perfect or Open Office); otherwise, make them understandable enough to be formatted during typesetting (*e.g*., use underlining for fractions and type the numerator and denominator on different lines).

References
Please inspect the examples below carefully, and adhere to the styles and punctuation shown. Capitalize only proper
names ('Miocene', 'Afar', 'The Netherlands') and the initial letter of the title of papers and books, e.g., write
'Principles and procedures of statistics', not **'**Principles and Procedures of Statistics'. Do not italicize Latin abbreviations: write 'et al.', **not** '*et al.*'

References in the text should use the 'author-year' (Harvard) format:
(Darwin and Morgan, 1993) or, if more than two authors, (Anderson et al., 1993)
(Hartman and Kester, 1975; Anderson et al., 1993; Darwin and Morgan, 1994) chronologically.

It is highly recommended that Citations/References Management Software programs such as Mendeley are used for organizing Citations and Bibliographic lists following the style of Crop Science Journal (alphabetical order) as shown in the following examples:

Journal article

Kalb J.E. 1978. Miocene to Pleistocene deposits in the Afar depression, Ethiopia. *SINET: Ethiop. J. Sci*. 1: 87-98.

Books

Whitmore T.C. 1996. *An introduction to tropical rain forests*. Clarendon Press, Oxford, 226pp.

Steel R.G.D. and Torrie J.H. 1980. *Principles and procedures of statistics*. 2nd ed. McGraw-Hill Book Co., New
York. 633 pp.

Contribution as a chapter in books (Book chapter)

Dubin H.J. and Grinkel M. 1991.The status of wheat disease and disease research in warmer areas. In: Lange L.O., Nose1 P.S. and Zeigler H. (eds.) *Encyclopedia of plant physiology. Vol. 2A Physiological plant ecology*. Springer- Verlag, Berlin. pp. 57-107.

Conference/workshop/seminar proceedings

Demel Teketay 2001. Ecological effects of eucalyptus: ground for making wise and informed decision. Proceedings of a national workshop on the eucalyptus dilemma, 15 November 2000, Part II: 1-45, Addis Ababa.

Daniel L.E. and Stubbs R.W. 1992.Virulenceof yellow rust races and types of resistance in wheat cultivars in Kenya.
In: Tanner D.G. and Mwangi W. (eds.). Seventh regional wheat workshop for eastern, central and southern Africa. September 16-19, 1991. Nakuru, Kenya: CIMMYT. pp. 165-175.

Publications of organizations

WHO (World Health Organization) 2005. Make every mother and child count: The 2005 World Health Report. WHO,
Geneva, Switzerland.

CSA (Central Statistical Authority) 1991. Agricultural Statistics. 1991. Addis Ababa, CTA Publications. 250 pp.

Thesis

Roumen E.C.1991. *Partial resistance to blast and how to select for it*. PhD Thesis. Agricultural University,
Wageningen, The Netherlands. 108 pp.

Gatluak Gatkuoth 2008. *Agroforestry potentials of under-exploited multipurpose trees and shrubs (MPTS) in Lare district of Gambella region.* MSc. Thesis, College of Agriculture, Hawassa University, Hawassa. 92 pp.

Publications from websites (URLs)

FAO 2000. Crop and Food Supply Assessment Mission to Ethiopia. FAOIWFP. Rome. (http://www. fao.or~/GIE
WS). (Accessed on 21 July 2000).

Proof correction

Page proofs will be sent to the author, shortly before publication, as an Adobe Acrobat portable document format (PDF) file attachment to an e-mail message. This is essentially the final form in which the paper will appear. Minor alterations may be made, to conform to scientific, technical, stylistic or grammatical standards.

Although proofs are checked before they are sent to the author(s), it is the responsibility of the author(s) to review page proofs carefully, and to check for correctness of citations, formulae, omissions from the text, *etc*. Author(s) should return their corrections within seven (7) working days from the date on which the proofs were sent to them. Failure to do so will cause the paper to be printed as in the page proofs.

Reviewers Recognition

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