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Contents

Original Research Article||

Growth, nodulation and yield response of field-grown faba bean (*Vicia faba* L.) to *Rhizobium* inoculation in Tocha District, Southern Ethiopia

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Abstract

Inoculation with effective and crop specific *Rhizobial* strain of bacteria is necessary to improve symbiotic nitrogen fixation and optimize faba bean productivity. Field experiment was conducted at Tocha district, southern Ethiopia during 2017-2019 main rainy seasons to evaluate the effects of Rhizobium strain on the yield and yield components of faba bean. The experiment consisted of 7 treatments: control, FB1018, FB1035, FB04, 50 kg ha^{-1} TSP + FB1018, 50 kg ha^{-1} TSP + FB1034 and 50 kg ha^{-1} TSP + FB04. A starter N-dose (9 kg N·ha^{-1}) was applied with different Rhizobium inoculants except for the control. Soils of the experimental plot before planting was silt loam in texture, moderately acidic in pH with high levels of organic carbon, total nitrogen and cation exchange capacity, and medium content of phosphorous. The experiment was laid out in Randomized Complete Block Design with three replications. Inoculation of FB1018 strain significantly ($p < 0.05$) increased the plant height (cm), number of pods per plant, above-ground biomass (kg), and grain yield (kg) as compared to the control. The maximum grain yield (3354.2 kg ha^{-1}) and minimum (1942.7 kg ha^{-1}) were obtained from the application of FB1018 strains and control treatment, respectively. Therefore, application of FB1018 strain with 9 kg N·ha^{-1} can be recommended to improve Faba bean yield at Tocha distric and other areas with similar agro ecology and soil conditions.

Key words: Faba bean, Fertilizer, *Rhizobium* strain, Yield

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INTRODUCTION

Faba beans is one of the legume crops capable of fixing nitrogen in an endosymbiosis association with root nodule bacteria. Ethiopia is one of the primary centers of diversification for faba beans that are produced in many regions of Ethiopia. The crop occupies about 26.9% of the total land area under pulse crops in the country (CSA, 2016). It is the most commonly cultivated pulse crops in Southern Nations Nationalities and Peoples Region (SNNPR). About 63,279.03 ha of land was covered with the crop and 104,076.6 tones yield was produced with average productivity of 1.65 tons ha^{-1} in 2015/16 cropping seasons (CSA, 2016). About 8,312 ha of land was covered with the crop in the study area and 13,239.1 tons of grain yield was produced with average productivity of 1.59 quintals per ha in 2015/16 cropping season (CSA, 2016).

Despite its multifaceted benefits, the productivity of faba bean, both national and regional, 18.93 and 16.39 quintal ha^{-1}, respectively, remained low compared to its attainable yield, which is >2 t /ha^{-1} (MoA, 2011; CSA, 2015). Biological nitrogen fixation, especially rhizobia-legumes symbiosis, is one of the alternative solutions and the promising technologies which play an important role in decreasing the consumption of inorganic N-fertilizers, enhancing soil fertility, and reducing the production cost, (Peoples et al., 1995). Nitrogen (N_2) fixed by nodulated legumes (pulses and oilseeds) is estimated to contribute 21.45-million-ton N annually to global agricultural systems (Herridge et al., 2008).

External seed inoculation of rhizobia is also one of sustainable and environment friendly practices to increase the nitrogen fixation potential of the crops since there might be low population of effective indigenous rhizobia or due to maximum competitions with non-effective ones (Tolera et al., 2009). However, the information on contribution of different *Rhizobium* strain alone and with fertilizer on yield and yield components of faba bean in Tocha district is limited. Therefore, the objective of this study was to identify optimum performing *Rhizobium* strains on yield and yield components of faba bean in the study area.

MATERIALS AND METHODS

Description of the study duration and area

The experiment was conducted from 2017 to 2019 main cropping season on farmers' field in Tocha district, Dawro Zone, Southern Ethiopia. The district is located at 499 km south of Addis Ababa, 247 km west of Hawassa and 39 km of Tarcha which is the principal city of Dawro Zone. The district has been receiving 600 - 2300 mm mean annual rain fall with a minimum and maximum temperatures of 19^{o}C and 28^{o}C, respectively over the experimentation periods. Mixed farming system is a dominant agricultural activity in the study area.

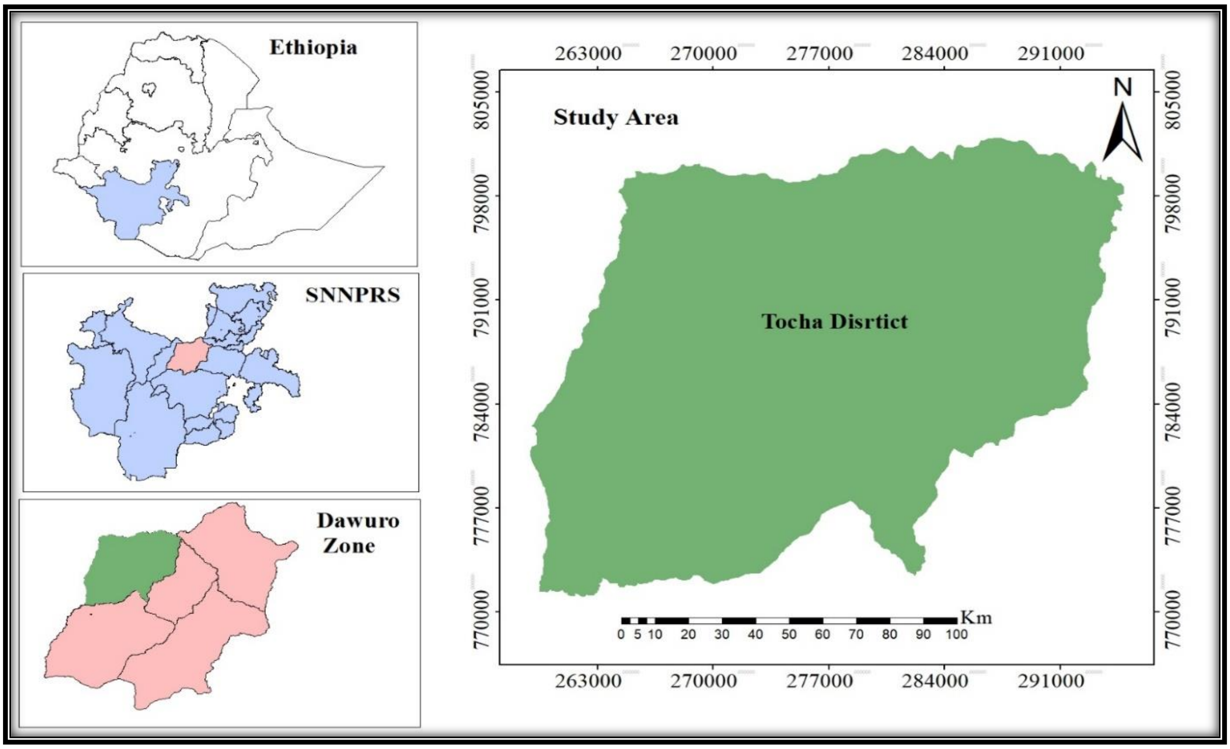

Figure 1. Map of the study area
Source: Authors - Extraction from ArcGIS Map 10.7.1

Soil Sampling and Analysis

Composite surface soil samples (0–30 cm depth) were collected from experimental area by zigzag sampling method before planting for determination of selected physicochemical properties of the soil. The collected samples were air dried at room temperature and were ground to pass through a 2 mm sieve for most parameters and through 0.5 mm sieve to determine total nitrogen and organic carbon. Soil particle size distribution was determined by hydrometer method (Bouyoucus, 1951). Soil pH was determined by potentiometric method at soil:water ratio of 1:2.5 (Van Reewijk, 1992). Cation exchange capacity was determined by 1 M ammonium acetate method at pH 7 (Chapman, 1965). Organic carbon was determined by the dichromate oxidation method (Walkley and Black, 1934). Total nitrogen was determined by the conversion of organic carbon and available P was analyzed by Olsen method (Olsen *et al.,* 1954).

Treatments, Design and Procedures

Faba bean seeds were surface sterilized by mercuric chloride (0.1%) for 2 minutes and rinsed with and soaked in distilled water for a minute. For inoculation with peat-based inoculants, seeds were moistened in sugar solution (48%) only to those inoculated treatments before application to get a thin uniform coating of inoculums on seeds immediately before sowing. The treatments consisted of 1) control (without fertilizer and strain), 2) FB1018, 3) FB1034, 4) FB04, 5) 50 kg ha^{-1} TSP + FB1018, 6) 50 kgha^{-1} TSP + FB1034, and 7) 50 kgha^{-1} TSP + FB04. A starter N-dose (9 kg N ha^{-1}) was applied in combination with the *Rhizobium* strains except for the control and the treatments were laid out in randomized complete block design (RCBD) with three replications.: The plot size was 4 m by 4 m with 1 m spacing between plots and blocks, with the seeds planted 10 cm and 40 cm spacing between plants and rows, respectively. TSP fertilizer (rate) was applied at the planting time and all other management practices were also applied uniformly as per site recommendations starting from field preparation to harvesting.

Data Collection and Measurement

Plant height (cm) from the ground level to the tip of 5 randomly taken plants at physiological maturity were taken. Total number of nodules was determined by counting from five plants from each net plot (2.4 m by 2.4 m) area at 50% flowering. Nodules from the plant roots were removed carefully. The nodules were separated from the soil by washing and the total numbers of nodules are determined by counting. Number of pods per plant was determined by counting from 5 randomly taken representative samples from each net plot (2.4 m by 2.4 m) area at harvest. Total above-ground biomass (kg ha^{-1}) was also taken after harvesting from aboveground plant parts from each net plot. Grain yield (kg ha^{-1}) was determined after threshing the seeds from each net plot. The seed yield was adjusted to a 12.5% moisture level and converted to kg ha^{-1}.

Statistical Analysis

SAS statistical software (SAS, 2007) was used for analysis of variance and mean separation among treatment was done by least significant differences (LSD) at $p<0.05$ probability level.

RESULTS AND DISCUSSION

Physicochemical Properties of the Soil

The analyzed soil results showed that soil particle size distribution of the experimental site was in proportions of 39, 54 and 7 % of sand, silt, and clay, respectively (Table 1). Based on USDA (1998) soil textural classification, the textural class of the soil in the experimental are is silt loam, which is suitable for faba bean production. The soil pH of the experimental field before planting showed that the pH value of the soil was 5.62. According to Jones (2003), the rating of soil pH was moderately acidic. The pH of the soils in the study area was within the satisfactory range for faba bean production as well as for most agricultural crops (Landon, 1991). The OC and TN content of the experimental site were 3.54 and 0.18%, respectively, which is rated as under high range (Tekalign 1991). The high TN contents indicated that the soil of the experimental site was sufficient in available N to support proper growth and development of agricultural crop production.

The analysis result also shows that available P content of the experimental site was 13.97 ppm, which made it rated as medium (Jones, 2003), indicating that the soil has probable yield responses to P application (Olsen et al., 1954). Based on the analysis, the cation exchange capacity (CEC) of the experimental site soil was 35.4 meq/100 g (Table 1). According to Landon (1991) rating, the CEC soil of the study site was under high class and adequate for crop production. Furthermore, such high CEC value provides the soil with maximum buffering capacity so that one can apply the required amount of fertilizer dosage without any immediate negative effects on the soils.

Table 1. Some physical and chemical properties of soil of experimental site before planting

Soil Properties	Values	rating	Reference
% sand	39		
% silt	54		
% clay	7		
textural class		silt loam	
Soil pH	5.62	Moderately acidic	Jones, 2003
Organic carbon (%)	3.54	very high	Tekalign, 1991
Phosphorus (ppm)	13.97	medium	Jones, 2003
Total nitrogen (%)	0.18	high	Tekalign, 1991
Available potassium (ppm)	59.55	low	Jones, 2003
Cation Exchange Capacity (meq/100g)	35.4	high	Landon, 1991

Growth Parameters

Plant Height

The plant height of faba bean was significantly ($p< 0.05$) affected by the application of different types of *Rhizobium* strains alone and with TSP fertilizer (Table 2). The maximum plant height (131.67 cm) and the minimum plant height (111.6 cm) were recorded from the treatment FB 1018 and control, respectively (Table 2). The lower plant heights obtained at the control treatments might be due to retarded growth caused by the imbalance in nutrient availability.

The significant increase in plant height in response to the application of *Rhizobium* inoculation might be attributed to the increased availability of nitrogen in the soil for uptake by plant roots, which might have sufficiently increased vegetative growth through enhancing cell division and elongation. Similarly, Sameh et al., (2017) reported that plant height of faba bean was significantly increased upon inoculation by all tested strains as compared with uninoculated treatments (control). The increment of plant height due to *Rhizobium* inoculation might also be due to the sufficient amount of nitrogen fixed by the bacteria which likely resulted in enhanced vegetative growth of the plants. In conformity with this result, Nyoki and Ndakidemi (2014) reported that *Rhizobium* inoculation in cowpea significantly improved the plant height measured at four, six and eight weeks after planting relative to the control treatment under both green house and field experiments.

Total Number of Nodules

The result showed that the total number of nodules per plant of faba bean was non-significantly ($p< 0.05$) affected by the *Rhizobium* strains alone and with TSP fertilizer. The maximum number of nodules per plant (29) was recorded from the treatment FB 1018 while the minimum number (21) was recorded from control treatment (Table 2). The result is also in conformity with the finding of Abebe and Tolera (2014), who reported that inoculation of *Rhizobium* strain did not significantly increase nodules per plant in contrast with uninoculated seeds on faba bean. Numerically, *Rhizobium* inoculation increased number of nodules per plant compared to un-inoculated treatment (control) which could be due to the fact that inoculated bacteria strain had good nodulation inducing capacity.

Table 2. Yield and yield component of faba bean as affected by *Rhizobium* strains

Treatments	NNo	Plant Height (cm)	Pod Number	AGB kg ha^{-1}	Seed Yield kg ha^{-1}
Control	21	111.6^{b}	12.8^{c}	4968.8^{b}	1942.7^{c}
FB1018	29	131.67^{a}	16.2^{a}	6750^{a}	3354.2^{a}
FB1034	20	126.3^{ab}	13.87^{bc}	5687.5^{ab}	2520.8^{b}
FB 04	23	125.93^{ab}	16.47^{a}	6270.8^{a}	2604.2^{b}
50kg ha^{-1} TSP + FB1018	26	128.53^{a}	15.83^{ab}	6304.2^{a}	2814.2^{ab}
50kg ha^{-1} TSP + FB1034	24	127.47^{a}	17.6^{a}	6125^{a}	2614.6^{b}
50kg ha^{-1} TSP + FB04	28	128.37^{a}	16.3^{a}	6322.9^{a}	2708.3^{b}
CV	21.2	6.9	8.1	12.1	10.4
LSD	NS	15.49	2.23	1299.6	479.31

Means in the table followed by the same letter(s) are not significantly different 5% level of significance, LSD (0.05) =Least significant difference at 5%; and CV (%) =Coefficient of variation; AGB = above ground biomass yield kg ha^{-1}; NNo= number of nodules per plant

Yield and Yield Components

Number of Pods per Plant

Significant ($p<0.05$) effects of *Rhizobium* strains alone and with TSP fertilizer were observed on the number of total pods per plant (Table 2). The highest number of total pods per plant (17.6) was recorded at an application rate of 50 kgha^{-1} TSP + FB1034, whereas, the lowest number of total pods (12.8) was obtained from the control (Table 2). The result is also in conformity with the finding of Birhanu (2021) who reported that the highest number of pods per plant (15) was recorded from the combination of 240 g ha^{-1} NPSZnB and 500 g ha^{-1} of *Rhizobium*; while, the lowest number of pods per plant of faba bean was recorded from the control plots. Similarly, Bezabih et al. (2018) reported that number of pods per plant showed significant response to phosphorus fertilization and *Rhizobium* inoculation. This result was also in agreement with the study by Çiğdem Kucuk (2011) who indicated that inoculation had given significantly higher number of pods per plant for common bean over the control (no fertilizer and no inoculant).

Total Above-ground Biomass

It was observed that the different types of *Rhizobium* strains alone and with TSP fertilizer had a significant ($p<0.05$) influence on the aboveground biomass production (Table 2). The study showed that the maximum aboveground biomass of 6750 kg ha^{-1} was obtained from plots receiving FB1038 of *Rhizobium* strains alone whereas the minimum above-ground biomass of 4968.8 kg ha^{-1} was obtained from plots received no treatments (control). Application of FB1018 of *Rhizobium* strains alone improves aboveground biomass production by 35.85% as compared with control treatments. The resort from the current trial was in line with the result of Sameh et al., (2017), who reported that Faba bean plants inoculated with *Rhizobium* strains recorded the maximum root dry weight (2.53 g/plant) and shoot dry weight (14.9 g/plant) with significant increases over the control.

Grain Yield

It was revealed that the application of *Rhizobium* strains alone and with TSP fertilizer brought significant ($p<0.05$) effect on grain yield increments (Table 2). The result showed that the maximum grain yield (3354 kg ha^{-1}) was recorded from the application of FB1018 *Rhizobium* strains and the minimum grain yield (1943 kg ha^{-1}) was obtained from control treatments (Table 2). Application of FB1018 of *Rhizobium* strains alone improved grain yield production by 72.6% from the control. The observed yield improvements with *Rhizobium* inoculation might be due to the increased N as result of atmospheric nitrogen fixation by effective strain application. In line with this result, Abebe and Tolera (2014) reported that inoculation significantly increased grain yield in faba bean. Sameh et al., (2017) observed that significantly higher grain yield (4.36 ton ha^{-1}) was obtained from inoculated seed as compared to control. Nyoki and Ndakidemi (2014) also reported that *Rhizobium* inoculation significantly improved the yield and yield components such as number of pods per plant, number of seeds per pod, number of seeds per plant, and seed yield over the control. Similarly, Abera and Tadele (2016) also reported the maximum grain yield (2416 kg ha^{-1}) from seed inoculation with *Rhizobium* strain (HB-129). Likewise, Bezabih et al., (2018) observed that *Rhizobium* inoculation independently increased the seed yield as compared to uninoculated seed, which might be due to the fact that inoculation of seeds with *Rhizobium* enhances nitrogen uptake (Bejandi *et al.*, 2012) and thereby plant growth and performance increases.

In general, inoculation gave significantly higher grain yield for the faba bean crops in the experimental site. Maximum yield with the *Rhizobium* inoculation could be due to the sufficient availability of nutrients in the soil and better nodulation under the influence of inoculation resulting in better growth and development, which might be attributed to enhanced allocation of photosynthates towards the economic parts.

Relationship between Faba Bean Yield and Yield Components

The result indicated that the parameters such as grain yield, above-ground biomass, number of pods per plant, plant height, and number of nodules per plant were positively and significantly correlated to each other but number of pods per plant are non-significantly correlated with number of nodules per plant. The comparable investigation was reported by (Paponov *et al.*, 1996) in which they reported that, highly significant ($p<0.01$) and positive correlation between nodule number, fresh weight, and grain yield of fenugreek.

Table 3. Pearson's simple correlation coefficient (r) of relevant parameters of faba bean

	NodN	PH	PodN	AGB	GY
NodN	1				
PH	0.57**	1			
PodN	0.32NS	0.54*	1		
AGB	0.72***	0.75***	0.45*	1	
GY	0.66***	0.69***	0.41*	0.78***	1

*** very high significant, ** highly significant, * significant, NS= none significant, NodN = Nodule number per plant, PH= Plant height, PodN= Pod number per plant, AGB= Above Ground Biomass yield per hectare, and GY= grain yield per hectare

CONCLUSION AND RECOMMENDATION

The analysis of soil samples collected before planting indicated that the experimental site had insufficient amount of soil fertility status for faba bean crop production. The inoculation of faba bean with *Rhizobium* strains alone and with TSP fertilizer revealed a significant improvement of the plant height, number of pod per plant, above-ground biomass, and grain yield as compared to the control Application of FB1018 Resulted in the highest grain yield. These results indicated that inoculation of faba bean with effective *Rhizobium* strains can reduce use of inorganic fertilization and improve productivity of crop yield. The use of FB1018 strain with 9 kg/ha starter N can be recommended for soils of the study area and similar agro-ecology.

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Original Research Article||

Registration of "Hachalu" (EW006 x EW003 (1)-4-2-1) Sesame (Sesamum indicum L.) Variety

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Abstract

Hachalu is a name given to a newly released sesame variety developed by Bako Agricultural Research Center and released in June 2021. Selection of this variety was made among recombinant inbred lines of sesame developed through pedigree breeding method. The two parents of the selected variety were collected from western Oromia of Ethiopia. This variety was selected out of fifteen inbred lines that were tested along with standard check Walin at three locations for two consecutive years (2018 and 2019) main cropping seasons. Hachalu was the best high yielding variety and the most stable among all lines for its grain yield performance and has resistance to bacterial blight which is very challenging for sesame production in the country. In addition to this, hachalu's oil content is high (54.9%) and has white seed color which has a great role in the market class. For these reasons, the variety was released for commercial production in major sesame growing areas of western Oromia and other similar agro-ecologies.

Key words: Grain yield stability, Oil content, Recombinant inbred line, *Sesamum indicum*

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INTRODUCTION

Sesame is a self-pollinated crop (Zhang *et al*., 2013). However, 2-48% natural crossing was reported due to insect pollination (Daniel and Parzies, 2011). Domestication of the crop is about 5000 years old in Harappa region of India (Fuller, 2003). Sesame is an oilseed crop grown for its seed, oil for local and export markets, a great source of income for farmers, traders and processors and source of foreign exchange earnings. It is one of the important oilseed crops which is described as the queen of oil crops because of its high oil content. Sesame seed is consumed as a source of calcium, potassium, tryptophan and methionine (Soundharya *et al.*, 2017). In Ethiopia, the production of sesame is practiced at both by small- and large-scale farmers levels; serving as an important export commodity.

Ethiopia is the 3rd sesame exporter in the world next to Nigeria and India. Sesame is the first export (79%) from oil seeds and 2nd (20%) agricultural export next to coffee in Ethiopia (Zerihun, 2012). In spite of its wider importance and huge nutritional value, limited number of adaptable varieties with tolerance to biotic and abiotic factors is one of the major sesame production constraints in Ethiopia. In view of this, a study was conducted with the aim of developing adaptable, high yielding, oil content and stable as well as disease resistant sesame variety for commercial production across tested environments and similar agro-ecologies of the country.

Varietal Origin and Evaluation

Hachalu (EW006 x EW003 (1)-4-2-1) sesame variety was developed from parental materials collected from Western Oromia and developed through hybridization and subsequent pedigree selection at Bako Agricultural Research Center. The variety was tested at multi locations together with sixteen genotypes including one standard check Walin during 2018 & 2019 cropping season.

Agronomic and Morphological Characters

Hachalu variety has determinate growth type. It has erect plant growth habit and the stem and leaf are purple in color. The stem of *Hachalu* has branching habits. The average 1000 seeds weight of *Hachalu* was 2.7 grams, and its average plant height was 127.8 cm. More detailed agronomic features of this new variety are presented in the following Table 1:

Yield Performance

The released variety, *Hachalu* showed higher mean seed yield (634.22 kgh^{-1}) with greater yield advantage of 12.88% over the standard check, *Walin*. Details of the compartative advantages of the newly released variety – *Hachalu* is presented in Table 2 below.

Table 1. Agro-morphological characteristics and oil content of Hachalu sesame variety

Descriptors	Detailed and specific discriptions
Variety Name	*Hachalu* (EW006 x EW003 (1)-4-2-1)
Adaption area	Well adapted to major sesame growing areas of western Oromia and other similar agro ecologies ✓ Altitude (m.a.s.l): 1250 - 1650 ✓ Rainfall (mm): 800 - 1100
Planting date	End of May to Early June
Seed rate (kgha^{-1})	5 (for row planting)
Spacing (cm)	40 between rows and 10 between plants
Fertilizer rate (kgha^{-1})	NPS: 100 and UREA: 50
Days to flowering	65.7-70.3
Days to maturity	115-131.7
Growth habit	Intermediate
1000 seed weight (g)	2.7
Plant height (cm)	109.3-146.3
Capsule per plant	69.2-91.9
Stem and branching character	Angular and branched
Growth pattern	Erect
Seed color	White
Crop pest reaction	Resistant to bacterial blight and other pests
Oil content (%)	54.9
Seed yield (kgha^{-1})	Research field: 634-929 Farmer's field: 628-870
Year of release	2021
Breeder/ Maintainer	BARC/OARI*

**Bako Agricultural Research Center/ Oromia Agricultural Research Institute*

Table 2. Mean seed yield (kgha^{-1}) among 16 sesame genotypes across six testing environments

Genotypes	Yield/ha						Pooled mean	Yield adv.
	2018			2019				
	Bako	Uke	Ose	Bako	Uke	Ose		
EW00 x BG006-7-1-1	268.33	326.00	541.33	264.69	532.61	283.80	369.46	
EW002 x BG006-2-1-1	406.00	357.33	562.33	340.52	619.48	444.69	455.06	
EW006 x EW003 (1)-4-2-1	929.00	830.67	567.00	361.88	596.77	520.00	634.22	12.81
EW006 x EW003 (1)-3-1-1	392.67	747.00	630.67	321.98	398.23	274.17	460.79	
EW006 x EW003 (1)-7-1-1	517.33	631.67	611.00	319.48	698.96	502.97	546.90	
EW003 (1) x Wama -9-1-1	490.33	430.00	692.00	303.23	625.83	419.79	493.53	
Dicho x EW006-1-1-1	703.00	939.67	714.33	325.84	526.67	530.83	623.39	10.88
Dicho x EW006-9-1-1	549.00	480.00	760.00	256.77	378.54	657.08	513.57	
Dicho x Obsa -4-1-1	503.00	345.67	452.00	228.75	622.81	537.08	448.22	
Obsa x BG006-4-1-1	637.67	522.67	620.33	362.29	913.13	375.84	571.99	1.74
EW003(1) x EW002-4-2-1	829.67	529.67	353.00	386.36	541.25	434.06	512.33	
EW003(1) x EW002-5-2-1	632.67	551.67	556.33	394.59	603.34	988.64	621.21	10.50
EW023(2) x BG006-13-1-1	845.67	521.33	594.67	311.67	598.33	316.35	531.34	
Obsa x EW023(2)-3-3-1	495.00	492.67	650.67	318.54	723.75	370.21	508.47	

EW003(1) x EW019-4-2-1	441.00	366.00	694.00	290.42	849.59	619.90	543.48
Walin	510.33	687.33	681.33	387.71	713.13	393.33	562.20
Mean	571.92	547.46	605.06	323.42	621.40	479.30	524.76
CV%	12.52	9.15	12.43	21.46	14.93	9.75	28.08
P value	**	**	**	ns	**	**	**
LSD	119.38	83.52	125.41	115.71	154.73	77.94	96.75

*Key: *, ** indicate significant at 0.05 and 0.01 probability level, respectively; ns = non-significant*

Stability and Adaptability Performances

Based on the AMMI result, the new variety, *Hachalu* (G3) ranked first for its stability for seed yield performance (Fig 1) and the GGE biplot confirmed that *Hachalu* (G3) variety fell in the central circle, indicating its high yield potential and relative stability compared to the other genotypes (Fig 2). The new variety, *Hachalu* is adapted to major areas of sesame production in western Oromia and similar agro-ecologies in altitude ranging from 1250 to 1650 meters above sea level. This variety can be grown in high rainfall areas where bacterial blight is a problem for sesame production.

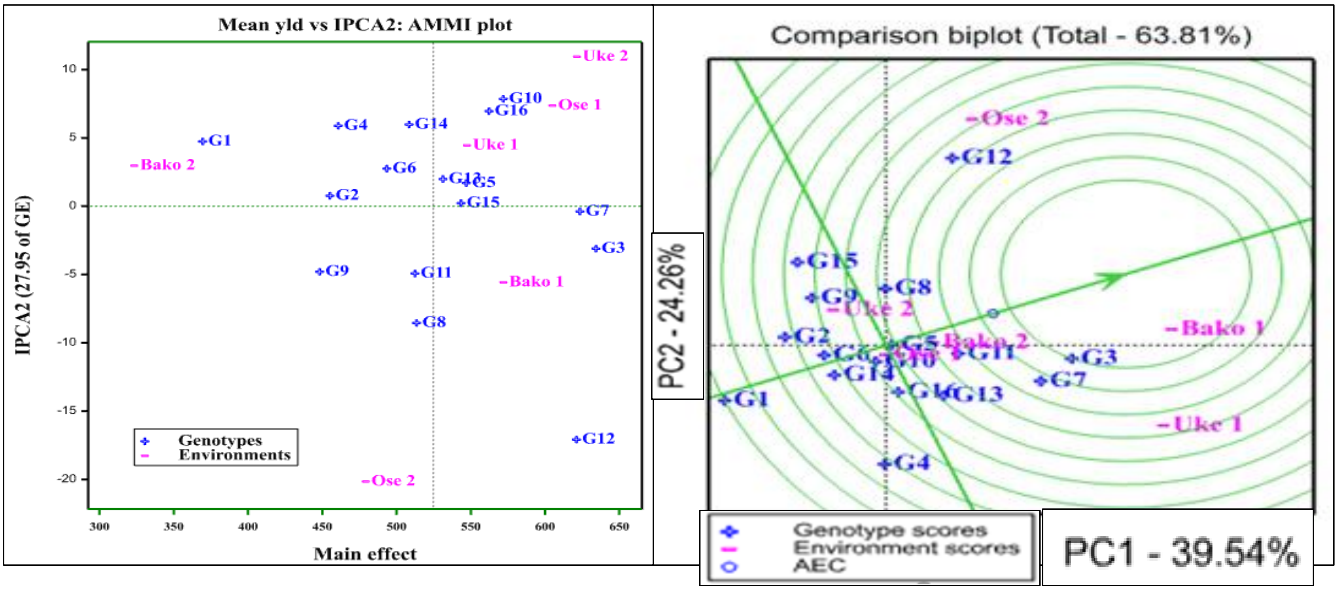

Figure 1. AMMI1 bi-plot showing Genotype and Environment means seed yield against IPCA2 (left) and GGE-bi-plot showing the "ideal" genotype (right)

Disease Reactions

Bacterial blight is the most yield limiting factor for sesame production in western Ethiopia as the disease is favored by the effect of high humidity and rainfall conditions in the area. In addition to higher yield, this variety showed better resistance to bacterial blight than the check (Fig 2).

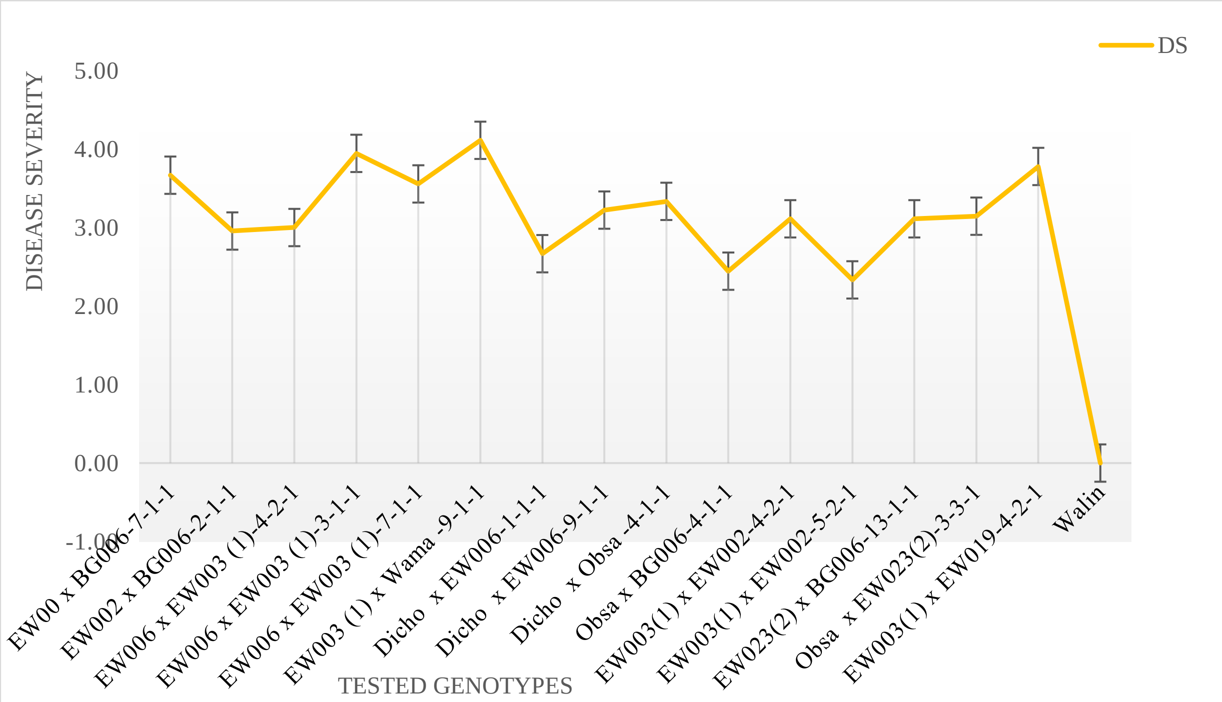

Figure 2. Performance of tested sesame genotypes against bacterial blight disease at Bako, Uke and Ose during trial cropping season

CONCLUSION

Hachalu variety was released in June 2021 for western Oromia and similar agro-ecologies due to its high grain yield and oil content, wider adaptability, better resistance to bacterial blight, white seed color and stable performance than the standard check and other tested genotypes. Therefore, smallholder farmers and other sesame commercial producers in western Oromia with similar agro-ecology can grow *Hachalu* variety with its full agronomic and other management recommendations.

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Original Research Article||

Evaluation of different blended fertilizer types and rates for better production of bread wheat (*Triticum aestivum L.*) at Adiyo District, South Westhern Ethiopia

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Abstract

Bread wheat (*Triticum aestivum* L.) is an important food crop and source of income for farmers. It is the most responsive crop to fertilizer applications. A field experiment was carried out on farmers' fields in 2016/17 and 2017/18 main cropping seasons to evaluate the response of bread wheat to different types and rates blended fertilizers at Adiyo district, South Western Ethiopia. Eight treatments: Control (T1), four rates of NPSB: (46 N,54 P_2O_5,10 S, 1.07 B (T2); 69 N, 72 P_2O_5, 13 S, 1.4 B (T3), 92 N, 90 P_2O_5, 17 S, 1.7 B (T4) and 92 N, 36 P_2O_5, 7 S, 0.71 B (T5)) and three rates of NPSB+Cu: T2+Cu (T6), T3+Cu (T7), T4+Cu (T8), were laid out in randomized complete block design with three replications. Cupper was supplemented in the treatments as foliar application. Crop parameters measured were analyzed using proc GLM procedures in the SAS version 9.3 for Windows. Analysis was also performed to investigate the economic feasibility of the fertilizers for wheat production. Results indicated that application of both types and three rates of each fertilizer significantly ($p<0.05$) affected all tested parameters except thousand seed weight, which was improved by only T4. The highest biomass (14.80 ton ha-1) and grain yield (6.537 ton ha-1) were obtained from the application of the highest rate of NPSB+Cu (T8) whereas the lowest biomass (9.36 ton ha-1) and grain yield (3.66 ton ha-1) were obtained from the control (untreated soil). The application of NPSB+Cu (T8) also gave the highest net benefit of Birr 46637 and the acceptable MRR% was 151.02%. Hence farmers at study area and elsewhere with similar agro-ecologies could use NPSB+Cu at a rate (92 N, 90% P_2O_5, 17 S, and 1.7 B) and 600 g ha^{-1} Cu as a foliar application or NPSB = 92, 90, 17, 1.7. However, further verification study is needed to give a reliable and consistent recommendation.

Key words: Economic benefit, Foliar application, NPSB, NPSBCu, Wheat, Yield

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INTRODUCTION

Wheat is one of the major cereal crops grown in the highlands of Ethiopia and which is regarded as the largest wheat producer in Sub-Saharan Africa (Efrem et al., 2000). Wheat is considered as highly responsive crop to starter fertilizers, particularly phosphorus and nitrogen (Ruiz, 2016). Wheat productivity in Ethiopia is low (2.67 ton ha^{-1}) (CSA, 2017) due to depleting soil fertility, low levels and imbalanced use of chemical fertilizers, limited knowledge on time and rate of fertilizer applications, and the unavailability of other modern crop management inputs (Anderson and Schneider, 2010). Therefore, the management of nutrients should be given adequate attention to increase yields and sustain productivity.

Fertilizer management is a key to wheat production and the responsiveness of wheat crop to the application of different fertilizer nutrients is studied extensively (Franzen *et al*., 2008; Knight *et al*., 2012; Abebaw and Hirpa, 2018; Diriba *et al*., 2019). Most researches focus on NP requirements of crops, and limited information is available on various sources of fertilizers potassium, sulfur, zinc and boron and other micronutrients. Therefore, application of other sources of nutrients beyond urea and DAP, especially those containing K, S, Zn and other micro-nutrients increase crop productivity (CSA, 2011). Balanced fertilizers containing N, P, K, S, Zn and B in blend form have been recommended to ameliorate site specific nutrient deficiencies and thereby increase crop productivity.

The results of a recent study on the Ethiopian soil map indicated that there is a wide spread of nutrient deficiencies (EthioSIS, 2016). The recent national soil inventory data revealed that S, B and Zn deficiencies are widespread in Ethiopian soils. Some soils are also deficient in K, Cu, Mn and Fe (ATA, 2016), all of which potentially hold back crop productivity. However, fertilizer trials involving multi-nutrient blends that include micronutrients are rare. In recent times, soil test-based fertilizer recommendation and calibration efforts have been tried by Ethiopian Agricultural Research Institute (EIAR) and Regional Agricultural Research Institutes (RARIs), but only limited to a certain location and crop types (ATA, 2016).

According to EthioSIS (2016) fertilizer type recommendation map, eight types of fertilizer blends are identified for Southern Nations Nationalities and Peoples' Regional State. Similarly, three and two types of fertilizer blends were identified for Adiyo Woreda and Boka Kebele, respectively. But this needs validation for the fertilizer types and determination of rates for the identified fertilizer types for specific crops. Therefore, this study was initiated with the objectives of (1) Evaluating the relative influences of NPSB and NPSB+Cu on wheat production and (2) determining the optimum rate of the selected blended fertilizer type for the production of wheat in Adiyo woreda.

MATERIALS AND METHODS

Description of the Experimental Area

A field experiment was carried out on three farmers' lands during the main cropping seasons for two years (2016/17 and 2017/18) at Boka Kebele, Adiyo Woreda of Kaffa Zone, Southern Nations, Nationalities and Peoples' Regional State (SNNPRS), Ethiopia. The altitude of the study areas ranged from 2435 to 2550 m.a.s.l. with latitude of 07º15 471' N and longitude of 36º25 112' E. The area received 600-1800 mm rainfall annually in a bimodal pattern and temperature ranged from 15-20ºC. Topographically, the area consists of a gently undulating plain with an average slope gradient of 6%. Crop produced in the area are mostly cereals, pulses and tubers. Wheat is extensively grown followed by faba bean (AWANDRDO, 2017). The dominant soil type of the area is Nitisols, with a textural class of clay loam (FAO, 1998).

Experimental Details and Treatment Set-ups

The treatments were laid out in Randomized Complete Block Design (RCBD) replicated three times on each of the three farmerss' fields. Eight treatments: Control (T1), four rates of NPSB: (46N, $54P_2O_5$, 10S, 1.07B or 150 kg NPSB + 41 kg urea top dressing (T2); 69N, $72P_2O_5$, 13S, 1.4B or 200 kg NPSB + 72 kg urea top dressing (T3), 92N, $90P_2O_5$, 17S, 1.7B or 250 kg NPSB + 102 kg urea top dressing (T4) and 92N, $36P_2O_5$, 7S, 0.71B or 100 kg NPSB + 161 kg urea top dressing (T5)) and three rates of NPSB+Cu: T2+Cu (T6), T3+Cu (T7), T4+Cu (T8), were used. Additional 600 g Cu ha^{-1} for three treatments; and 100 kg KCl for all treatments were applied.

The plot size was 3 x3 m (9 m2) and the spacing between rows was 20 cm. The improved wheat variety (Danda'a) was received from Sinana Agricultural Research Center and used as a test crop. Urea was used as a source of N in addition to NPSB and NPSB+Cu blends. Blended and KCl fertilizers were applied at planting; whereas remaining N from urea was top dressed after 45 days of planting (Table 1). The CuSO4 used as a source of Cu by foliar application was applied 45 days after germination. The test crop was planted by drilling and other crop management practices were applied as per the recommendations for the area.

Table 1. Treatments used in the study

Treatment	Fertilizer types and rates					Cu (g)
	Fertilizer in blended form and Urea	Fertilizer in nutrient form (total, kg)				
	NPSB, NPSBCu and Urea	N	P_2O_5	S	B	
T1	Control	0	0	0	0	0
T2	150 kg NPSB + 41 kg urea top dressing	46	54	10	1.07	0
T3	200 kg NPSB + 72 kg urea top dressing	69N	$72P_2O_5$	13S	1.4B	0
T4	250 kg NPSB + 102 kg urea top dressing	92N	$90P_2O_5$	17S	1.7B	0
T5	100 kg NPSB + 161 kg urea top dressing	92N	$36P_2O_5$	7S	0.71B	0
T6	T2 + Cu	46	54	10	1.07	600
T7	T3 + Cu	69N	$72P_2O_5$	13S	1.4B	600
T8	T4 + Cu	92N	$90P_2O_5$	17S	1.7B	600

***N.B:** Basically, blended NPSB fertilizer contain full nutrient PSB; and nearly half N (fertilizer in nutrient form) in each treatment case. All PSB rates were applied at planting. N was applied by split application; nearly half* *at planting with blends and the remaining by top dressing from urea after 45 days of planting. Cu was applied 45 days after germination by foliar application.*

Soil Sampling and Analysis

Representative composite surface soil samples were collected from 0-20 cm depth at each experimental unit just before sowing. After manual homogenization, the samples were ground to pass through sieves (2 mm for soil pH, texture, cation exchange capacity and available phosphorus; 0.5 mm for total nitrogen and organic carbon analysis) and analyzed for texture, pH, organic carbon, total nitrogen, cation exchange capacity and available phosphorus.

Agronomic Data Collection

The yield and yield components: plant height (cm), spike length (cm), number of tillers per plant, thousand seed weight (g), biomass yield (ton), and grain yield (ton) were collected and subjected to analysis of variance (ANOVA). The grain yield was determined from each experimental plot and adjusted to constant moisture levels of 12%.

Economic Analysis

A partial budget analysis was carried out to determine the net benefit and percent marginal rate of return (%MRR) of specific fertilizer type and rate. Wheat grain yield was valued at an average open market value of the local market price of Birr 900 per 100 kg whereas the average price of urea and NPSB fertilizers were Birr 10 and 14 per kg, respectively. The price of copper sulfate was Birr 1625 per kg. The cost of other production practices like, seed and weeding were assumed to remain the same among the treatments. The grain yield was down adjusted to reflect the situation in actual production by farmers (CIMMYT, 1988).

Data Analysis

The data obtained from the field were subjected to combined analysis of variance (ANOVA) over years after confirmation of homogeneity of error variance using SAS, version 9.3, using the general linear model (GLM) procedure (SAS Institute, 2011). A significant difference between and among treatment means was assessed using the least significant difference (LSD) test at 0.05 level of probability.

RESULTS AND DISCUSSION

Physico-chemical Properties of Soil

Soil samples collected before planting from the study area was analyzed in the laboratory. The analysis results indicated that the experimental sites soil textural class was clay loam with the proportion of 37% sand, 35% clay, and 28% silt. The soil pH value of the area was 5.1 and classified as strongly acidic as per the pH rating category suggested by Tekalign (1991).

The organic matter content for soils of the experimental site was 7.3% and is classified in the highest range as rating of Tekalign (1991). In most highly acidic soils, microbial activity is low, slowing down the decomposition rate and results in accumulation of organic matter. The total nitrogen value of the experimental soil was 0.4% which is rated high based on Tekalign (1991). Generally, the high total nitrogen content of the soil might be due to the highest organic matter content of the area. The available phosphorus content of the experimental site was 12.5 ppm, which makes the soil rated as having low P (Jones, 2003). Masresha (2014) reported low amount of available phosphorus content on soils that are cultivated repeatedly due to P fixation and P mining. Habtamu, *et al*. (2015) also reported that low content of available phosphorus was due to fixation problems. The CEC of the site was 5.6 cmol (+) kg^{-1}. According to Landon *et al.*, (1991) the cation exchange capacity of the site was found to be in the lower range.

Table 2. Selected physico-chemical properties of the Study area soil before planting

Soil properties	Unit	Values
pH-H_2O (1:2.5)	-	5.1
Sand	%	37%
Clay	%	35%
Silt	%	28
Organic Matter	%	7.3
Total Nitrogen	%	0.4
Available phosphorus	ppm	12.5
Cation Exchange Capacity	cmol $_{(+)}$ kg^{-1}	5.6

Texture	-	Clay loam

Yield and Yield Components of Wheat as influenced by Types and Rates of Blended Fertilizer

Data analysis indicated that a year by treatment effects did not occur, so data are averaged across years. Average wheat yield and yield components are presented in Table 1 and 2. In general, application of both fertilizer types and rates significantly (p<0.05) improved yield and yield components of wheat in comparison to control. Mean biomass and grain yield of both years and combined over years were significantly affected by different fertilizer types and rates (Table 1). The grain yields significantly increased as the rates of the two blended fertilizer rates increased. However, averaged over years, significantly highest biomass (14.80 ton ha^{-1}) and grain yield (6.5 ton ha^{-1}) of wheat were obtained by application of NPSB + Cu at a rate 250 NPSB + 600 Cu ($CuSO_4$) and 102 kg urea top dressing (92 N, 90 P_2O_5, 17 S, 1.7 B + Cu). All yield components except thousand seed weight were affected by fertilizer types and rates in similar trend with grain yields increasing with application rates of the fertilizers (Table 2).

Table 3: Combined mean grain and biomass yield of bread wheat as influenced by blended fertilizer types and rates at Adiyo district

Treatment	Biomass yield ton/ha	Grain yield ton/ha
1. Control	9.364^{d}	3.657^{f}
2. NPSB = 46, 54, 10, 1.07	12.353^{c}	5.229^{e}
3. NPSB = 69, 72, 13, 1.4	13.525^{b}	5.839^{c}
4. NPSB = 92, 90, 17, 1.7	13.537^{b}	6.203^{b}
5. NPSB = 92, 36, 7, 0.71	13.654^{b}	5.852^{c}
6. NPSBCu = Tr2 + Cu	12.506^{c}	5.472^{de}
7. NPSBCu = Tr3 + Cu	12.864^{bc}	5.765^{cd}
8. NPSBCu = Tr4 + Cu	14.80^{a}	6.537^{a}
Mean	12.83	5.569
LSD (0.05%)	1.08	0.31
CV%	9.51	8.62

LSD (0.05%): least significant difference at 5% level; CV: coefficient of variation; ; means in a column followed by the same letters are not significantly different at 5% level of significance.

Applications of different types of blended fertilizers at varying rates increased biomass yield of bread wheat by 31.91-58.04% over the control. This might be due to better crop nutrition enhanced through blended micronutrients (B and Cu) with macronutrients (N, P, and S), which might have resulted in improved vegetative growth of crops. In agreement with this finding Fayera *et al.*, (2014) reported that above ground dry biomass yield of teff was significantly increased by the application of blended fertilizers.

The significant increase in wheat yield with the application of the different types and rates of blended fertilizers (NPSB and NPSB+Cu) was 42.98 to 78.75% improvement over the control (Table 3). Mulugeta, *et al.* (2017) reported that the application of some macro and micro nutrients significantly increased grain yield and yield components of bread wheat as compared to the control.

The response of wheat yield to blended fertilizer types and rates showed variation between treatments; indicating that the application of higher NPSB rate with copper was vigorous for wheat crop production. The higher wheat grain yield was recorded by application of 92 N, 90 P2O5, 17 S, 1.7 B + 600 g Cu when compared with that of 92 N, 90 P2O5, 17 S, 1.7B. It suggests that the inclusion of Cu is important fertilizer management practice for wheat production at the study area. This result is in line with that reported by Noabur and Jeff (2020), who showed that wheat responses to copper was effective in correcting deficiency limitation for growth of wheat. Increasing the application of blended fertilizer (NPSB) rates on the bread wheat production constantly increased the amount of yield in the experimental site. Diriba et al., (2019) also reported that increasing rate of blended fertilizers increased the grain yield of wheat.

Table 4. Combined mean yield components of bread wheat as influenced by types and rates of blended fertilizers at Adiyo district

Treatment	PH (cm)	SL (cm)	TPP	TSW (g)
Control	84.2^{c}	7.0^{c}	3.9^{d}	49.1^{b}
NPSB = 46, 54, 10, 1.07	93.7^{b}	7.8^{b}	5.4^{abc}	49.9^{b}
NPSB = 69, 72, 13, 1.4	93.8^{b}	7.9^{b}	5.2^{bc}	50.1^{b}
NPSB = 92, 90, 17, 1.7	96.2^{ab}	8.0^{b}	5.0^{c}	56.5^{a}
NPSB = 92, 36, 7, 0.71	96.7^{ab}	8.0^{b}	5.6^{ab}	49.4^{b}
NPSBCu = Tr2 + Cu	93.6^{b}	8.0^{ab}	5.3^{bc}	50.5^{b}
NPSBCu = Tr3 + Cu	94.0^{ab}	8.1^{ab}	5.8^{a}	49.6^{b}
NPSBCu = Tr4 + Cu	97.5^{a}	8.4^{a}	5.8^{a}	49.3^{b}
Mean	93.72	7.9	5.26	50.55
LSD (0.05%)	3.61	0.39	0.47	4.10
CV%	5.85	7.44	13.43	12.25

N.B*: *LSD (0.05%): least significant difference at 5% level; CV: coefficient of Variation; PH: plant height; SL: spike length; TPP: number of tillers per plant; TSW: thousand seed weight; Means in a column followed by the same letters are not significantly different at 5% level of Significance

Partial Economic Analysis

Partial economic analysis also indicated that application of NPSB + Cu at rate 250 kg NPSB + 600gm Cu and 102 kg top dressing (92N, $90P_2O_5$, 17S, 1.7B + 600gm Cu) gave the highest net benefit and inclusion of Cu in NPSB blend gave 151.02% MRR. Thus it could be recommended that farmers at the study and similar AEZ could apply 250 kg NPSB + 600gm Cu and 102 kg urea top dressing ha^{-1} for optimum wheat production. Application of NPSB at rate 250 kg NPSB with 102 kg urea top dressing gave modest wheat grain yield and could be optionally used in the absence of Cu blends and lower NPSB rates might be accepted on the farmer yield goal.

Table 5. Partial budget and dominance analysis for blended fertilizers on bread wheat at Adiyo district

No.	Treatment	GY (kg ha^{-1})	Adjusted GY (kg ha^{-1})	FC (ETB ha^{-1})	AC (ETB ha^{-1})	TVC (ETB ha^{-1})	GB (ETB ha^{-1})	NB (ETB ha^{-1})	MRR%
1	Control	3657.4	3291.66	0	0	0	29624.94	29624.94	
2	NPSB = 46,54,10, 1.07	5229.0	4706.10	2469	450	2919	42354.9	39435.90	
5	NPSB = 92, 36, 7, 0.71	5851.9	5266.71	2849	406.5	3255.5	47400.39	44144.89	
6	NPSBCu = Tr2 + Cu	5472.2	4924.98	3444	550.2	3994.2	44324.82	40330.62	D
3	NPSB = 69, 72, 13, 1.4	5839.5	5255.55	3448	598.1	4046.1	47299.95	43253.85	D
7	NPSBCu = Tr3 + Cu	5765.4	5188.86	4423	698.5	5121.5	46699.74	41578.24	D
4	NPSB = 92, 90, 17, 1.7	6203.7	5583.33	4418	819.1	5237.1	50249.97	45012.87	
8	NPSBCu = Tr4 + Cu	6537.0	5883.30	5393	919.6	6312.6	52949.70	46637.10	

Table 6. Analysis of net benefit and MRR% of blended fertilizers on bread wheat after removal of dominated treatments

No.	Treatment	GY (kg ha^{-1})	Adjusted GY (kg ha^{-1})	FC (ETB ha^{-1})	AC (ETB ha^{-1})	TVC (ETB ha^{-1})	GB (ETB ha^{-1})	NB (ETB ha^{-1})	MRR%
1	Control	3657.4	3291.66	0	0	0	29624.94	29624.94	
2	NPSB = 46,54,10, 1.07	5229.0	4706.10	2469	450	2919	42354.9	39435.90	336.1
5	NPSB = 92, 36, 7, 0.71	5851.9	5266.71	2849	406.5	3255.5	47400.39	44144.89	1399.4
4	NPSB = 92, 90, 17, 1.7	6203.7	5583.33	4418	819.1	5237.1	50249.97	45012.87	43.8
8	NPSBCu = Tr4 + Cu	6537.0	5883.30	5393	919.6	6312.6	52949.70	46637.10	151.02

N.B: *Yield adjustment: 10%, ETB: Ethiopian Birr, GY: grain yield, FC: fertilizer cost, AC: application cost, TVC: total variable cost, GB: gross benefit, NB: net benefit, D: indicates dominated treatments that are rejected, MRR: marginal rate of return*

CONCLUSION AND RECOMMENDATION

Based on the results of this study, it is generally concluded that, application of blended fertilizer types and rates revealed considerable difference of biomass yield and grain yield over untreated soil at the study area. Application of blended fertilizer types and rates significantly affected plant height, spike length, number of tiller per plant, thousand seed weight, biomass yield and grain yield. In conclusion, application of NPSBCu at a rate of 250 kg NPSB + 600gm Cu and 102 kg urea top dressing (92N, 90P2O5, 17S, 1.7B + 600gm Cu) significantly improved bread wheat yield and gave high net benefit and %MRR. Both the highest net benefit and MRR% was obtained by application of 92N, 90P2O5, 17S, 1.7B + 600 gm Cu at Adiyo district. Hence the application of NPSBCu: 92N, 90P2O5, 17S, 1.7B + 600 gm Cu predominantly or as option NPSB: 92N, 90P2O5, 17S, 1.7B can be used for bread wheat productivity in the study area. However, to reach at a conclusive recommendation, the experiment should be repeated with multi-locations and soil types in different agro-ecologies for wider use.

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Original Research Article||

Adaptation and performance evaluation of "Potchefstroom Koekoek" chicken breeds under farmer's management practice in Debub Ari and Bena-Tsemay districts of South Omo Zone, Ethiopia

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Abstract

The performance evaluation and adaptation of Koekoek breeds of chicken was conducted at Debub Ari and Bena-Tsemay districts of southern Ethiopia. Eighteen households were selected purposely from both districts and training was given. Each selected households were provided with 30-days old chicks and 18 hay-box brooders. The chickens were vaccinated for New Castle Disease, Gumboro, and Mareks. The chickens were supplied with commercial starter ration for the first 45 days and then made to feed on locally available feeds. Mortality during the first two weeks was 21.67% and 5.22% after the first two weeks up to 45 days with the overall survival of 73.11%. The highest percentage of mortality occurred during the first two weeks. The mortality due to disease was low. The average body weights of both male and female Koekoek chickens at the age of 20 weeks was 1.404 and 1.213 kg, respectively. Koekoek chickens had an average of 186.28 days age at first laying. The average egg production potential of the breed was 154.17 eggs per year per hen with a relative egg weight of 47.078 g. Thus, the breeds were highly preferred due to survival, adaptation, scavenging, disease resistance, egg production and adaptation similarity with local breeds under the existing farmers' management conditions. Therefore, the Koekoek breeds of chicken should be made accessible to households, with increased awareness of the farmers via training for better management and scaling up of breeds to enhance the productivity and maximize the household's income.

Key words: Breed, Chicken, Dual-purpose, Koekoek, Potchefstroom and Production

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INTRODUCTION

Chicken production as one part of livestock sector that plays a vital role in poverty alleviation, creating job opportunities for the job-less youth with a decent livelihood (Gororo and Mabel, 2016). The egg production potential of local breeds was 30-60 eggs per year per hen with an average egg weight of 38 g under on-farm management, but exotic breeds produce around 250 eggs per year per hen with the relative egg weight of 60 g as reported by Haftu (2016). To increase the production potential transforming from traditional scavenging to semi-scavenging system and increasing the numbers of commercial breeds are best options to insure the domestic red meat and egg consumption practices for better nutrition and economy (Shapiro, 2015).

Lack of commercial layers and early maturing chicken breeds are major constraints of Ethiopian chicken producers (Zemelak et al., 2016). Shumuye et al., (2018) reported for Tigray region, that Koekoek chickens were best breeds for a scavenging and have broody behavior which makes the breeds similar in characteristics with the local counterparts. The Agro-ecology based performance evaluation improved the living standards of farmers by increasing chickens' productivity (Zemelak et al., 2016).

The productive performance of Koekoek chickens and complementarity of the breeds to livelihoods of farmers in the South-Omo zone in general and Debub Ari and Bena-Tsemay districts in particular were not formerly evaluated. Inputs such as provision of improved breeds, improvement of existing management practices and advancing the awareness as well as attitudes of the farmers through training might bring considerable improvements in chicken production and productivity. The gaps in chicken productivity and opportunities better livelihoods for the farming community are given attention via adaptation and performance evaluation of improved breeds. Therefore, in order to solve chicken productivity problems, adapting and evaluating the Koekoek's performance in South Omo Zonal administration in general and Debub Ari as well as

Bena-Tsemay districts in particular were believed to lead to sustainable improvement in chicken production, income generation, animal protein consumption and finally contribute to the regional and national development goals of the country. This study was therefore targeting adaptation, compatibility with environment and productive performance evaluation of Potchefstroom Koekoek chicken breeds over formerly distributed breeds (local or other exotic types) in Debub Ari and Bena-Tsemay districts of South Omo zone.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted in Debub-Ari and Bena-Tsemay districts of South Omo Zone, South Nation Nationalities and Peoples Regional State (SNNPRS) of Ethiopia. Details of the study area is illustrated in the map (Figure 1) below.

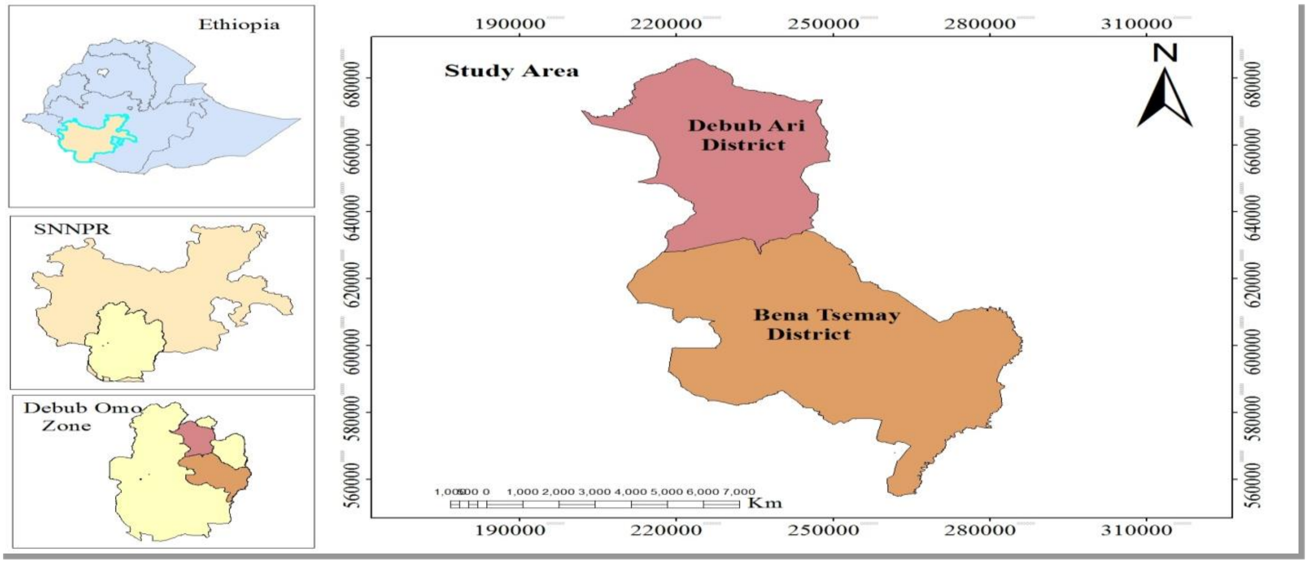

Figure 1: Map of the study area

Debub-Ari District

Debub-Ari district is found in the Southwestern part of SNNPRS, Ethiopia. It is located at 774 km southwest of Addis Ababa (capital of Ethiopia) and 529 km southwest of Hawassa (capital of SNNPRS). Debub-Ari covers an area of 1,520 km2 with the population of 219,708. The district lies on 50.67'-60.19' N latitude and 360.30'-360.73'E longitude, with the respective elevation of 500-3,500 m. a. s. l. The average annual rainfall ranges from 400 to 1,600 mm with an average annual temperature of 10.1-27.50C. The dominant livestock types of the district are cattle, goat, sheep, donkey, horse, and chickens (South Omo Zone statistical abstract, 2010).

Bena-Tsemay District

Bena-Tsemay district is found in the Southwest part of SNNPRS, located at 713 km southwest of Addis Ababa and 468 km southwest of Hawassa. Bena-Tsemay covers an area of 2,922.8 km^2 with a population of 61,061. The district lies between 5^0.01-5^0.73N latitude and 36^0.38'-37^0.07'E longitude, with the respective elevation of 500-2,500 m.a.s.l. and average annual rainfall ranging between 400 and 1,600 mm. The average temperature ranges from 10.1-27.5^{0}C and the dominant livestock types are cattle, goat, sheep, and chickens (South Omo Zone statistical abstract, 2010).

Household selection procedures

From each of the two districts, two kebeles were selected purposely. A total of 18 households were purposefully selected from each kebele, who were willing to take the chickens and participate in the study. Out of the total (18) households, 12 were females headed.

Distribution and management of chickens

Training on housing, health management, feeding, water provision and data recording was provided to the study participants before distributing the chicken. Chicks of 30-days old koekoek breeds and 18 hay-box brooders were provided to each selected household.

Disease prevention and feeding

The health follow up was undertaken by animal health researchers of the respective centers. Chicks were vaccinated for New Castle Disease, Gumboro and Mareks as directed by national veterinary case team. Chicks were supplied with commercial starter ration for the first 45 days and then made to feed on locally available feeds like sorghum, maize, kitchen left overs, sunflower grain, miller ground waste and while they were also scavenging around the homestead.

Data collection

The mortality of chickens, survival, causes of mortality, growth performance, sexual maturity, age at first laying, number of eggs produced per hen per year, Egg weight, Partial budget analysis and the final net income were obtained during the data collection period. The data was collected for one year in order to know the annual egg production.

Data analysis

Descriptive statistics such as mean, standard error and percentage of the collected data were analyzed using Statistical Package for Social Sciences (SPSS) version 16, Inc., Chicago, Illinois, USA, 2007).

Model**: -** Yik = µ + Ai + Єik, where:

Yik = the value of the respective variable

µ = the overall mean of the breed

Ai = the effect of i^{th} district (i = 1-x districts, (Where, 'x'= Debub Ari and Bena-Tsemay).

Єik = random error term.

RESULTS AND DISCUSSIONS

Mortality and survival of distributed chickens

The on-farm mortality and survival evaluation of Koekoek chickens were presented in (Table 1). The on-farm mortality evaluation during the first two weeks was highest (21.67%) and decreased after the first two weeks (5.22%) with the average overall survival of 73.12%. Approximately similar percentage of the survival of chickens using hay-box brooder at on-farm management was 79.8% for Areka area (Aman et. al, 2016).

The highest survival was reported by Hassen (2019) for Asayta district, with the average survival rate of 98.3%, which after 5.5 months declined to 93.3%. The observed variation might be due to the agro-ecologic and managerial difference between the two sites.

The highest percentage of mortality during the first two weeks was due to stress that attributed while transporting too long distance, associated injury and predator attacks (Tekalegn et. al, 2019). The percentage of mortality decreased to 5.22% after the first two weeks due to the stress compensation of chickens and adaptability to the area.

The mortality due to disease was lower than other causes of mortality due to the effective vaccination schedule provided according to the recommendations of the national institute of veterinary for dual purpose breeds. As observed during the intensive follow up and according to farmer's perception Koekoek breeds of chicken have less exposure to disease when compared to other exotic breeds distributed formerly, and to some extent Koekoek breeds share the same adaptation and resistance properties with that of the local chickens.

Table 1. Survival and mortality of chickens

Parameters	Districts (percentage)		
	Debub Ari	Bena-Tsemay	Av. total
Mortality in the first 2 week	21.11	22.22	21.67
Mortality after the 1st 2 week - 45 days	2.65	7.78	5.22
Total		23.76	30.00
Survival	76.24	70.00	73.11
Causes of Mortality			
Mortality due to disease	11.54	11	11.27
Mortality due to predator	28.20	28	28.10
Mortality due to injury	24.36	20	22.18
Mortality due to stress	35.90	41	38.45
Total	100	100	100

Av. = average; values in the table represent percentage of the parameters.

Body weight of male and female chicken

The average body weight of Koekoek breeds for male and female at the age of 20 weeks under farmer's management was 1.404 ± 0.097 and 1.213 ± 0.061 Kg, respectively (Table 2). Similarly, Aman *et al*. (2016) reported that, the average body weight of male and female Koekoek chickens at the age of 20 weeks was 1.5 and 1.1 kg, respectively. Kasa (2016) also reported 1.34 and 1.03 kg body weight at 20 weeks, respectively for the case of Jimma zone of Oromia region. Similar result was also reported recently by Atsbaha *et al.* (2018), where the average body weights of Koekoek chicken breeds at the age of first twenty weeks was 1.01 and 1.40kg for female and male, respectively. Differently, higher average body weight was reported by Hassen (2019) for Asayta districts of Afar region, where the average body weight of Koekoek chicken breeds at the age of 20 weeks under agro pastoral management condition was 2.23 and 1.91 kg for male and female chickens, respectively. The variations might be attributed to the difference of management and agro ecological sites, i.e., largely arid in the case of Asayta districts and mid land in the case of the present study.

Table 2: Productive performance of chickens

Parameters	Districts (Mean ±SE)		
	Debub Ari	Benatsemay	Average total
Body weight of male	1.25±0.17Kg	1.558±0.07Kg	1.404±0.097Kg
Body weight of female	1.081±0.08 Kg	1.344±0.07 Kg	1.213±0.061 Kg
Age at first egg laying	185.56±4.65days	187.0±4.356days	186.28±3.10days
Total number of eggs/year/hhs	1787.34±55.6	1195.8±28.2	1491.57±32.51
Number of layer hens	11.11±1.996	8.11± .992	9.61±1.494
Number of eggs per year	160.88±27.86	147.45±28.43	154.17±21.76
Egg weight	46.78±1.99g	47.38±2.142g	47.078±1.421g

g = gram; kg = kilo gram; SE = standard error; values in the table represent mean and standard error

Age at first laying

The age at the first egg laying of Koekoek female chickens was presented in Table 2. As the result of overall total indicated the female Koekoek chickens had the average age of first egg laying as 186.28 days /6.2 months. Similar result was reported by Atsbaha et al. (2018) for Mehoni areas of Southern Tigray, where the average age of first laying was 6.48 months. The late age of first laying was reported by this study than Aman et al. (2016) for Wolaita areas of southern region, the Koekoek breeds reportedly reaching the age of sexual maturity at 4.733 months, which might be attributed to management standard of farmers especially feed types and feeding. Similarly, late age of first laying was reported by current study than Debre-Zeit Agricultural Research Center (2012); that is for 5 months under intensive management condition, which is attributed to the free-range management system and use of nutritionally deficient feed resources after 45 days in the current study.

Number of eggs per year per hen

The average yearly egg production potential of Koekoek breeds was presented in Table 2. The overall egg production potential of Koekoek chickens was 154.17 eggs per year per hen with the relative egg weight of 47.078 g. Similar result was reported by Atsbaha et al. (2018), with the average yearly egg production potential of koekoek having 156.29 eggs per year per hen with the relative egg weight of 40.30g. But the highest number of eggs per year per hen was reported by Hassen (2019) for Asayta districts of Afar region (182 eggs per year per hen) The difference in the egg production potential might be due to the types of feed and feeding difference in which commercial feed for the former trial conducted at Asayta district gave higher values compared to scavenging with locally available feed supplementation after 45 days in the present study.

Farmers' perception during field day

As observed during the data collection period and farmer's perception during the field day, Koekoek chicken breeds were good scavengers like the indigenous breeds, with some of chickens showing signs of broody behavior, having higher disease resistance when compared to other exotic chicken breeds that were previously distributed.

The farmers invariably accepted the breed color, preference of egg, scavenging behavior of the breed, and adaptation to the agro-ecological conditions. Finally, the farmers participated in field day showed interest to rear the breed for the future expansion and production for better productivity and profitability.

Partial budget analysis

The partial budget analysis of Koekoek chicken breeds in terms of all the costs and total return were recorded to be 28,303 birr (Table 3). The profit was calculated by adding the cost of feed, medication and chicken purchase as total variable cost and sale of cock, egg and hens as a total return and then subtracting total variable cost from total return. Although the profit was not similar in all participant households, on average each participant households got 1572.4 Ethiopian birr after the completion of the package.

Table 3. Partial budget analysis

Code	Cost				Income				
	Chick purchase	Feed cost	Medication cost	TVC	Cock Sale	Egg Sale	Hen Sale	TR	profit
1	240	980	75	1295	1400	695	1700	3795	2500
2	240	800	75	1115	1050	1281	1600	3931	2816
3	240	780	75	1095	1400	365	720	2485	1390
4	240	1400	75	1715	1300	1423	2100	4823	3108
5	240	880	75	1195	2250	88	1200	3538	2343
6	240	680	75	995	590	120	600	1930	225
7	240	580	75	895	400	90	500	990	35
8	240	600	75	915	1100	220	450	1770	885
9	240	800	75	1115	1000	894	1100	2994	1909
	Debub Ari district			10,335			26,256		15,921
10	240	850	75	1165	2100	515	1000	3615	2480
11	240	750	75	1065	1400	717	600	2717	1682
12	240	580	75	895	960	323	450	1733	868
13	240	750	75	1065	830	508	1320	2658	1623
14	240	480	75	795	600	290	700	1590	795
15	240	480	75	795	550	320	900	1770	975
16	240	680	75	995	800	386	900	2086	1091
17	240	480	75	795	1000	480	600	2080	1285
18	240	900	75	1215	750	968	1200	2918	1703
Bena-Tsemay district			8785				21,167		12,382
Average total			19,120				47,423		28,303
Overall profit									1572.4

TVC = total variable cost; TR = total return; values in the table represent the numbers or amounts of the respective variable or codesThe breeds share nearly similar resistance behavior with that of the local chickens.

CONCLUSION AND RECOMMENDATIONS

Although stress was main cause of mortality, *"Potchefstroom koekoek"* breeds showed better adaptation (survival) and productive performance under existing farmers management. More over back-yard attitude was observed among the farmers regarding day old chick management, i.e., it is impossible to rear day old chicks without the broody hen.

In addition, the scavenging behavior of this breed was better and more or less similar with that of local breeds. The farmers showed no contradicting idea about the breed color, egg preference, scavenging behavior, adaptation and finally the farmers participated in the field visit showed interest for further expansion. "*Potchefstroom Koekoek*" breeds were highly preferred due to the survival, scavenging ability, disease resistance, egg productivity under existing condition with similar adaptation to that of local breeds.

Therefore, accessibility to the improved breeds should be given attentions by extension programs with intensive training for the farmers to have information in selecting chicken breeds for better productivity.

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Original Research Article||

Determinants of households' food consumption expenditure in South-Western Ethiopia

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Abstract

Most of poor communities in developing countries live disproportionately in rural areas where agriculture is the main means of livelihood. The food expenditure is generally used as a main yardstick for measuring the standard of living in developing nations. However, previous studies do not pay attention in identifying food expenditure of rural households. This study was designed to analyze food consumption expenditure of households in rural communities of South-West Ethiopia. The study employed cross sectional data collected from 182 randomly selected households. Primary data were collected from sample households through interview schedule, focus group discussions and key informant interview while secondary data were collected by reviewing different documents. Descriptive statistics and multiple linear regression econometric models were used for analyzing the data. The study result indicates that age of household head and market distance were negatively and significantly affected household food consumption expenditure while education level of household head, livestock holding size, nutritional training and income of households has positively affected household food consumption expenditure. Significant factors are consequences for food consumption expenditure in the study area. Therefore, policy and development interventions should give emphasis to training and awareness program to equip households with appropriate nutritional knowledge and modern technologies supporting agricultural practices to increase both production and income of rural households so as to enhance household food consumption behavior in the study area.

Key words: Food, consumption expenditure, multiple linear regression, Southwestern Ethiopia

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INTRODUCTION

Most of poor communities in developing countries live disproportionately in rural areas and they are directly or indirectly dependent on smallholder agriculture, that are poorly integrated into markets, for their food, income and livelihoods (Fischer and Qaim, 2012). Though there is a growth in agricultural production most of the Sub-Saharan Africa (SSA) countries including Ethiopia have not been able to ensure food security at either national or household level (Bezu et al, 2014). The extent to which rural households are able to feed themselves depends on their own food production as well as ability to purchase food using non-farm and farm income (Baiphethi and Jacob, 2009). Ethiopia is one of the lowest income countries in the world with an average per capita income and still suffering from persistent and widespread poverty and food insecurity (Husmann, 2016). More importantly, poverty is disproportionately affecting people in the rural areas of the country where about 80.5% of the rural population rely on agriculture for their livelihoods (Abro et al, 2014; Thomas, 2013).

Consumption is one of the economic activities to meet various needs of goods and services. It represents the total quantity of goods and services bought by consumers during a period, which is the expression of total consumer demand (Ndubueze et al, 2015) and consumption expenditure as the amount that household spends on purchasing goods and services such as clothing, food items, entertainment, health services and acquisition of assets among others (IFPRI, 2018). Food consumption plays an important role in the economic growth and development of both developed and particularly for developing nations. It has a considerable impact on the circular flows of income in the economy, having a significant effect on the economic activities of a country (Amran, 2017).

Consumption behavior of a particular product is a deciding factor for eating, drinking and food choices and it helps in understanding why, when, where, and how people consume certain foods or diets (Berhane et al, 2011). Levels and composition of food consumption are major determinants of the nutritional wellbeing of individuals, which in turn, have important implications for health, productivity, and income (Seleshe, 2014). The household food, nutrition and health have relations with the consumption decisions of households (Alem and Soderbom, 2012). Food consumption behavior in Ethiopia is tidily associated with cultural taboos and religious practices (Hoddinott et al, 2015), which might lead to lack of dietary diversity causing high rate of stunting and other nutritional complications (Atkinson, 1992). Levels and composition of food consumption can be used to measure the wellbeings of households in Ethiopia (Ajmair and Akhtar, 2012). In developing nations, the consumption expenditure on different food items can generally be used as a main yardstick for measuring the households' well-being and standard of living.

Some Researchers (Sotsha et al, 2019; Jodlowski et al, 2016; Iorlamen et al, 2014) have studied the major factors that affect the people's food consumption such as socio-economic and demographic factors. It is reported that family size, saving or investment lifestyle, education and environment were important determinants of consumption levels (Kostakis, 2014). According to the Engel's law, food expenditure increases as income and household size increase, but the food budget share declines as income rises (Kostakis, 2014). Hence, it is argued that low-income households spend a larger share of their income on food, compared to higher-income households. Although, Hone and Marisennayya (2019) found that demographic and socio-economic traits such as income, gender, age, and marital status, place of residence and status of employment have important impact on household expenditures on foods. Furthermore, the household behavior of expenditures on food is directly related to the household size and income. Studies conducted in Addis Ababa city and Debre Markos town found that household income and family size being main determinants of the household consumption behavior (Kuma, 2010; Wolle, 2020).

The above-mentioned studies however, are focused on determinants of food consumption expenditure in urban contexts. There is lack of evidence on the issue of food consumption expenditure for rural areas particularly, in Southwest Ethiopia. It is believed that information on the rural household's food expenditure plays an important role to monitor and explain inequalities in living standards, general welfare and food security. Hence, the finding of this study can contribute to create awareness on households' dietary intake patterns and factors influencing food expenditure, which are inputs for governments and policy makers to design appropriate programs and strategies that help to alleviate poverty and to enhance food security and to improve living standards of the rural households.

This study was, therefore, conducted with the objectives of analyzing the rural households' dietary intake pattern as well as determining factors affecting rural households' food consumption expenditure and has contributed new body of knowledge that is assumed to provide rural context evidence-based information pertinent for better planning and implementation of development interventions in the study area.

MATERIALS AND METHODS

Description of the Study Area

The research was conducted in Southwestern Ethiopia, Yayu and Gomma Districts. Yayu is located about 582 km while Gomma is 395 km west of Addis Ababa. The districts agro-ecology is lowland and highland, respectively. Yayu mean annual temperature is about 20°C and the mean annual rainfall is 1724 mm. Yayu has a total population of 57,938 (27,969 males and 29,969 females). Gomma, on the other hand, has a mean annual temperature of 18°C and a mean annual rainfall of 2100 mm. The district has a total population of 350,882, (172,888 men and 177,994 women). Coffee-based agriculture is the main livelihood source of the households in Gomma (IPMS, 2014; Tadesse et al, 2008).

Sample Size and Sampling Procedures

Sample selection was done employing three-stage sampling method. At the first stage, the study area was purposely selected based on the researcher's interest. In the second stage, three kebele's were selected using simple random sampling method. At the end, 188 respondent households were selected from the three kebele's by simple random sampling method. To determine the required sample size, this study used a simplified formula developed by (Yamane, 1967) at 95% confidence level.

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

N = total population of the study kebele

e = precision level at 7.1%

n = sample size

$$\frac{2850}{1 + 2850(0.07)^2} = 188$$

Data Types, Sources and Collection Methods
A cross-sectional survey was conducted in rural households of the study area. In this study, both qualitative and quantitative data types were collected from both primary and secondary sources. Primary data were collected from sampled households using semi-structured questionnaire, interview guide for Focused Group Discussion (FGD) and key informant interview (KII) checklist. Secondary data were gathered from district offices of agriculture, trade and marketing and from other published documents.

Methods of Data Analysis
Data were analyzed using descriptive statistics and econometric model. To analyze the rural household dietary intake pattern, frequency distribution, mean, percentage and standard deviations were employed. Multiple linear regression model was used to determine the relationship between the dependent variables and a set of explanatory variables by using SPSS version 20.

The Economic Model
Following Wooldridge (24), the multiple linear regression model is specified as

HHC = βo + βnXn +un

Where: HHC= total household consumption expenditure per month of a household (in Birr); βn=coefficient of the explanatory variables TLU Variance Inflation Factor (VIF); Xn = explanatory variables and un = error term and βo = constant

Before running the model all the hypothesized explanatory variables were checked for the existence of multi-collinearity and normality of data distribution. To check multi-collinearity Variance Inflation Factor (VIF) and the tolerance factor were used and p-p plot was used to normality distribution. For VIF, the minimum possible value is 1.0; while value greater than 10 indicates a probably collinearity between the explanatory variable in question and the rest of the predictors in the model. VIF was estimated using the formula stated below:

$$VIF = \frac{1}{1-R^2}$$

Where: R^2, is the multiple correlation coefficients between variable X (one of the independent variables).

On the other hand, tolerance (TOL) is an inverse of VIF. A small tolerance value indicates that the variable under consideration is almost a perfect linear combination of other independent variables in the equation and that it should not be added to the regression equation.

Study variables
Dependent variables: Households' food consumption expenditure was measured by total money expended on food items. All food consumed from own production, purchase and gift were considered and changed to Ethiopian Birr.

Table 1. List of variables and their expected direction of effect on food expenditure

Variables	Type	Unit	Expected sign
Dependent Variable			
Household Food Consumption Expenditure	Continues	Birr (Ethiopian Local Currency)	
Independent Variable			
Sex (household head)	Dummy	1 male, 0 female	Negative
Age (household head)	Continuous	Years	Negative
Education level	Continuous	Schooling years	Positive
Household size	Continuous	AE	Positive
Land holding size	Continuous	Hectare	Positive
Livestock owned	Continuous	TLU	Positive
Income of household	Continuous	Birr	Positive
Market distance	Continuous	km	Negative
Credit use	Dummy	1 user, 0 non user	Positive
Nutritional Training	Dummy	1yes, 0 not received	Positive

Independent variables: The factors hypothesized to affect the food consumption expenditures were age of household head, education level of household head, household size, and household land holding size, livestock holding size, income of household, market distance from residences of respondents, credit use and receiving nutritional training (Table 1). In the above Table, all hypothesized independent variables were described with their expected effect on dependent variables. The selection of variables was informed by several authors (Donkoh et al, 2014; Habib, 2016 Meng et al, 2012).

RESULTS AND DISCUSSIONS

Description of the sampled households

A total of 182 households were involved in the analysis. The households' characteristics (Table 2) showed that out of the households sampled 71.4% of them were headed by males and 28.6% by females. About 34.1% of the households had experiences of using credit services and 48.4% participated on nutritional training. The mean of age and education level of the household heads were 42.2 years of age and 4.7 years of schooling, respectively. The mean family size was 5.2. The average land and livestock holding of the households is 3.01 hectare and 2.38 TLU, respectively. The average monthly income of household was 4,341.60 ETB and the average distance from home to the nearest market place was 4.15 km.

Table 2. Description of explanatory variables

Continues Variables	Minimum	Maximum	Mean	SD
Age	24	76	42.2	10.75
Education level	0	12	4.70	3.58
Family size	1	10	5.2	1.7
Land-holding size	0.00	8.00	3.01	1.90
Livestock	0	7.9	2.38	1.93
Income	400	51,917	4,341.60	7200
Market Distance	0.2	15	4.15	3.24

Dummy Variables		Frequency (n=188)	%
Sex of HH	Female	52	28.6
	Male	130	71.4
Credit use	No	120	63.9
	Yes	62	34.1
Nutritional Training	No	94	51.6
	Yes	88	48.4

Source: own survey.

Dietary intake patterns of households

The type of meal that is consumed in any rural households largely depends on the economic status and cultural preferences of people (Arimond, 2011). Meals types mainly prepared and consumed as staples are rich in carbohydrates. As shown in Table 3 below, all households depend upon cereals to fulfill their energy needs. These foods have become the sole source of energy households often consumed. This shows the extent to which cereal-based foods are consciously chosen by people in the study area. The KII also showed that food made from maize, sorghum and teff together with side dishes from pea, bean and lentils are frequently consumed among all households. Legumes and pulse are essential in household diets as side and flavoring components, but also as a complementary provider of micronutrients. Pulses/legumes are rich source of plant proteins and have many health benefits that households get from production or purchase. The findings are in concordance with a study done in Nepal, Bangladesh and Mozambique, where dietary patterns are heavily dominated by starchy staples (Arimond et al., 2011; Bhandari et al., 2016).

The consumption of micro-nutrient rich foods in the study area was poor. Micronutrients can be obtained from vegetables, fruits, and meat and milk/milk products. Micronutrients are particularly essential for children and women especially during pregnancy and lactation (Zerfu and Ayele, 2013). The higher the consumption of these foods, the less likely women and children suffer from micronutrients deficiency. The present study revealed that the frequency of consumption of micronutrient rich foods was low.

The majority 61.8% of households in the area consumed vegetable rarely and 38.3% sometimes. Rural food consumption is largely determined by what is produced and available. Fruit and vegetable consumption behavior of households were influenced by seasonal availability. Moreover, divergent opinions were noted regarding vegetable and fruit consumption from KII and FGD. The participants also pointed out that cultivated food grains are not enough to cover the annual food demand for most of households in the study area. Some households face food shortage during the rainy season from June to September, during which time the families depend on vegetables, tubers and root crops. Vegetables such as cabbage, kale, lettuce, carrot and beet root are the most favored species in home gardens to help families overpass a critical food shortage gap. People eat lots of bananas, mangoes, avocados, guavas, or oranges, but only when they are seasonally available. However, leafy vegetables and fruits are perceived by majority of rural communities as not important part of the daily diet and hence are not included in the daily meals.

On the other hand, only few households buy fruits and vegetables from the market in the off season (October to April), as the home gardens don't dry out. These seasonal changes influence the availability of seasonal food crops hence may positively or negatively affect its market price, forcing consumers to change their food preferences often going for what is cheaper or is readily available. Households with access to irrigation water and facilities are producing vegetables during such off season and consume regularly, while households without access to irrigation had to buy vegetables and fruit from the market, which reduced their frequency of consumption. This finding confirms earlier reported (Workicho et al, 2016).

Foods that are acquired from livestock products such as meat (88.5%), milk (55.8%) and eggs (94.5%), are consumed rarely. There were households who were not at all consuming meat and dairy product in a year. Apart from households who have access to dairy caw and small animals like poultry, livestock products are consumed only by a limited number of households who afford to buy. Therefore, the demand and availability of various food sources, except for cereal crops and pulses, is low. The cost and availability of foods in turn, reduces dietary energy for significant number of the households in the study area. Further, discussion held with FGD indicated that, animal source foods (ASF) are mostly consumed during religious and social ceremonies. Wealthy households are able and prefer to buy ASFs and nurture their family. One KII noted that, *only those households who have access to enough dairy cattle have consumed milk and milk products*. Poor households never consider consuming livestock product. Some households having access to dairy cow do not use for home consumption due to other priorities such as grain staples. From this discussion, one can easily understand that, the food habits and the lack of nutritional knowledge results in poor consumption behavior. In the study area regarding the consumption pattern, majority of the households always consume pulse food, cereal food and fruits respectively. Hence, frequency of food intake, lack of awareness on the benefits of various fruits and vegetables and inability to access livestock products signifies imbalanced consumption practices in the area. The observations of the current study are in line with the findings of Black et al, (2013) and Jebessa et al (2019). The consumption of foods rich in micronutrients should be encouraged in order to prevent micronutrient deficiencies and ensure better health of women and children (Akpan et al, 2013).

Table 3: Consumption pattern of households (n=188)

Foods	Not at all	Rarely	Sometime	Always
	n (%)	n (%)	n (%)	n (%)
Cereal food	0	0	0	182(100)
Pulse food	0	0	29(15.8)	154(84.2)
Vegetables	0	112(61.8)	70(38.2)	0
Meat	20(11.5)	162(88.5)	0	0
Milk	68(37.2)	102(55.8)	12(7.0)	0
Egg	0	172(94.5)	10(5.5)	0
Fruits	0	105(57.4)	57(31.1)	20(11.4)
Root and tubers	0	112(61.8)	70(38.2)	0

Source: Own survey

Household Food Consumption Expenditure

Households expend their income on food and non-food goods and services. The minimum monthly food consumption expenditure level is 3400 Birr and maximum 9700 Birr with mean of 5807.81 and 2711.10 SD (standard deviation). The mean food consumption per adult equivalence was 893.70 with 862.40 SD. The food expenditure of households covers around 57-67% of total households' expenditure.

Determinants of household food consumption Expenditure

Prior to the estimation of the parameters of the model, data have been tested for multi-collinearity problem. Multi-collinearity test for the existence of serious problem of multi-collinearity among the variables was examined by the help of Variance inflation factor (VIF) and tolerance. The information showed no serious multi-collinearity problem (for all variables tolerance > 0.1 or VIF < 10). On the other hand, the normality was checked by P-P plot and showed that the points generally follow the normal line with no strong deviations. The model containing explanatory variables was significant, indicating that the model was able to distinguish between the various explanatory variables used. The regression model as a whole explained 31.0% (R2 = 0.310) of the variations in all cases. The Durbin-Watson test is another measure of model adequacy, which for the current research data was 1.538.

The variables that were assumed to have influence on food consumption expenditure were tested in the model, 6 out of 10 of which were found to be significant. Two of the significantly influential variables (age and distance from market) negatively affected the food consumption expenditure.

Income: is one of the basic factors for the people to improve their diets. According to the multiple linear regression, income was found to have positive relationship with household consumption expenditure and significant at 1% level. The positive relation of this variable indicates that the high-income households are more likely to expend more on their diet than low-income households. The increase in income will change patterns of spending. The model output result shows that a unit increases in income of households result in an increase of 0.019 Ethiopian Birr on the food consumption expenditure. The results from the current work are in line with the findings of Akpan (2013) and Amran (2017), who noted that as consumption is usually hypothesized to be a function of disposable income, which follows therefore, that income determines the households' level of consumption. Higher income makes the household to have more choices to the various goods that will be consumed (Sekhampu, 2012; Lorlamen, 2015; Oladimeji 2018; and Habu 2019).

Educational level of household head: It is obvious that education increases the knowledge and skill of the people in a society. Education has been hypothesized to have a positive relationship with household consumption. The model output also revealed that education level of household heads had a positive influence on the household food consumption expenditure at 1% significance level. As the household head acquires a higher education, the expenditure on food tends to increase. This implies that education increases knowledge of nutritional diets and proves one of the most important determinants of consumption. Educated household heads could have better understanding on the health benefits of various foods and they spent a significant amount of their budget on diet. On the other hand, education helps to form certain food habits and change others. The result of this study is in agreement with previous reports on significance of education to household food consumption expenditure (Yimer, 2011; Iorlamen et al, 2014).

Age of household head: Contrary to expectations, the age of household was found to be negatively affected at 1% significance level. This suggests that as household heads advance in age, their expenditure on food decreases. This study result is in line with the report of Sotsha (2020), that pointed out that the child support grant does not increase the household food expenditure and older household heads are likely to spend less as they become more risk averse. Rubhara (2017) also reported that as age of household head increase food expenditure decreases. But contrasting to Iorlamen et al, (2014), who showed that changes in the age of the household head lead to differences in nutritional requirements of a household and increase in the age of the household head was positively associated with increased food expenditure.

Market distance: The multiple linear regression model indicated that distance to market has significant and negative influence on household food consumption expenditure at 10% level of significance. The negative estimated coefficients in the models, implies that households far from market centers have expended less than those closer to market. The model also revealed that, a one unit increase in market distance results in 15.509 decrease in the household consumption expenditure. The probable reason for this was that households who are close to markets had opportunity to purchase different food groups from market or shops more often than those far away. This is in congruent with the results of the study conducted by Stifel and Minten (2017), which showed a strong link between remoteness from markets and household food consumption expenditure. Moreover, Sibhatu, (2015) and Hirvonen (2015) argued that better market access through reduced distances could contribute to better food consumption. The longer the distance to the market, the less frequently the farmers makes visits, which leads to less likelihood of them getting market information and goods/commodities (Matchaya and Chilonda , 2012).

Nutrition training: the multiple linear model analysis indicates that nutritional training has a positive association with household consumption level and significant at 5% level as it was hypothesized. The model output showed that having some training on nutrition, increases household food consumption. This implies that training improves knowledge on the individual food items and helps to make general evaluations of the diets of a household. Nutrition aspects go along with knowledge and awareness to ensure proper selection of foods for good health. Training also can inform consumers, helping them to wisely choose foods. It also provides with the relevant skills needed to prepare food well and spend more money on food items.

Table 4. Determinant of household food consumption expenditure

Variables	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	548.131	117.760		4.655	0.000***
Sex of household head	-27.487	40.947	-0.043	-0.671	0.503
Land size	2.367	9.634	0.016	0.246	0.806
Credit use	-39.190	38.253	-0.065	-1.024	0.307
Income	0.019	0.003	0.484	7.347	0.000***
Education level	11.598	5.097	0.145	2.276	0.024**
Age of household head	-3.410	1.727	-0.128	-1.975	0.050**
Market distance	-15.509	5.873	-0.176	-2.641	0.009***
Family size	-7.425	10.712	-0.044	-0.693	0.489
Nutritional Training	71.970	37.025	0.126	1.944	0.054*
Total livestock holding	19.388	9.645	0.131	2.010	0.046**
R	0.574		Estimate Std. Error	241.60	
R Square	0.330		Durbin-Watson	1.538	
Adjusted R Square	0.291		Prob > F	0.0000	

Significant at 10%, ** Significant at 5%, * at 1% probability levels; Source: multiple linear regression model*

The result of this study is consistent with findings of Powell (2017), who revealed that lack of nutrition information results into poor dietary eating that leads to inadequate nutrient intake.

Similarly, Nathan, (2014) and Nsele, (2008) showed that awareness encouraging people to consume healthy meals, and carrying out proper child feeding approaches.

Livestock Size: livestock size significantly ($p<0.10$) and positively influences consumption expenditure. The multiple linear regression indicated that as the livestock size increase household consumption expenditure level increases. This implies that households owning more livestock are more likely to expend their resources on food consumption than households with smaller livestock size. Livestock possession is also closely related to production in the rural area that helps to generate income for additional food purchase (Jodlowski, 2016; Rubhara, 2020).

CONCLUSION AND RECOMMENDATIONS

The result of the regression model showed that income, education level, nutrition training and livestock size significantly and positively influenced households' food consumption expenditure. Age of the household head and distance from the nearest market on the other hand, had a negative but significant influence on the households' food consumption expenditure.

The majority of household frequently consume starchy staples while consumption of vegetables, fruits and dairy products were rare. The study also found monthly estimated household expenditure on food and farm size as the main factors influencing farm household total expenditure in the study area.

Based on these finding, it can be recommended that agricultural interventions should work for the production and consumption targeting better dietary diversity to improve nutrition. Cultivation of vegetables and fruits and consuming them can prove to be an important factor in maintaining better nutritional status. It is commanding that the government and non-governmental organizations act to improve dietary intake pattern of households. The government should properly target rural households to raise the income level and nutritional awareness for improved consumption of healthy foods. The concerned and relevant regional and federal government agencies should look into market infrastructure for the improvement of food consumption practices of the community considered for the current study.

Abbreviations

ETB: Ethiopian Birr; FGD: Focus group discussion; KII: key informant interview; PAs: Peasant Association; SPSS: statistical package for the social science; SSA: Sub-Saharan Africa; TLU: Tropical Livestock Unit; VIF: Variance Inflation Factor, WB: World Bank; SD: standard deviation

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Authors' contributions

GMJ: comprehended the idea, collected the data, did analysis, wrote abstract, background, methodology, result discussion and Conclusion. ABB contribution to the paper overall management of the article, technical input at every step and participated in manuscript preparation. Both authors read and approved the final manuscript.

Availability of supporting data

The data sets analyzed during the current study will be made available on email request to the corresponding author.

Ethical approval and consent to participate

Ethical clearance was obtained from Jimma University College of Agriculture and Veterinary Medicine. Permission was obtained from selected districts' Agricultural and Natural Resource Offices and PAs administrations through formal requests. The consent form has been read to all participants and those agreeing to participate in this study signed one.

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Journal of Science and Development

Guide to Authors

Manuscripts are submitted online after registering as an Author at https://journals.hu.edu.et/hu-journals/index.php/agvs/user/register

For details of manuscript preparation, please refer to the guide below, or visit the above website

Scope of the Journal

The ***Journal of Science and Development (JSD)*** is a multi-disciplinary, peer-reviewed bi-annual journal published by the Research and Development Directorate of Hawassa University. **JSD** publishes articles on a wide range of disciplines, articles on a range of disciplines of agriculture and veterinary sciences including, Agricultural Biotechnology, Agribusiness, Agricultural Economics, Agricultural Engineering, Agricultural Microbiology, Agricultural Extension, Agronomy, Animal Healthcare, Animal Genetics, and Breeding, Animal Nutrition, Conservation Agriculture, Forestry and Agroforestry, Horticulture, Livestock Parasitology, Livestock Production, Plant Genetics, and Breeding, Plant Protection, Post-harvest Biology and Management, Community Nutrition, Sustainable Agriculture, Poultry, Soil Science, Veterinary Anatomy and Physiology, Veterinary Clinical and Preventive Medicines, Veterinary Diagnostics, Veterinary Epidemiology, Veterinary Pathology, Veterinary Toxicology.

General requirements

Upon submission of a manuscript, the authors are required to state that the paper has not been submitted for publication to any other journal or will not be submitted elsewhere in the future. Manuscript submission implies that the author and all co-authors agree to assign copyright to *JSD*. Manuscripts should be written in English, with spelling according to recent editions of the Advanced Learner's Dictionary of Current English (OUP). The font size for the text is 11- point Times New Roman, at exactly 1.5-point line spacing throughout (TNR 11/1.5).

Types of articles

Research articles

Research articles should report original research findings. They should not exceed 6000 words in length, including title, abstract and references; 3-4 tables and 5-6 figures are permitted.

Review articles

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 A4 paper, 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 '°', thus '°C', **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.

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