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Full Length Research Paper

Effect of different doses of NPK fertilizer on the growth and yield of rice in Ndop, North West of Cameroon

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This study was conducted in 2015 in Ndop, Ngoketujia Division in the North-West region of Cameroon. Four varieties of rice were used: NERICA3, NERICA7 (upland rice), NERICA36 and NERICA42 (lowland rice). Two types of fertilizers N-P-K (23-10-05 and N-P-K (20-10-10) were tested at different doses (0 kg-contol; 180 kg, 200 kg, 220 kg-treatments). The trial was set up in a Randomized Complete Block Design (RCBD) in a manner following conventional methods. Application of fertilizers was done at 21 and 51 days after planting (DAP). The growth parameters were evaluated weekly while yield parameters were collected at maturity. The fertilizer N-P-K (23 10 05) gave a better growth with appropriate doses compared to N-P-K (20 10 10) in all the varieties used in this study while fertilizer N-P-K (20 10 10) gave a better yield than N-P-K (23 10 05) in the same varieties. In terms of output of rice, fertilizer N-P-K (20 10 10) proves better at dose 200 kg than fertilizer N-P-K (23 10 05) at the same dose. For good growth and yield the use of appropriate doses of fertilisers will significantly improve the yield of rice.

Key words: Rice varieties, fertilisers, fertilizers doses.

INTRODUCTION

Rice (*Oryza sativa* L.) is an important cereal in the world and can be grown in different habitats as lowland, irrigated and upland rice (FAO, 2004). It originated from China and India and later spread into other parts of the continent and Africa of tropical climatic settings and is regarded as the 3th cereal after wheat and maize (FAO, 2011). Rice is cultivated for its quality grains which are rich in carbohydrate. Despite the importance of rice, the major constraints to its productivity in Cameroon are poor soil, poor cultivation methods, use of low yielding seeds, high costs of agricultural inputs, pests such as birds, insects, insufficient rice researchers and disease (Piebiep, 2008).

FAO (2011) reported that the annual production of rice in 2010 was 699 million tons, with Asia recording 90% production and America 5% production. Africa only contributed 3% of this production with Cameroun having a low production rate which keeps decreasing from 107.000 tons in 1985 to 65.000 tons in 2010 (FAO, 2013). The outputs of rice per hectare in Cameroun are estimated to be 1 ton for upland rice and 2 tons for lowland rice (AfricaRice, 2011). Rice production

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nationwide in Cameroon is cultivated on 100.000 ha by about 98000 household. Most of the production comes from irrigated areas of the Far North, North, North-west (Ndop plain), and Mbam basin (Tonga and Makenene) regions. From these regions, the Far North region produces about 2/3 of the nation's rice (Malaa et al., 2011).

The African continent shelters only 12% of the world population but absorbs 32% of the world rice imports (Nguefack et al., 2008). The rate of rice yearly consumption in Africa increases by 4.5% (SNDR, 2009).The national demand for this rice in Cameroon was estimated at 300.000 tons in 2009 and in 2013 it was estimated at 500.000 tons (Folefack, 2014).

To nourish the world population which is continuously increasing and which will reach 9 billion in 2050, it is necessary that the world production of rice increases by 50% (FAO, 2008).To improve on the situation in Cameroon, the use of fertilizers are an option to improve on the soil chemical properties and to compensate for the potassium, phosphorus and nitrogen deficiencies (Roose et al., 2008; Konate et al., 2012). Thus, this study was to investigate how the use of different doses of fertilizer will improve on the growth and yield of NERICA rice under field conditions.

MATERIALS AND METHODS

Study site

The study was carried out in Ndop plain in the experimental plots of Institut de la Recherche Agricole pour le Developpement (IRAD) and at the Upper Nun Valley Development Authority (UNVDA), Ngoketujia Division in the North-West region of Cameroon. The town lies between longitude 1015' and 1050' east, and between latitude 54' and 510' North with an altitude of about 300 m. The climate is of equatorial type and is characterized by a rainy season (from March to November), and a dry season (from November to February).The annual average temperature is 27.2°C and annual average pluviometry is 2500 mm. The rainfall pattern is monomodal (DDMN, 2015). The topography of Ndop is dominated by plains and erosion of volcanic materials from the surrounding mountainous chains, which makes the soil ferralitic and fertile.

Setting up of trial

The trial was set up in a Randomized Complete Block Design (RCBD) in a manner following conventional methods. Each block had four treatments: 0, 180, 200 and 220 kg/ha, replicated three times. 100 kg/ha of urea was uniformly applied to all the treatments during tilling and before flowering. These treatments were separated by border rows of 1 m wide. Four varieties of rice were used for this study (NERICA3 NERICA7 NERICA36 and NERICA42). NERICA3 and NERICA7 were upland varieties and NERICA36 and NERICA42 were lowland varieties. For each variety 24 plots of 9 m^2 were used. The seeds were planted at 25 × 25 cm apart and this gave a density of 16 plants per m². Application of fertilizer was done 21 days after planting (DAP). The second application of fertilizer was done at 51 DAP. Weeding was done 3 times. Two types of fertilizers were used (N-P-K (20 10 10) and N-P-K (23 10 05).

Determination of growth and yield parameters

Growth parameter

The average plant height of three plants were chosen randomly from the middle of each plot and measured using a graduated ruler. Tiller number was counted at 7 days intervals 21 DAP before the onset the of flowering

Yield parameter

Data related to yield were collected as from 50% of flowering. This was done when at least 30% of the plants produced panicles with paddy filled with seeds. The yield parameters recorded were as follows:

i. Number of panicles per plant: This parameter enabled a more precise estimation of the yield level and the potential capacity of production. This was done by simple counting.

ii. Number of seed per panicles: Three plant were chosen randomly per treatment and the number of seeds per panicle were counted and an average recorded per plant.

iii. Percentage of filled seed per panicles: Filled seeds per panicle were separated from panicles without seeds and calculations done to obtain the percentage of filled seeds per panicle with respect to the total number of seeds per panicle.

iv. Weight of 1000 filled seeds: Among the filled seeds previously counted, samples of 1000 seeds were weighed. The different weights of the 1000 seeds were recorded. It should be noted that all the weighing were done at paddy moisture of 14%. This rate was obtained after sun drying for 48 h.

v. Yield: Yield of the different varieties of rice used for this study was calculated using the formula (Randrianarison, 2011):

$$Y = PL/m^2 \times Pan/C \times Gr/Pan \times \%\ FGr \times W1000Gr \times 10^{-7}$$

Where: Y = yield; PL/m² = number of plant per meter square; Pan/C = number of panicles per plant; Gr/Pan = total number of grain per panicles; % FGr = percentage of filled grains per panicle; W1000Gr = weight of 1000 filled grains; 10^{-7} conversion unit.

Data analysis

All data collected from the four varieties of rice used were subjected to analysis of variance (ANOVA) as described by Wichura, 2006 using the statistical software STATGRAPHIC version 16. Mean variability amongst the varieties were determined. Their treatment means were separated using Duncan Multiple Range Test (DMRT) for statistical significance at 95% confidence interval (P≤0.05).

RESULTS

Effect of the different doses of fertilizer ((N-P-K (20 10 10) and N-P-K (23 10 05)) on the vegetative growth of the different varieties of rice

The result represent two types of fertilizers ((N-P-K (20 10 10) and N-P-K (23 10 05)) applied on the different varieties of rice, NERICA3 (N3), NERICA7 (N7), NERICA36 (N36) and NERICA42 (N42) respectively) and at different dosage (0 kg-control, 180, 200 and 220 kg-

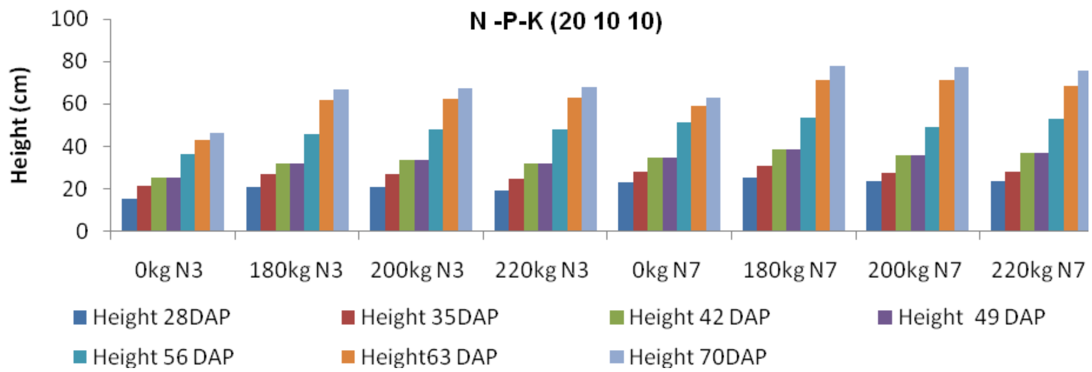

Figure 1. Effect of fertilizer N-P-K (20 10 10) on the height of upland rice. DAP, Day after planting; N3, NERICA3; N7, NERICA7.

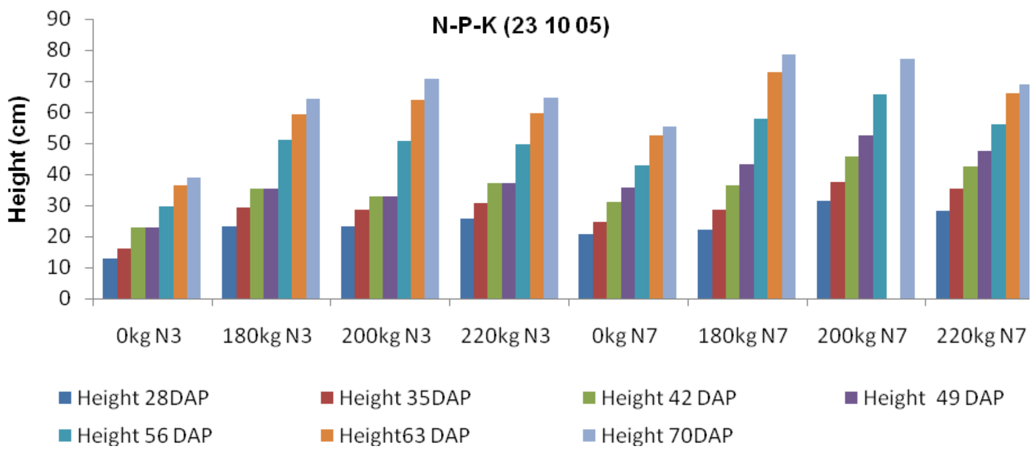

Figure 2. Effect of fertilizer N-P-K (23 10 05) on the height of upland rice. DAP, Day after planting; N3, NERICA3; N7, NERICA7.

treatments respectively). The results are presented in Figures 1 to 8 respectively. Each bar chat represents two varieties of rice showing plant height grown at different days after planting (DAP).

Plant height for upland rice: NERICA3 and NERICA7

Figure 1 show that the application of N-P-K (20 10 10) at different doses (180, 200 and 220 kg) increase the height of the plants at different DAP compared to the control (0kg). Varieties N3 and N7 had their highest heights of 70 and 80 cm respectively at a dose of 180 kg/ha, while the height of the control was not more than 30 cm.

Figures 2 also showed that the application of N-P-K (23 10 05) at different doses (180, 200 and 220 kg respectively) significantly increase the height of the plants compared to the control. N3 showed a height of 70 cm at a dose of 200 kg while the height of the control was 15 cm. N7 had a height of 83 cm at a dose of 180 kg while the control had a height of 30 cm.

Plant height of lowland rice: NERICA36 and NERICA42

The application of the different doses of fertilizers using N-P-K (20 10 10) in lowland rice as in upland rice (N3 and N7 respectively) increases the heights of N36 and N42 compared to the control. With fertilizers N-P-K (20 10 10) N36 had a height of 60 cm at a dose of 200 kg while the control had a height of 15 cm. N42 had a height of 83cm at a dose of 180 kg while the control had only 30 cm (Figure 3).

Figure 4 also showed that the application of N-P-K (23 10 05) significantly increases the heights of N36 and N42 using different dosage compared to the control. Variety N36 had a height of 75 cm at a dose of 220 kg/ha while the height of the control was 25 cm. N42 had a height of 85 cm at a dose of 180 kg/ha while the control had a

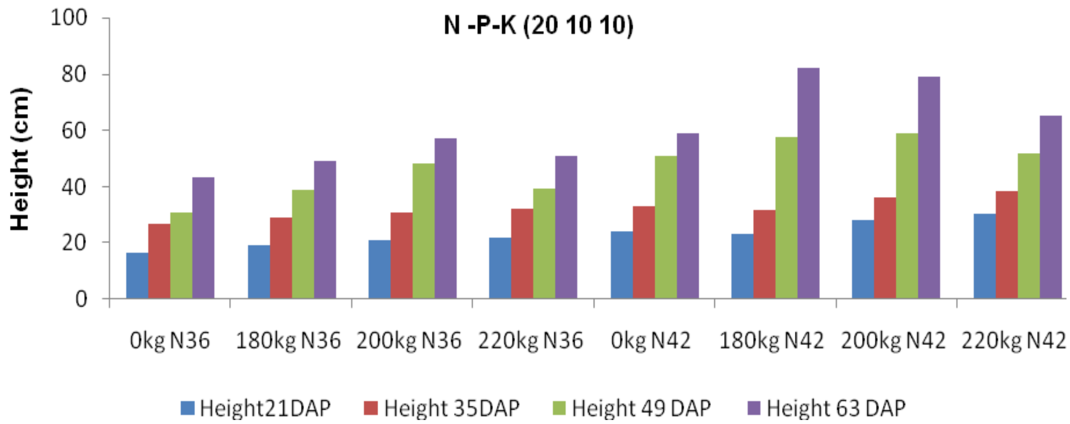

Figure 3. Effect of fertilizer N-P-K (20 10 10) on the height of lowland rice. DAP, Day after planting, N36, NERICA36; N42, NERICA42.

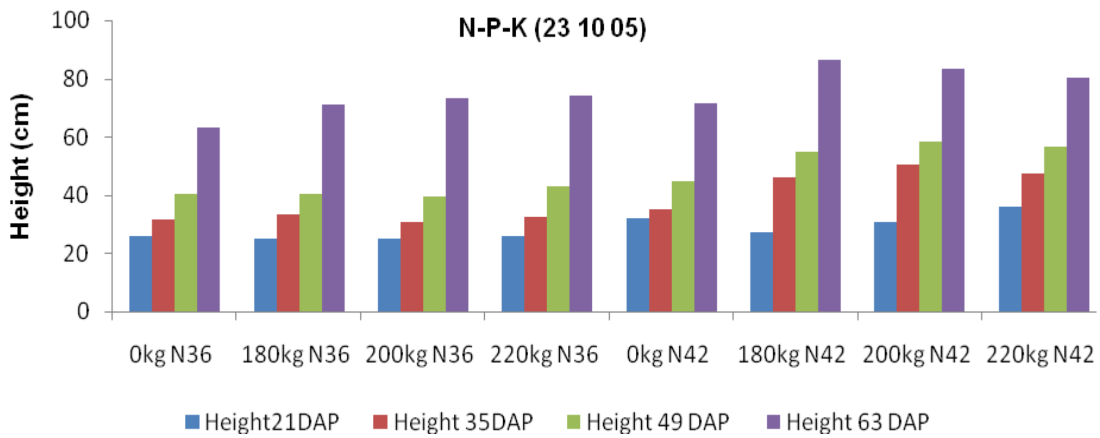

Figure 4. Effect of fertilizer N-P-K (23 10 05) on the height of lowland rice. DAP, Day after planting, N36, NERICA36; N42, NERICA42.

height of 30 cm.

Tiller number of upland rice

The application N-P-K (20 10 10) increase the number of tillers of N3 and N7 compared to the control. N3 showed the greatest number of tillers (5) at a dose of 180 kg whereas the control had only one (1) tiller. N7 produced 5 tillers at a dose of 180 kg while the number of tillers of the control was less than 2 (Figure 5).

The effect of fertilizer N-P-K (23 10 05) on the number of tillers of N3 and N7 also increased compared to the control. N3 produced the greatest number of tillers (7) at a dose of 200 kg whereas the control produced less than 2 tillers as in N7 (Figure 6).

Tiller number of lowland rice

Figure 7 shows that the application of the various doses of N-P-K (20 10 10) led to an increase in tiller number of the lowland rice varieties N36 and N42 respectively compared to the control. N36 had the greatest number of tillers (4) at a dose 200 kg of N-P-K (20: 10: 10) compared to the control that had 2. The greatest number of tillers for N42 was 6 at a dose of 180 kg compared to the control that had 3.

Comparing tiller numbers for N36 and N42 with control (Figure 8) using N-P-K (23 10 05), N36 had the greatest

Influence of the different doses of fertilizers ((N-P-K (20 10 10) and N-P-K (23 10 05)) on the Yield of the different varieties of rice

Yield of NERICA3

The application of the different doses of fertilizers significantly improved the yield of the NERICA3 compared to the control. The yield of NERICA3 with

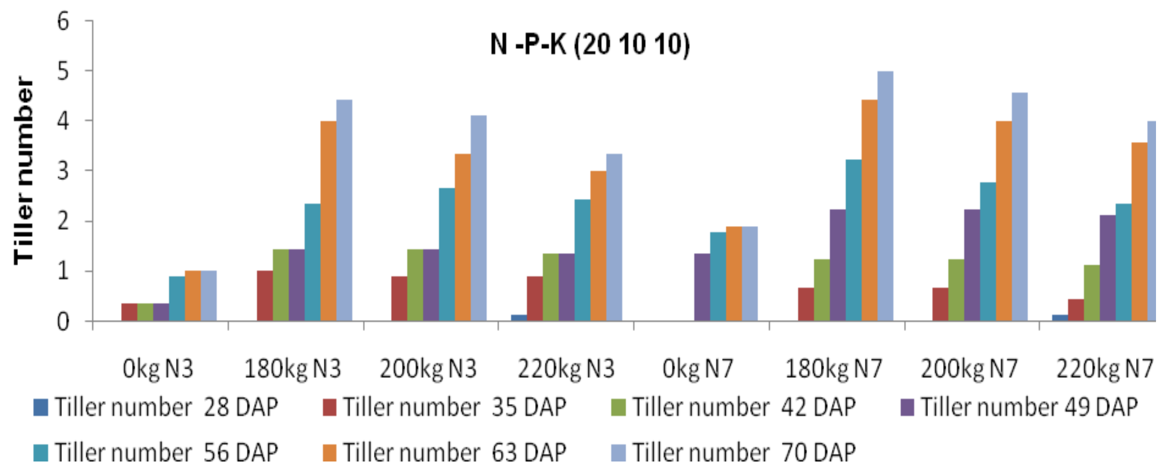

Figure 5. Effect of fertilizer N-P-K (20 10 10) on the tiller number of upland rice. DAP, Day after planting, N3, NERICA3; N7, NERICA7.

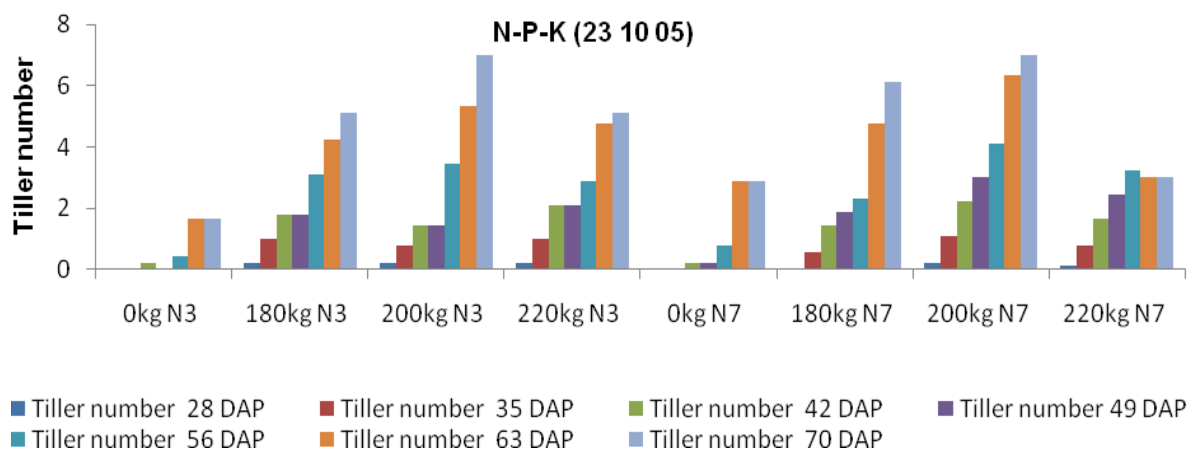

Figure 6. Effect of fertilizer N-P-K (23 10 05) on the tiller number of upland rice. DAP, Day after planting; N3, NERICA3; N7, NERICA7.

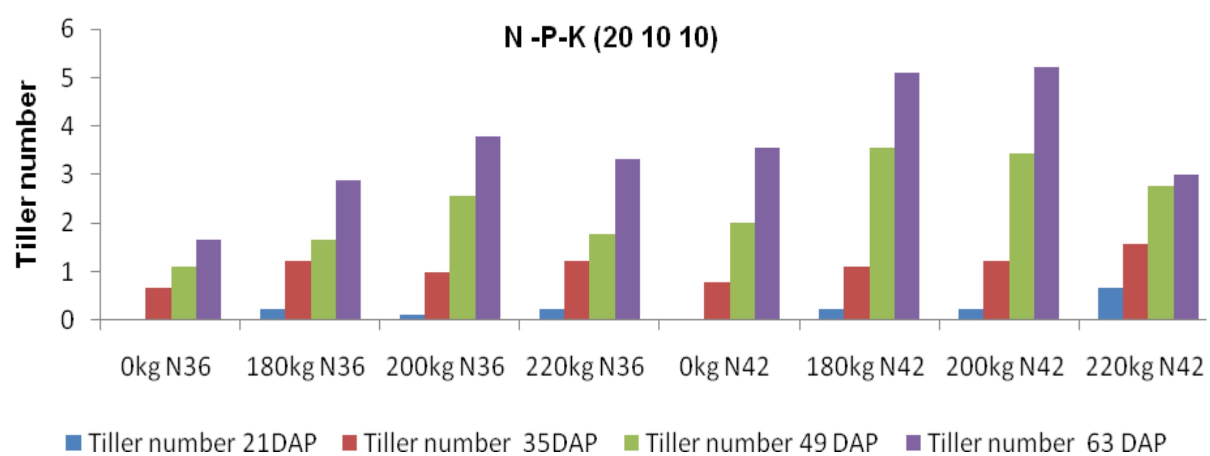

Figure 7. Effect of fertilizer N-P-K (20 10 10) on the tiller number of lowland rice. DAP, Day after planting, N36, NERICA36; N42, NERICA42.

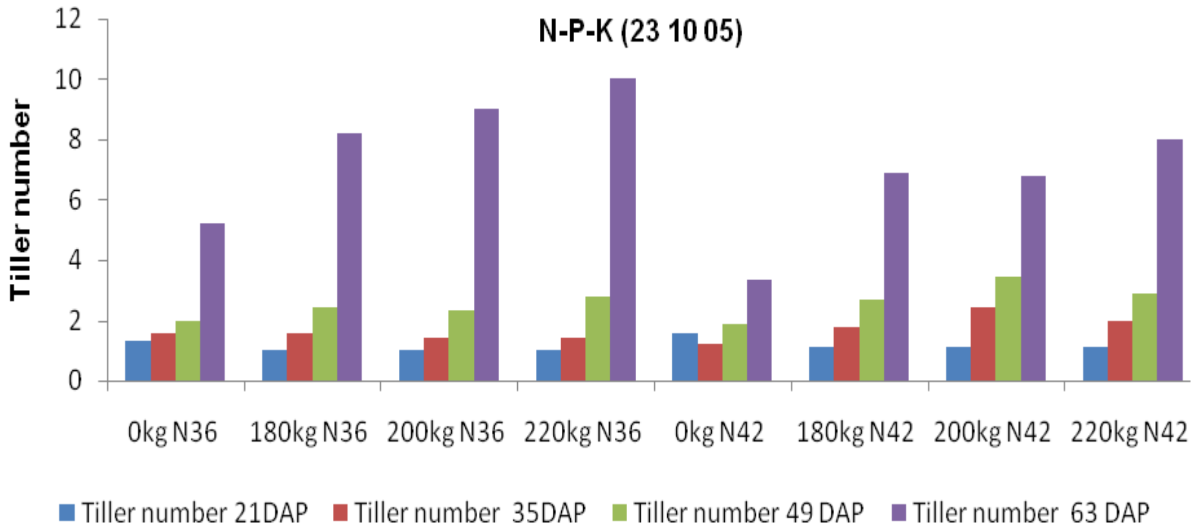

Figure 8. Effect of fertilizer N-P-K (23 10 05) on the tiller number of lowland rice. . DAP, Day after planting, N36, NERICA36; N42, NERICA42.

Table 1. Effect of the different doses of fertilizers ((N-P-K (20 10 10) and N-P-K (23 10 05)) on the yield of NERICA3.

Quantity (kg/ha)	P/t	Hp	P/m2	%FG	W1000	YD (t/ha)
NERICA3 N-P-K (20 10 10)						
0	3.00±0.57[a]	15.67±0.33[a]	121.00±36.67[a]	60.30±3.70[a]	23.66±2.18[a]	0.63±0.15[a]
180	10.33±1.20[c]	20.67±0.33[b]	237.00±23.45[c]	81.42±4.61[a]	32.00±3.00[b]	5.69±0.23[c]
200	12.33±0.88[c]	20.33±0.33[b]	312.67±21.36[d]	54.43±6.70[a]	28.00±1.52[b]	5.65±0.25[c]
220	7.00±3.05[b]	20.00±2.00[b]	181.33±99.44[b]	74.45±15.91[a]	29.33±0.88[b]	3.99±0.80[b]
NERICA3 N-P-K (23 10 05)						
0	3.50±0.47[a]	14.67±0.13[a]	119.00±33.57[a]	59.20±3.10[a]	21.56±2.08[a]	0.61±0.9[a]
180	7.66±0.33[b]	23.00±0.57[b]	183.33±4.63[b]	89.81±2.1[a]	24.00±.00[b]	5.32±0.45[b]
200	10.00±0.57[c]	24.00±0.57[b]	255.00±4.58[c]	86.69±3.25[a]	24.33±0.33[b]	4.86±0.58[b]
220	11.66±0.33[c]	23.66±0.88[b]	335.00±12.66[d]	68.65±2.48[a]	25.33±0.33[b]	5.82±0.20[b]

The values are expressed in averages more or less standard deviation in the same column and for each parameter the averages which are followed with the same letter are not significantly different using DMRT test P (≤0.05). W1000, Weight of 1000 full grains; P/t, Numbers of panicle per plant; Hp, Height of panicles; P/m2, Numbers of Panicle per m^2; %GP, Percentage of full grain per panicle. YD: (t/ha), yield in tons/ ha.

different doses of N-P-K (20 10 10) was recorded and it was observed that at a dose of 180 kg, the variety had an output of 5.69 tons/ha compared to the control whose output was 0.63 ton/ha. At the same rate of dose of N-P-K (23 10 05), an output of 5.32 tons/ha was recorded for the same variety whereas the control had an output of 0.61 ton/ha (Table 1).

Yield of NERICA7

Application of N-P-K (20:10:10) on NERICA7 with a dose of 220 kg showed that the variety had an output of 6.08 tons/ha while the control had output of 0.72 tons/ha. There was no significant difference between the dosage of 200 and 220 kg with an output of 5.95 tons/ha whereas the control had an output of 0.70 ton/ha (Table 2).

The application of N-P-K (23 10 05) was also monitored for NERICA36 using different doses and it was observed that a significantly difference (P≤0.05) was obtained compared to the control. At a dose of 220 kg the variety had output of 4.47 tons/ha compared to the control which had an output of 0.90 tons/ha. At a dose of 180 kg/ha there was an output of 4.39 tons/ha whereas an output of 0.9ton/ha was observed with the control (Table 3).

Looking at the application of N-P-K (23 10 05) on the yield of NERICA42, it was also observed that there was a significant difference (P≤0.05) in yield output compare to the control. At a dosage of 220 kg, the variety had an output of 6. 36 tons/ha compared to the control which had an output of 0.62 ton /ha. Also at 220kg rate of fertilizer

Table 2. Effect of the different amount of fertilizers ((N-P-K (20 10 10) and N-P-K (23 10 05)) on the yield parameters of NERICA7.

Quantity (kg/ha)	P/t	Hp	P/m2	%FG	W1000	YD (t/ha)
NERICA7 N-P-K (20 10 10)						
0	2.00±0.57[a]	23.33±3.17[a]	99.66±17.35[a]	72.26±2.17[b]	23.67±0.33[a]	0.72±0.27[a]
180	6.33±0.33[b]	22.33±0.33[a]	184.00±3.60[b]	69.65±7.12[b]	29.00±0.57[b]	4.70±0.23[b]
200	7.00±0.57[b]	22.66±1.45[a]	183.00±4.04[b]	75.79±5.07[b]	28.00±0.57[b]	4.03±0.30[b]
220	11.66±0.33[c]	23.00±0.57b[a]	351.33±9.20[c]	46.81±1.01[a]	28.00±0.57[b]	6.08±0.25[c]
NERICA7 N-P-K (23 10 05)						
0	3.00±0.27[a]	21.31±2.97[a]	95.56±16.55[a]	69.22±3.17[b]	20.67±0.23[a]	0.70±0.47[a]
180	7.00±0.50[b]	23.67±0.67[b]	189.33±4.05[b]	84.58±1.43[c]	24.00±1.73[b]	5.02±0.11[b]
200	8.66±0.67[b]	25.00±0.57[b]	211.33±6.64[c]	74.34±3.06[b]	25.67±1.02[b]	5.94±0.59[b]
220	11.00±0.58[c]	24.33±0.67[b]	370.00±3.2[d]	48.56±3.13[a]	28.00±0.58[b]	5.95±0.23[b]

The values are expressed in averages more or less standard deviation in the same column and for each parameter the averages which are followed with the same letter are not significantly different using DMRT test P (≤0.05). **W1000**, Weight of 1000 full grains; **P/t**, numbers of Panicle per plant; **Hp**, height of panicles; **P/m2**, numbers of Panicle per m^2; **%GP**, percentage of full grain per panicle. **YD,** (t/ha):yield in tons/ ha.

Table 3. Effect of the different rates of fertilizers ((N-P-K (20 10 10) and N-P-K (23 10 05)) on the yield parameters of NERICA 36.

Quantity (kg/ha)	p/t	Hp	P/m2	%FG	W1000	YD (t/ha)
NERICA36 N-P-K (20 10 10)						
0	2.90±0.67[a]	15.13±0.36[a]	91.50±3.98[a]	7.92±3.99[c]	22.00±0.67[a]	0.90±0.24[a]
180	7.00±0.54[b]	19.33±0.67[b]	216.60±5.00[b]	76.67±1.14[c]	25.66±0.33[b]	3.78±0.14[b]
200	10.00±0.49[c]	19.67±0.34[b]	264.65±4.91[c]	56.89±2.12[a]	26.66±0.88[b]	3.81±0.15[b]
220	10.00±0.56[c]	20.67±0.32[b]	287.33±2.33[d]	69.21±3.37b[b]	26.67±0.33[b]	4.47±0.25[c]
NERICA36 N-P-K (23 10 05)						
0	3.00±0.57[a]	14.33±0.66[a]	93.00±2.88[a]	76.92±4.96[b]	23.00±0.57[a]	0.92±0.14[a]
180	8.00±0.57[b]	19.00±0.57[b]	207±22.51[b]	74.34±3.06[b]	26.00±0 57[b]	4.39±0.29[c]
200	8.33±0.33[b]	20.00±0.00[bc]	222±8.08[bc]	54.89±2.95[a]	29.00±0.00[cd]	3.90±0.06[bc]
220	9.66±0.88[b]	20.66±0.33[c]	257.33±10.17[c]	69.21±3.37[b]	28.66±0.66[c]	3.67±0.17[b]

The values are expressed in averages more or less standard deviation in the same column and for each parameter the averages which are followed with the same letter are not significantly different using DMRT test P (≤0.05). W1000, Weight of 1000 full grains; P/t, numbers of Panicle per plant; Hp, height of panicles P/m2, numbers of Panicle per m^2; %GP, Percentage of full grain per panicle. YD, (t/ha): Yield in tons/ ha.

Table 4. Effect of the different rates of fertilizers ((N-P-K (20 10 10) and N-P-K (23 10 05)) on the yield parameters of NERICA42.

Quantity (kg/ha)	p/t	Hp	P/m2	%FG	W1000	YD (t/ha)
NERICA42 N-P-K (20 10 10)						
0	2.00±0.57[a]	17.66±0.88[a]	138.33±0.88[a]	72.26±2.17[a]	26.00±1.00[a]	0.62±0.12[a]
180	9.66±0.33[b]	21.33±0.88[b]	207.00±17.15[b]	63.98±2.78[a]	28.00±1.00[a]	4.67±0.09[b]
200	9.00±0.57[b]	21.33±0.33[b]	278.66±5.20[c]	72.46±2.78[a]	27.00±0.57[a]	5.42±0.21[c]
220	12.33±0.88[c]	22.66±0.33[b]	305.33±1.76[d]	69.48±1.84[a]	28.66±0.33[a]	6.36±0.21[d]
NERICA42 N-P-K (23 10 05)						
0	2.30±0.67[a]	16.60±0.78[a]	139.31±0.98[a]	70.21±2.37[a]	25.00±3.00[a]	0.60±0.22[a]
180	8.00±0.57[b]	21.33±0.29[b]	191.00±4.71[b]	69.12±2.34[a]	29.00±1.00[b]	4.68±0.20[b]
200	9.66±0.33[b]	22.33±0.33[b]	213.00±4.16[c]	61.81±2.34[a]	26.66±0.88[a]	4.65±0.21[b]
220	12.66±0.87[c]	22.67±0.30[b]	294.33±2.40[d]	54.60±1.71[a]	26.00±0.57[a]	5.19±0.44[b]

The values are expressed in averages more or less standard deviation in the same column and for each parameter the averages which are followed with the same letter are not significantly different using DMRT test P (≤0.05). W1000, Weight of 1000 full grains; P/t, Numbers of panicle per plant; Hp, Height of panicles P/m2: numbers of Panicle per m^2; %GP, Percentage of full grain per panicle. YD (t/ha), Yield in tons/ ha.

dose, an output of 5.19 tons/ha was observed compared to the control that had an output of 0.60 ton/ha (Table 4).

DISCUSSION

Studies on the use of different fertilizers on different varieties of rice at different dosage on the growth and yield of rice indicated that the heights of all the varieties increased with the different doses of fertilizers. Variety NERICA42 had the highest height whereas NERICA3 had the smallest height. This difference in height could be attributed to the genetic materials of these varieties. Increased in the dosage of fertilizer N-P-K (23-10-05) had a greater influenced on the height of the rice varieties used in this study compared to the fertilizer N-P-K (20-10-10). These results corroborate with those of Gala et al. (2011) who reported that the increasing amount of nitrogen improves considerably the vegetative growth of rice. The effect of height in the control experiment with no fertilizer had a greater influence in the height of all the rice varieties, which in turns affected the number of leaves hence leading to a lower foliar index. Thus, when the foliar index of a plant is high the more the photosynthetic rate and the higher the output. The larger the leaf area of a plant the more the photosynthetic area and consequently the output is also high. Oladele and Awodum (2014) specified that the biofertilisations of rice starting from symbiotic microorganisms increase growth parameters and that the number of leaves of a rice plant is a very significant component in the production of paddy.

The number of tillers increased significantly with the fertilization between the 49 and 63 days after planting for all the varieties of NERICA compared to the control. However, the plants treated with N-P-K (23-10-05) had the greatest number of tillers compared to those with N-P-K (20-10-10). This could be due to the fact that the more the amount of nitrogen in a combined fertilizer the higher the tilling. Sanogo et al. (2014) reported that combined fertilizer containing more nitrogen influences more tilling of NERICA. Also, a good number of tillers give a good number of panicles which is a significant component of the output which occurs during the vegetative phase, influenced by factors such as the fertilization, water stress and other farming techniques (Lacharme, 2001).

Lowland rice produces more tillers than upland rice in this study, which could be due to the presence of enough water present in lowland. Water stress during tilling considerably reduces the number of tillers in rice (Mohamed, 2005; Saidou et al., 2014). Also, Excess fertilizer increases the percentage of empty grains. This would be explained by the fact that when the number of panicle is high, energy for their metabolisms are insufficient, which could influence the filling of the grains coupled with water stress which has a negative impact on the filling of the grains. This is similar to the work of Gala et al. (2011) and of Saidou et al. (2014) who reported that after fecundation, the plant is very sensitive to water stress.

The average output of NERICA3 with high dosage of fertilizer yielded 5.4 tons of paddy per hectare and that of NERICA7 that yielded 5.0 tons per hectare. This result could be explained by the fact that NERICA3 had more full grains than NERICA7 which could be concluded that NERICA3 yields better than NERICA7. These results are similar to those of Sanogo et al. (2014) and of Suh et al. (2015) who reported that, with an adequate fertilization of NERICA varieties, the yield is increased. With a dose of varieties of lowland rice we noticed that the fertilizer N-P-K (20-10-10) has the highest output at the 220 kg, NERICA36 yielded 4.47 tons per hectare and NERICA42 yielded 6.36 tons per hectare contrary to the fertilizer N-P-K (23-10-05) whose outputs was lower. NERICA36 had an output of 4.39 tons per hectare at a dose of 180 kg and NERICA42 yielded 5.42 tons per hectare at a dose of 200 kg. This could be explained by the fact that rice fertilized with N-P-K (23-10-05) gives more tillers than when treated with N-P-K (20-10-10) because of high amount of nitrogen present. This could lead to the production of a high percentage of empty grains. These results are similar to those of Didace et al. (2006) who reported that high amounts of nitrogen increases the vegetative growth and lowers the quantity of full grains which is an important component in the output. Approximately 30% of the grains of rice treated with N-P-K (23-10-05) were infected contrary to the rice fertilized with N-P-K (20-10-10) where only 6% of grains were infected, and such a percentage of infected grains considerably decrease the production. This could be due to the inadequacy between the various major elements of N-P-K (23-10-05) in the fertilization of rice. The fertilizer N-P-K (23-10-05) had a significant effect (P≤0.05) on all the yield parameters. This could be as a result of increasing rate of nitrate present. This is in accordance with works of Dekhane et al. (2014) who reported that the increasing rate of nitrate fertilizer considerably improves yield parameters such as: The number of panicle per plant, the number of panicle per m^2 and the weight of 1000 grains. The average yield of NERICA3 between the different doses was 5.33 tons per hectare, which was a little bit less than that with N-P-K (20-10-10) that yielded 5.66 tons per hectare. This difference in rice yield fertilized with N-P-K (23-10-05) compared to the rice yield fertilized with N-P-K (20-10-10) could be due to the nitrogen rate present in the two types of fertilizers used. Because when there is more nitrogen than the other elements the vegetative part is higher and there is less energy for the grains thus, when more grains are empty, the yield decreases following reports of Sanogo et al. (2010) and Bagayoko (2012).

Conclusion

This study carried out on the effect of different rates of NPK fertilizer on the growth and yield of rice revealed that the different doses of NPK fertilizer significantly improved the output of rice compared to the control. Thus, with an adequate fertilization of NERICA, a better output will be achieved. Comparing varietal performance, the best yield was obtained with NERICA3 at a dosage of 200 kg of the fertilizer N-P-K (20-10-10) and N-P-K (23 10 05) while that of NERICA7 was obtained at a dosage of 220 kg of the two fertilizers. Yields of 6.08 t/ha with N-P-K (20-10-10) and 5.95 t/ha with N-P-K (23-10-05) were obtained. However, at a dosage of 220 kg with N-P-K (20-10-10), NERICA36 had an output of 4.47 and 3.90 t/ha with N-P-K (23-10-05). NERICA 42 on the other hand had its best output of 6.36 t/ha with N-P-K (20 10 10) and 5.19 t/ha with N-P-K (23 10 05) at a dosage of 220 kg/ha. This study has given significant indications on the type and on the adequate dosage of fertilizer NPK for a better output per hectare in the upland and lowland rice grown in Cameroun.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

AfricaRice (2011). Acquis de la crise politique pour la sécurité alimentaire en Afrique. Cotonou, Benin. 22p.

Bagayoko M (2012). Effects of plant density, organic matter and nitrogen rates on rice yield in the system of rice intensification (sri) in the “office du Niger” in Mali. J. Agric. Biol. Sci. 7:1990-6145.

DDMN (2015). Délégation Départementale du MINADER Ngoketunjia.

Dekhane SS, Patel DJ, Jadhav PB, Kireeti A, Patil NB, Harad NB (2014). Effect of organic and inorganic fertilizer on growth and yield of paddy cv gr 11. Int. J. Inf. Res. Rev. 2:26-28.

Didace K (2006). The effect of land factors and management practices on rice yields (case study in Cyili in land valley, Gikonko District, Rwanda). Master thesis. International institute for information science and earth observation Enschente, the Netherlands 85 p.

FAO (2004). Organisation des Nations Unies pour l'Alimentation et l'Agriculture, Production year book. Vol. 58 Rome 1.

FAOSTAT, (2008). FAO statistical databases. Available online at htt://faostat.fao.org/site/342/ default. aspx. Accessed January 2013.

FAO (2011). Annuairestatistique de la FAO (FAOSTAT). www.fao.orgInternational Seed Testing Association (2001). International Rules for Seed Testing. Seed Sci. Technol. 335 p.

FAOSTAT (2013). FAO statistical databases. Available online at htt://faostat.fao.org/site/342/ default. aspx. Accessed January 2015.

Folefack DP (2014). Booster la production locale du riz pour le renforcement de la sécurité alimentaire au Nord Cameroun. J. Appl. Biosci. 82:7449-7459.

Gala B, Camara Y, Keli Z (2011). Rentabilités des engrais minéraux en riziculture pluvial de plateau cas de la zone de Gagnoa dans le centre ouest de la cote d’ivoire. J. Appl. Biosci. 46:3153-3162.

Konate Z, Gala Bi T, Jérémie MF, Sekou A, Yaokouame A, Maméri K, Zagbahi J (2012). Alternatives à la fertilisation minérale des sols en riziculture pluviale de plateau: apports des cultures du soja et du niébé dans la fertilité d’un ferralsol hyperdystrique au Centre-ouest de la Côte d’Ivoire. J. Appl. Biosci. 54:3859-3869

Lacharme M (2001). «Fascicule2» le plant de riz: données morphologiques et cycle de la plante. Memento technique de riziculture: 22 p.

Malaa D, Ntam F, Kouebou C (2011). Suivi du marché du riz, l'utilisation mondiale de riz 14 p.

Mohamed D (2005). Analyse du fonctionnement d’une parcelle de riz irrigué sur sol alcalin. Application à la gestion intégrée de la fertilisation azotée et du calendrier cultural dans le delta intérieur du fleuve Niger (Mali). Thèse de doctorat. Ecole nationale supérieure agronomique de Montpellier 176 p.

Nguefack J, Leth V, Lekagne Dongmo JB, Torp J, Amvam Zollo PH, Nyasse S (2008). Use of Three Essential Oils as Seed Treatments Against Seed-borne Fungi of Rice (*Oryza sativa* L.). American-Eurasian. J. Agric Environ. Sci. 4:554-560.

Oladele S, Awodum M (2014). Response of lowland rice to biofertilizers inoculation and thier effects on growth and yield in southwestern Nigeria. J. Agric. Environ. Sci. 3:371-390.

Piebiep G (2008). Evaluating the constraints and opportunities for sustainable rice production in Cameroon. Res. J. Agric. Biol. Sci. 6:734-744.

Randrianarison L (2011). Contribution à l’étude économique de la fertilisation du sol sur culture de riz en sri: cas de l’utilisation du compost tananamadio et du taroka dans la commune rurale de behenjy. Mémoire d’ingénieur Agronome université d’Antananarivo 66 p.

Roose E, De Noni G, Sabir M, Laouina A (2008). Efficacité de la GCES en milieu semi-aride, AUF, EAC et IRD éditeurs, Paris 425 p.

Saidou A, Gnakpenou KD, Balogoun I, Hounnahin SR, Kindomihou MV, (2014). Effet de l’urée et du NPK 15-15-15 perlés et super granulés sur la productivité des variétés de riz IR841 et NERICA-L14 en zone de bas-fond au Sud-Bénin. J. Appl. Biosci. 77:6575-6589.

Sanogo S, Camara M, Zouzou M, Keli Z, Messoum F, Sekou A (2010). Effets de la fertilisation minérale sur des variétés améliorées de riz en condition irriguée à Gagnoa, Côte d’Ivoire. J. Appl. Biosci. 35:2235-2243.

SNDR (2009). Stratégie nationale de développement de la riziculture au Cameroun. Mouture III. Yaoundé 21 p.

Suh C, Malaa D, Woin N, Mbong G, Djomo SH (2015). Fertilizer requirement for productivity of upland rain fed rice (*Oryza sativa* L.) in the western highlands of Cameroon. Abstracts in innovative bioscience for a sustainable and competitive agriculture. 22[ht] annual conference Camaroon Biosience Society, IRAD Nkolbisson Yaoundé, Cameroun.

Wichura MJ (2006). The coordinate free approach to linear models. Cambridge Series in Statistical and Probabilistic Mathematics. Cambridge. Cambridge University press, 14: 199 ISBN 978-521-86842-6.MR2283455 available: http://www.ams.org/mathscinet-getitemmr=228345.

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Relevance of endo-β-mannanase enzyme in coffee seed deterioration process

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The endo-β-mannanase acts on the hemicellulose fraction of the endosperm cell walls, mainly mannans and galactomannans. This process weakens cell walls and allows radicle protrusion during seed germination, but may also occur during the deterioration process. Thus, the aim of this research was to determine the activity of endo-β-mannanase enzyme in dry coffee seeds and in soaked seeds, evaluating its relationship between physiological qualities. Coffee seeds obtained by different processing methods (natural, fermented and demucilated) and drying (sun, shade and dryer) were used. Seed quality was evaluated by germination and tetrazolium tests, and the endo-β-mannanase enzyme activity was determined in dry seeds and after 10 days of soaking. From the results, it was concluded that there is significant inverse relationship between the physiological quality of coffee seeds and the expression of endo-β-mannanase, and seeds with lower percentages of germination and viability of embryos have a higher activity of the enzyme. After ten days of soaking, coffee seeds had higher expression of endo-β-mannanase as compared to the dry seeds for all treatments of fruit processing and drying.

Key words: *Coffea arabica* L., processing, drying, physiological quality.

INTRODUCTION

The germination of coffee seeds occurs slowly and unevenly and many factors have been suggested as likely responsible for these characteristics. Among them, a resistant endosperm layer surrounding the embryo may contribute to germination delay. For germination to occur it is necessary that the embryo breaks the barrier imposed by the endosperm tissues surrounding the embryo. This tissue layer is called 'cap region' and it

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consists of high cellulose and hemicellulose polysaccharides content, conferring the embryo resistance and protection (Silva et al., 2005; Eira et al., 2006).

Therefore, in order for the germination process to occur, some enzymes play an essential role promoting cell walls weakening and softening of the cap region, allowing radicle protrusion. α-Galactosidase, β-mannosidase and endo-β-mannanase enzymes are usually considered as the main responsible for hydrolysis of mannans present in the cap region during germination of coffee seeds (Marracini et al., 2001; Nunes et al., 2006; Joet et al., 2013). These enzymes act in the hydrolytic degradation of cell walls, allowing radicle protrusion (Nonogaki et al., 1992; Silva et al., 2004). Cap endosperm weakening by endo-β-mannanase enzyme has been suggested as a prerequisite for the germination of tomato seeds (Mo and Bewley, 2003), *Datura ferox* (Arana et al., 2006), pepper (Caixeta et al., 2014) and coffee seeds (Silva et al., 2004).

There are two steps which characterize weakening of endosperm structures surrounding the coffee embryo; the first one increased cellulase enzyme activity and the second increased endo-β-mannanase activity (Schröder et al. 2009). The role of these enzymes is regulated by phytohormones as abscisic acid, which inhibits both enzyme and gibberellin, inducing endosperm degradation and consequently promoting germination (Bewley et al., 2012; Silva et al., 2004).

Different isoforms of endo-β-mannanase has already been identified to be linked to the germination process in coffee seeds. Four types of seeds were soaked (Silva et al., 2004) and eight different isoforms using germinated seeds (Marraccini et al., 2001). These results suggest that different endo-β-mannanase isoforms have varied functions during coffee seeds germination and subsequent seedling growth. However, little is known about the role of these enzymes in seeds with different quality levels as well as the presence of the enzyme in dry seeds.

Besides participating in the germination process, some studies have associated the activity of endo-β-mannanase enzyme to coffee seeds deterioration process, given the increased enzyme activity during storage, when seeds loose quality (Veiga et al., 2007). Therefore, the loss of quality in coffee seeds is related, among other factors, with increased activity of endo-β-mannanase enzyme.

Post-harvest treatments as processing and drying stand out among the factors, which may affect the quality of seeds and coffee beans. Recent results have shown that changes that occur in coffee seeds during the post-harvest operations influence the chemical composition and integrity of enzyme systems, affecting its physiological quality (Bytof et al., 2007; Saath et al., 2014; Taveira et al., 2015). Therefore, the aim of this study was to determine endo-β-mannanase enzyme activity on dry and soaked coffee seeds, evaluating the relationship between this activity and the effects of processing and drying of seeds in physiological quality.

MATERIALS AND METHODS

The study was conducted at the Seed Central Laboratory, Department of Agriculture in Universidade Federal de Lavras. *Coffea arabica* L. fruits were harvested in the cherry stage and subjected to three different types of processing: natural (seed kept in the fruits themselves), fermented (fruit mechanically peeled and seeds demucilated by fermentation in water during 24 h at 25ºC) and demucilated (peeled fruit and mucilage removed, both mechanically). Three drying methods were used: in the sun, in the shade and in a drier at 35°C, until seeds reached moisture of 11 ± 1%. After processing and drying, physiological quality and activity of endo-β-mannanase enzyme were assessed.

To assess the quality of seeds, germination test was conducted according to requirements from the Rules for Seed Analysis (Brasil, 2009), with results expressed in percentages. The tetrazolium test was conducted with four replicates of 25 coffee seeds, which were soaked in water for 36 h for extraction of embryos, and kept in 0.5% tetrazolium solution at 30°C for 3 h. The embryos were ranked into viable and non-viable according to location and extent of damage (Clemente et al., 2012).

Endo-β-mannanase enzyme activity was determined on 50 dry seeds and on coffee seeds soaked in water for 10 days, under constant temperature of 30°C. The seeds were grinded in a cooled mill at 4°C, with polyvinylpyrrolidone antioxidant (PVP). In microtubes containing 200 mg of ground seeds, 600 µL of extraction buffer containing 0.1 M Hepes and 0.5 M NaCl (pH 8,0) plus ascorbic acid (5 mg of acid for every ml of buffer) was added. Then, the microtubes were vortexed for 1 min and centrifuged at 10,000 g for 30 min at 4°C. The supernatant was applied to the gel which was made with 6 ml LBG (*Locust Bean Gum*-Sigma), 0.24 g agarose (*Qbiogene*) and 24 mL buffer pH 5.0. Gel holders were covered with *Gelbond film* and the gel was applied to it. After solidification, the gel was stored in refrigerator for 24 h and then it was drilled with a hole punch of 2 mm. In each hole, was applied 2 µL of enzyme extract in 3 replicates of each sample. The gel was kept in a germination chamber at 25°C for a period of 21 h in the dark, in a moist chamber (plastic trays lined with two layers of moistened paper towel and sealed with plastic wrap) for the enzyme to act. For reading, the gel was first washed in distilled water, then washed in buffer (gel buffer) for 30 min and washed again in distilled water. The gel was covered with Congo red dye 0.5% for 30 min and placed in ethanol for 10 min to remove the dye. After removing ethanol with distilled water, it was added, 1 M NaCl solution until visual observation of white halos in the holes containing the samples. At that time, a diameter measure of the samples was performed with a caliper. A standard curve generated by commercial endo-β-mannanase from *Aspergillus niger* (Megazyme) was used to calculate the activity of the endo-β-mannanase enzyme, performed according to Downie et al. (1994).

Physiological evaluations results were analyzed in a completely randomized design (3x3 factorial design), with three processing methods for fruits (natural, fermented and demucilated) and three drying methods (drying in the sun, shade and dryer) with four replicates. The endo-β-mannanase enzyme activity results were analyzed in a completely randomized design (3x3x2 factorial design) with three processing methods for fruits (natural, fermented and demucilated) three drying methods (drying in the sun, shade and in dryer) and two methods of preparing the seeds (dry and soaked seeds) with three replications. Data were subjected to variance analysis. Means were compared using the Tukey test ($p > 0.05$).

RESULTS AND DISCUSSION

The variance analysis showed a significant effect between processing and drying factors on the germination tests results and significant effect of fruit processing on the embryos viability in the tetrazolium test. Coffee seeds from processing via fermentation, showed better physiological performance as compared to other treatments, regardless of the drying type (Table 1). Seeds submitted to mechanical depulping (demucilation) and dried in shade also showed similar results.

There was no significant interaction of factors on the viability of embryos in tetrazolium test, only seen in the processing methods. Regardless of the drying method employed, seeds obtained through fermentation and mechanical depulping showed higher embryo viability results in the tetrazolium test as compared to the coffee beans processed by natural method (Table 2).

Higher values was found in the viability of embryos than in the germination test. The tetrazolium test is performed in a shorter time, thus reduces possible adverse factors, for example, attack of microorganisms, in which case can occur in the germination test affecting the test evaluation, and it does not happen in the tetrazolium test. Thus, small differences can be found between the results of both tests (Clemente et al., 2012; Krzyzanowski et al., 1999). On the other hand, differences between results of the germination test and the tetrazolium test have been observed when evaluating the physiological quality of coffee seeds (Dussert et al., 2006; Coelho, 2015). In these studies, the differences between these results are more common in poorer quality seeds and have been attributed to increased endosperm sensitivity to stress conditions than embryos.

Regarding the types of processing, there were better results in physiological quality of coffee seeds coming from pulped and demucilated fruits, which can be related to the effect of processing on the chemical and enzymatic composition of the seeds, as already observed in other studies of coffee beans. Superior drink characteristics were observed in pulped coffee as compared to natural coffees (Selmar et al., 2006; Bytof et al., 2007). These authors observed that in coffee processed using a wet method, which showed better quality, there is greater expression of the ICL gene, which codes for the isocitrate lyase enzyme, and this expression increases more rapidly during the processing of pulped coffees as compared to expression in natural coffees. The isocitrate lyase enzyme and endo-β-mannanase are related to the germination process.

As for the endo-β-mannanase enzyme activity results in the dry seeds and soaked seeds, there was a significant interaction between processing and drying factors. With the results presented in Table 3 and Figure 1, it is observed that in coffee seeds from natural processing, there was increased activity of endo-β-mannanase enzyme in relation to other types of processing. Furthermore, the soaked seeds also have increased activity of endo-β-mannanase than dry seeds.

Table 1. Coffee seed germination percentage under different methods of processing and drying.

Processing	Germination (%)		
	Drying		
	Sun	Shade	Dryer
Natural	28.0^{cA}	42.0^{bA}	40.0^{bA}
Fermented	86.0^{aA}	81.0^{aA}	74.0^{aA}
Desmucilated	67.0^{bB}	86.0^{aA}	75.0^{aB}
CV (%)		13.34	

The average followed by different letters (lowercase in the column and capital in line) are statistically different from each other, at 5% significance by Tukey test.

Table 2. Percentage of viability of embryos in coffee seeds in tetrazolium test under different processing methods.

Tetrazolium	
Processing	Viability (%)
Natural	80.33^{b}
Fermented	97.33^{a}
Desmucilated	94.33^{a}
CV (%)	4.45

The average followed by different lowercase letters is statistically different from each other, at 5% significance by Tukey test.

In studies on the regulation of coffee seeds germination, Silva et al. (2005) observed increased activity of endo-β-mannanase and β-mannosidase enzymes to 8 days of soaking. After seed germination, indicated by the root protrusion, the enzyme activity reduced.

In this study, the major enzymatic activity of the endo-β-mannanase was linked to loss quality in coffee seeds, as better physiological performance results were observed in seeds that were withdrawn from the fruit that had mesocarp removed by mechanical demucilation or by fermentation with water and dried in shade, which presented greater endo-β-mannanase enzymatic activity. This shows an inverse relation between physiological quality of coffee seeds and the endo-β-mannanase activity.

In the study of Silva et al. (2005), the endo-β-mannanase enzyme activity was determined during

Table 3. Endo-β-mannanase activity (μmol.min^{-1}) in soaked and dry coffee seeds obtained from different methods of processing and drying.

Processing	Drying					
	Drying		Sun		Shade	
	Soaked	Dried	Soaked	Dried	Soaked	Dried
Natural	8.406^{a}	5.518^{a}	5.138^{a}	1.722^{b}	9.191^{a}	4.670^{a}
Depulped	2.502^{b}	1.970^{b}	4.451^{b}	2.816^{a}	1.579^{b}	1.372^{b}
Desmucilated	2.196^{b}	1.264^{c}	2.453^{c}	1.442^{b}	1.787^{b}	0.933^{b}
CV (%)	6.83					

The average followed by different lowercase letters in column are statistically different from each other, at 5% significance by Tukey test.

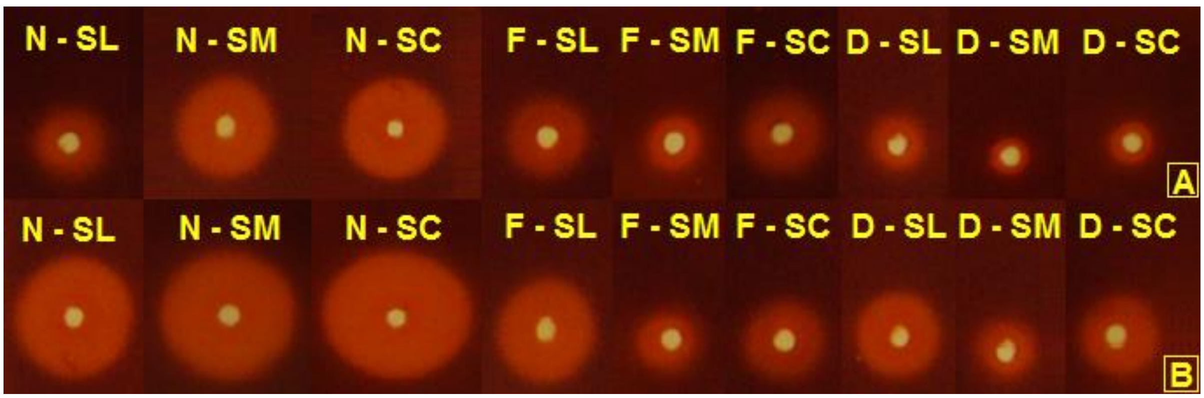

Figure 1. Endo-β-mannanase enzyme activity, in agarose gel, in coffee beans (*Coffea arabica*) subjected to different types of processing: natural (N), fermented (F), demucilated (D); and to different methods of drying sun (SL), shade (SM) and dryer (SC). Dry seeds (A) and Soaked seeds (B).

Table 4. Activity of endo-β-mannanase (μmol.min-1) soaked seeds and dry coffee seeds obtained by different methods of processing and drying, dried and soaked.

Drying	Processing					
	Desmucilated		Depulped		Natural	
	Soaked	Dried	Soaked	Dried	Soaked	Dried
Sun	2.453^{Aa}	1.442^{Ba}	4.451^{Aa}	2.816^{Ba}	5.138^{Ac}	1.722^{Bb}
Shade	1.787^{Ab}	0.933^{Bb}	1.579^{Ac}	1.372^{Ac}	9.191^{Aa}	4.670^{Ba}
Dryer	2.196^{Aab}	1.264^{Bab}	2.502^{Ab}	1.970^{Bb}	8.406^{Ab}	5.519^{Ba}
CV (%)	6.83					

The averages followed by the same uppercase letter in row and lowercase letter line in column do not differ statistically from each other, at 5% significance by Tukey test.

germination process, when it acts to weaken the cell walls and soften the endosperm region where root protrusion occurs. It is noteworthy that during the deterioration process degradation of cell walls by action of endo-β-mannanase also occurs and is thus related to the deterioration of seeds.

Regarding the drying method (Table 4), there was increased activity of endo-β-mannanase enzyme in seeds dried in the sun, and lower activity in seeds dried in a mechanical dryer for seeds demucilated mechanically or demucilated via fermentation (de-pulped). As for seeds kept in the fruits themselves (natural process), there was a accentuated activity of the enzyme in the seeds dried in shade, followed by those dried in a mechanical dryer. According to Borém et al. (2008), natural coffee grains require longer exposure to air drying than the depulped so that a reduction of moisture can occur. The same occurs in coffee beans drying process and may lead to denaturation of some enzymes (Saath et al., 2014). On the other hand, longer drying time can provide increased activity of some antioxidative enzymes involved in response to neutralize reactive oxygen species produced under stressful conditions caused by the slower drying, as observed by Dussert et al. (2006). The same was observed in this study, where greater activity of endo-β-mannanase enzyme was observed in treatments whose seeds have been subjected to stress conditions such as seeds dried in the fruits themselves.

Regarding the soaking of coffee beans, there is increased activity of the endo-β-mannanase enzyme in comparison with the dry seeds (Table 4). According to Silva et al. (2004) and Farias et al. (2015), immediately after the start of imbibition, isoforms of endo-β-mannanase enzyme was observed, occurring even before radicle protrusion, in the cap region surrounding the radicle, other isoforms of the same enzyme were detected later in other regions of the endosperm, with progressive increase in enzyme gene expression along the germination time.

In a study using seeds harvested in cherry and green cane maturation stage, increased activity of endo-β-mannanase enzyme was observed in coffee beans harvested in the cherry stage, when seeds had better physiological quality as compared to green cane stage (Veiga et al., 2007). Furthermore, the authors observed a gradual increase in enzyme activity during storage of these seeds, when loss of quality was detected.

During storage, there is a reduction in seed quality due to a deterioration progress, which, among other events of degradation of cell walls and damage to membrane systems, occurs. Endo-β-mannanase enzyme acts to break down mannans present in cell walls (Silva et al., 2004). Thus, the increased activity of this enzyme in poorer quality seeds can be related to the advance of deterioration process, as noted in the seeds that had a worse physiological quality.

The endo-β-mannanase enzyme is a preexistent enzyme but is also synthesized "again" when the seeds are soaked (Ren et al., 2008). In this study, it is possible to see that the expression of endo-β-mannanase is noticeably higher in seeds soaked for 10 days in all treatments when compared with the dry seed treatments (Table 3 and Figure 1).

Iglesias-Fernández et al. (2011) assessed the expression of four genes involved in the expression of endo-β-mannanase enzyme (*At*MAN7, *At*MAN6, *At*MAN2 and *At*MAN5) in *Arabidopsis thaliana* seeds subjected to periods of 0, 10, 20, 24, 30, 36, 42 and 48 h germination, by Real Time PCR. The *At*MAN5 gene showed higher expression in dry seeds, and after 24 h of soaking the expression of this gene reduced drastically. The *At*MAN2, *At*MAN6 and *At*MAN7 genes showed elevated expression until the period of 42 h of germination; however, within 48 h, expression was substantially reduced, showing that in fact, the activity of endo-β-mannanase participates in walls breaking processes to allow germination. Right after the radicle protrusion, the enzyme activity reduces. On the other hand, the enzyme activity may vary between dry and soaked seeds, with dry seeds having lower endo-β-mannanase activity as compared to the enzyme activity in soaked seeds (Dirk et al., 1995). This fact is due to activation of the enzyme during the germination process. Thus, with soaking, synthesis of enzymes occurs to act on the molecules to break energy production necessary for embryo growth. Previous studies have demonstrated that peak activity of this enzyme in germination occurs near the root protrusion (8-9 days) in the cap endosperm of coffee seeds (Silva et al., 2005).

Analyzing all these results, it can be suggested that the action of endo-β-mannanase enzyme in coffee seeds is complex and is associated with different physiological events from the process of maturation, germination, until the loss of quality with deterioration. Therefore, there is need for additional studies, including molecular studies to identify all different isoforms of the enzyme as well as the functions of each one.

Conclusion

There is an inverse relationship between the physiological quality of coffee seeds and the expression of endo-β-mannanase. After ten days of soaking, coffee seeds had higher expression of endo-β-mannanase as compared to the dry seeds. Endo-β-mannanase enzyme activity in *C. arabica* L. seeds is related to the deterioration process.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Arana MV, De Miguel LC, Sánchez RA (2006). A phytochrome-dependent embryonic factor modulates gibberellin responses in the embryo and micropylar endosperm of *Datura ferox* seeds. Planta 223(4):847-857.

Bewley JD, Bradford KJ, Hilhorst HWM, Nonogaki H (2012). Seeds. Physiology of development, germination and dormancy. Springer. http://dx.doi.org/10.1007/978-1-4614-4693-4

Borém FM, Coradi PC, Saath R, Oliveira JA (2008). Qualidade do café

natural e despolpado após secagem em terreiro e com altas temperaturas. Cienc. Agrotec. 32(5):1606-1615.
Brasil (2009). Regras para análise de sementes. Brasília: Ministério da Agricultura, Pecuária e Abastecimento. MAPA/ACS. pp. 21-89.
Bytof G, Knopp SE, Kramer D, Breitenstein B, Bergervoet JH, Groot SP, Selmar D (2007). Physiological and biochemical alterations during germination and storage of habanero pepper seeds. Afr. J. Agric. Res. 9(6):627-635.
Clemente ACS, Carvalho MLM, Guimarães RM (2012). Suitability of the tetrazolium test methodology for recently harvested and stored coffee seeds. Cienc. Agrotec. 36(4):415-423.
Coelho SVB, Figueiredo MA, Clemente ACS, Coelho LFS, Rosa SDVF (2015). Alterações fisiológicas e bioquímicas em sementes de café secas em sílica gel e soluções salinas saturadas. Pesqui. Agropecu. Bras. 50(6):483-491.
Dirk LM, Griffen AM, Downie B, Bewley JD (1995). Multiple isozymes of endo-β-D-mannanase in dry and imbibed seeds. Phytochemistry 40(4):1045-1056.
Downie B, Hilhorst HWM, Bewley JD (1994). A new assay for quantifying endo-β-mannanase activity using Congo Red dye. Phytochemistry 36(4):829-835.
Dussert S, Davey MW, Laffargue A, Doulbeau S, Swennen R, Etienne H (2006). Oxidative stress, phospholipid loss and lipid hydrolysis during drying and storage of intermediate seeds. Physiol. Plant. 127(2):192-2014.
Eira MTS, Da Silva EAA, Castro RD, Dussert S, Walters CJ, Bewley D, Hilhorst HWM (2006). Coffee seed physiology. Braz. J. Plant Physiol. 18(1):149-163.
Farias ET, Da Silva EA, Toorop PE, Bewley JD, Hilhorst HWM (2015). Expression studies in the embryo and in the micropylar endosperm of germinating coffee (*Coffea arabica* cv. Rubi) seeds. Plant Growth Regul. 75(2): 575-581.
Iglesias-Fernández R, Rodríguez-Gacio MC, Barrero-Sicilia C, Carbonero P, Matilla A (2011). Three endo-β-mannanase genes expressed in the micropylar endosperm and in the radicle influence germination of *Arabidopsis thaliana* seeds. Planta 233(1):25-36.
Joet T, Laffargue A, Salmona J, Doulbeau S, Descroix F, Bertrand B, Lashermes P, Dussert S (2013). Regulation of galactomannan biosynthesis in coffee seeds. J. Exp. Bot. 65(1):380-380.
Krzyzanowski FC, Vieira RD, França Neto JB (1999). Vigor de sementes: conceitos e testes. Londrina: Abrates.
Marraccini P, Rogers, WJ, Allard C, André ML, Caillet V, Lacoste N, Lausanne F, Michaux S (2001). Molecular and biochemical characterization of endo-β-mannanases from germinating coffee (*Coffea arabica*) grains. Planta 213(2):296-308.
Mo B, Bewley JD (2003). The relationship between b-mannosidase and endo-β-mannanase activities in tomato seeds during and following germination: a comparison of seed populations and individual seeds. J. Exp. Bot. 54(392):2503-2510.
Nonogaki H, Matsushima H, Morohashi Y (1992). Galactomannan hydrolyzing activity develops during priming in micropylar endosperm tip of tomato seeds. Physiol. Plantarum 85(2):167-172.
Nunes FM, Reis A, Domingues MRM, Coimbra MA (2006). Characterization of galactomannan derivatives in roasted coffee beverages. J. Agric. Food Chem. 54(9):3428-3439.
Ren Y, Bewley D, Wang X (2008). Protein and gene expression patterns of endo-β-mannanase following germination of rice. Seed Sci. Res. 18(3):139-149.
Saath R, Broetto F, Biaggioni MAM, Borém FM, Rosa SDVF, Taveira JHS (2014). Activity of some isoenzymatic systems in stored coffee grains. Cienc. Agrotec. 38(1):15-24.
Schröder R, Atkinson RG, Redgwell RJ (2009). Re-interpreting the role of endo-β-mannanases as mannan endotransglycosylase/hydrolases in the plant cell wall. Ann. Bot-London 104(2):197-204.
Selmar D (2007). Transient occurrence of seed germination processes during coffee post-harvest treatment. Ann. Bot-London 100(1):61-66.
Selmar D, Bytof G, Knopp SE, Breitenstein B (2006). Germination of coffee seeds and its significance for coffee quality. Plant Biol. 8(2):260-264.
Silva EAA, Toorop PE, Nijsse JJ Bewley D, Hilhorst HWM (2005). Exogenous gibberellins inhibit coffee (*Coffea arabica* cv. Rubi) seed germination and cause cell death in the embryo. J. Exp. Bot. 56(413):1029-1038.
Silva EAA, Toorop PE, Van Aelst AC, Hilhorst HW (2004). Abscisic acid controls embryo growth potential and endosperm cap weakening during coffee (*Coffee arabica* L., cv. Rubi) seed germination. Planta 220(2):251-261.
Taveira HSJ, Borém FM, Rosa SDVF, Oliveira PD, Giomo GS, Isquierdo EP, Fortunato VA (2015). Post-harvest effects on beverage quality and physiological performance of coffee beans. Afr. J. Agric. Res. 10(12):1457-1466.
Veiga AD, Guimarães RM, Rosa SDVF, Pinho EV, Silva L, Veiga A (2007). Armazenabilidade de sementes de cafeeiro em diferentes estádios de maturação e submetidas a diferentes métodos de secagem. Rev. Bras. Semen. 29(1):83-91.

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Socioeconomic profile and farm management practices of smallholder cocoa farmers in three cocoa producing districts in Southwestern Ghana

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There is paucity of knowledge about the current socioeconomic status and farm management practices of cocoa farmers in Ghana. And not up-to-date an accurate knowledge of socioeconomic profile and farm management practices of cocoa farmers is necessary to ensure sustainable cocoa production. In this study, we assessed socioeconomic profile and farm management practices of smallholder cocoa farmers in three cocoa producing districts in Southwestern Ghana. The study was conducted using a multi-stage sampling technique to select farmer households for interviews. In total, 180 farmer households were interviewed on socioeconomic characteristics and 60 of them were interviewed about their farm management practices. Statistical analyses were carried out through chi-square and regression analyses. Most (73.9%) of the farmers interviewed were males and 76.7% of them were above 40 years. The age and sex groups of farmers were significantly different among districts. 28.9% of farmers have no formal education, while 66.7% have up to basic education. Majority of the farmers (53.3%) have household size within the range of 6 to 10 persons. Ethnic backgrounds of farmers were mostly locals and migrants in the three districts. About 78.3% cultivate hybrid type of cocoa. The methods of land acquisition as well as farmers experience in cocoa farming were different in the three districts. On farm management practices, about 75% applied fertilizer on their farms, 73.3% adopted manual means of weeds control, and over 80% of farmers applied insecticides against pest. The present study has revealed significant differences in factors of socioeconomic characteristics and farm management practices of smallholder farmers in cocoa-growing areas of Ghana and has implications for achieving sustainable cocoa production.

Key words: Cocoa, socioeconomic factors, farm maintenance, West Africa.

INTRODUCTION

Cocoa (*Theobroma cacao* L) is one of the most important cash crops cultivated throughout the humid tropics of West Africa, Southeast Asia, South America and the Caribbean (Ruf and Schroth, 2004), but majority of the

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world's cocoa comes from the West African sub-region (Asare, 2005; Boateng, 2008). Cocoa is one of the major foreign exchange earners for some countries in Africa such as Ghana, Cote d'Ivoire, Nigeria, and Cameroon (Nkamleu et al., 2010).

Cocoa is a small tree of about 4 to 8 m tall and is grown primarily in three tropical regions, namely, Southeast Asia, Latin America, and West Africa. However, the vast majority of the world's cocoa comes from West Africa, where it is estimated that the crop is cultivated on over five million of hectares of land (Ruf and Schroth, 2004). Within the West Africa, cocoa production has for the past 100 years been the leading export of the region (Gockowski et al., 2004) and accounts for about 55% of total household income (IITA, 2002).

In Ghana, the cocoa sector is critically important as it accounted for 8.2% of national GDP and 30% of total export earnings in 2010 (Ghana Statistical Service, 2010). Ghana is the second largest producer and second largest world exporter of cocoa beans after Cote d'Ivoire. About 90% of the country's cocoa is grown on smallholder farms. It is estimated that 700,000 households in Ghana are growing cocoa, mostly on 2 to 3 hectares of land (ICCO, 2010) and the crop accounts for over 67% of total household income (Kolavalli and Vigneri, 2011). Cocoa cultivation in Ghana depend mostly on rain fall and cocoa farmers continue to rely on traditional methods such as the hoe and cutlass method for farming (GAIN, 2012). It is noteworthy that although Ghana is one of the top producers of cocoa in the world, yields are a bit low compared to Cote d ' Ivoire (Mohammed et al., 2011).

Many factors account for the low productivity of cocoa including socioeconomic characteristics and farm management practices (Baffoe-Asare et al., 2013). Studies on the socioeconomic characteristics and farm management practices of cocoa farmers have been reported from many cocoa-growing areas (Juhrbandt and Ba`rkmann, 2008; Bisseleua et al., 2013; Vaast and Somarriba, 2014). In Ghana, there is a plethora of studies on socioeconomic characteristics of smallholder cocoa farmers (ISSER, 2001; Baffoe-Asare et al., 2013). Studies on farm management practices such as fertilizer application have also been reported (Appiah et al*.,* 1997; Ghana Cocoa Board, 2002). Evidence suggests that growth in the cocoa sub-sector has been achieved through the adoption of improved farming practices (Baffoe-Asare et al., 2013). However, there is a dearth of knowledge about differences in socioeconomic characteristics and farm management practices of cocoa farmers in cocoa growing areas in Ghana. Up-to-date and accurate knowledge of the socioeconomic profile and farm management practices of cocoa farmers is necessary for sustainable cocoa production (Aneani, 2012).

The purpose of this study was to investigate socioeconomic status and farm management practices of smallholder farmers of Ghana. Specifically, the objectives of the study were to: (1) evaluate differences in socioeconomic characteristics and farm management practices among the three cocoa districts; and (2) determine the relationships between factors of socioeconomic characteristics and farm management practices.

MATERIALS AND METHODS

Study area

The present study was carried out in three districts producing cocoa in Southwestern Ghana. The three districts were Twifo-Heman Lower Denkyira district (5° 50'- 5° 51' N, 1° 50 ' - 1° 10'W) in the Central Region, Bia district (6° 20' N - 6° 38' N, 2° 58'- 3° 58 'W) in the Western Region and Atwima-Mponua district (6° 32' - 6° 75' N, 2° 00' - 2° 32' W) in the Ashanti Region. Mean monthly temperature in the selected districts is between 24 and 30°C. The average annual rainfall in the three districts is above 2000 mm. Vegetation type varies from wet semi equatorial to moist semi deciduous forest (Forestry Commission, 2010). Geology comprises of the Lower Birrimian rock series, a pre-Cambrian formation that dominates the Ghanaian forest zone (Forestry Commission, 2010). The underlying rocks are acidic in nature. However, illegal lumbering and farming along the reserves serves as the main source of livelihood for the inhabitants.

Data collection

The data used in this study was obtained from smallholder cocoa-growing farmer households using a multi-stage sampling procedure. The first stage in the selection of farmers' involved purposive selection of three cocoa growing districts since the chuck of the country's cocoa comes from those districts. The second stage involved random selection of two communities per district based on willingness to cooperate and history of cocoa production. In total, 180 cocoa farmer households were interviewed for socioeconomic characteristics and 60 households for farm management practices. Thirty households per community were selected for evaluation of socioeconomic characteristics of farmers.

Data collection was achieved using a semi-structured questionnaire for interviewing of farmers. The first part of the interviews was for socioeconomic characteristics. The questionnaire used was pre-tested on a sample size of 60 households based on the number of plots demarcated per community and adjustments made before used (Larson et al., 2011). Household heads were asked specific questions relating to their age, sex, marital status, educational background, ethnic group, years of farming cocoa, family size and sources of energy and water. The second part of the interviews was about farm management practices; 10 household heads per community, including those surveyed for socioeconomic characteristics were interviewed about routine farm management practices. Farmers were asked various questions about fertilizer application, weeding, herbicide and pesticide applications, and pruning of trees. Data were also collected on ways of land acquisition, sources of labour and varieties of cocoa planted.

Statistical analysis

Descriptive statistical analysis was performed to summarize factors of socioeconomic characteristics and farm management practices of cocoa farmers. The results of the descriptive statistics are presented in the form of tables and graphs. In order to determine differences in factors of socioeconomic characteristics and farm management practices among the three districts chi-square analysis was carried out. The factors were coded following a binary choice model as either present (1) or absent (0). Regression models were used to evaluate the relationships between factors of socioeconomic characteristics and farm management practices. The models were fitted separately between factors of socioeconomic characteristics, and fertilizer application, pest and disease control, and weeds control and pruning. Data analysis was achieved using SPSS software and a p-value of ≤ 0.05 was considered as significant.

RESULTS

Socioeconomic characteristics

About (32.8%) of the cocoa farmers in the three districts were between 41 and 50 years of age. However, distribution of number of farmers in age groups ($\chi^2 = 22.1$, $p < 0.05$) varied among the three districts. There were more people above 60 years in the Twifo-Heman Lower Denkyira district, whereas most of the farmers in Atwima-Mponua district and Bia district are between 41 and 50 years (Table 1). Males formed 73.9% of the farmers and 83.8% of them were married. Sex group of farmers was significantly ($\chi^2 = 2.9$, $p < 0.05$) different among the three districts. Most (66.7%) of the farmers had only basic level education and household size was mostly 6 to 10 persons. Ethnic backgrounds of farmers in the districts were different ($\chi^2 = 81.9$, $p < 0.001$). Major source of water used by farmers in all the three districts was borehole. About 98% of the farmers depended on the national grid for their source of electricity.

Farmers differed in terms of experience, that is, number of years in cocoa cultivation in the three districts ($\chi^2 = 22.7$, $p < 0.05$). Most of the famers in Twifo-Heman Lower Denkyira district (53.3%) and Bia district have been involved in cocoa over 16 years, whereas (31.7%) of farmers in Atwima-Mponua district have 6 to 10 years of experience in cocoa farming. Overall, about 52.8% of farmers have access to extension services in the three districts.

More than half (57.2%) of the farmers cultivated about 0.4 to 2.0 hectares of cocoa farm whereas 11.1% owned cocoa farms greater or equal to 6.4 hectares. Means of acquisition of land for cocoa cultivation varied among the districts ($\chi^2 = 30.3$, $p < 0.001$). In total, about 58% of farmers obtained land for cocoa cultivation through inheritance whereas only 2.8% did outright purchase. In Twifo-Heman Lower Denkyira district about 85% of the farmers interviewed inherited land for cocoa cultivation as compared to Atwima-Mponua district and Bia district, which are, 62.5% and 46.7, respectively. Majority (78.3%) of farmers cultivated hybrid type of cocoa but the proportion of farmers who cultivated the various cocoa varieties was different in the districts ($\chi 2= 21.3$, $p < 0.001$). Source of labour on cocoa farms was mostly self (44.4%) followed by the use of hired farm laborers 35.6%) and then family members (20%).

Fertilizer application

In total, 75% of the farmers interviewed apply fertilizer on their farms. About 46.7% of farmers apply *Asasewura* fertilizer (locally formulated fertilizer). The types of fertilizer used, however, differ in the three districts ($\chi^2 = 31.3$, $p < 0.001$). For instance most of the farmers in Twifo-Heman Lower Denkyira district (55%) use *Asasewura* fertilizer, whereas those in Bia district used mostly (65%) *Cocofeed* fertilizer. Farmers in Atwima-Mponua district used equal proportions of *Asasewura* and *Sidalco* fertilizers. The most (51.7%) common method of fertilizer application in all the three districts was broadcasting. Foliar method of fertilizer application was recorded in Twifo-Heman Lower Denkyira district and Atwima Mponua district, whereas ring method of fertilizer application was recorded only in the Twifo-Heman Lower Denkyira district. In Bia district, the only method of fertilizer application was broadcasting. Three periods of fertilizer application were recorded and about half (51.2%) of farmers apply fertilizer in April-June period (Table 2). The type of fertilizer applied was positively correlated with farm size ($r^2 = 0.11$, $p < 0.05$), farmers' experience ($r^2 = 0.11$, $p < 0.05$) and access to extension services ($r^2 = 0.11$, $p < 0.05$). Farmers' age was negatively related to the period of fertilizer application ($r^2 = -0.001$, $p < 0.05$), although, younger cocoa farmers apply more fertilizers than older farmers. Access to extension services was positively correlated with method of fertilizer application ($r^2 = 0.09$, $p < 0.01$). The quantity of fertilizer applied differed in the three districts ($\chi^2= 7.9$, $p < 0.01$) and was positively influenced by farmers' age ($r^2 = 0.32$, $p < 0.05$), sex ($r^2 = 0.32$, $p < 0.05$) and type of land acquisition ($r^2 = 0.32$, $p < 0.05$).

Pest and disease control

Pest and disease control was achieved through mainly spraying of cocoa farms with insecticides for capsids and fungicides for black pod disease (Table 3). About 38.3% of cocoa farmers spray cocoa farms against capsids thrice in a year. Overall, about (78.3%) of the farmers apply 1 to 3 containers/ha (a container is equivalent to 1 L) of insecticide on farms and this was mostly (61.7%) achieved in April-June period. The amount of insecticide applied, frequency of spraying per year as well as periods of spraying cocoa farms against capsid were not statistically different in the three districts ($p > 0.05$ for all analysis). Frequency of spraying against black pod disease differed in the three districts ($\chi^2 = 28.0$, $p < 0.01$). Farmers in Bia district, commonly spray farms thrice per year whereas those in Twifo-Heman Lower Denkyira

Table 1. Summary of socioeconomic characteristics of farmers interviewed.

Factors	Group	Twifo-Heman LowerDenkyira district	Atwima-Mponua district	Bia district	Total frequency
Age	≥ 20	0	3	2	5
	21-30	4	2	4	10
	31-40	4	12	11	27
	41-50	13	22	24	59
	51-60	18	9	12	39
	>60	21	12	7	40
Sex	Male	49	41	43	133
	Female	11	19	17	47
Marital status	Married	52	47	52	157
	Single	8	13	8	29
Formal education	Basic level	43	39	38	120
	Secondary	4	1	3	8
	None	13	20	19	52
Household size	1-5	27	25	21	73
	6-10	30	30	36	96
	≥ 11	3	3	3	11
Ethnicity	Akan	58	43	29	130
	Sefwi	1	3	28	32
	Other	1	14	3	18
Source of electrical energy	National grid	60	59	59	178
	Lantern	0	1	1	2
Source of water	Bore hole	57	55	38	150
	Hand-dug well	1	3	21	25
	Bore hole/stream	2	2	1	5
Farmers'experience (years)	1-5	9	11	14	34
	6-10	13	19	15	47
	11-15	6	19	13	38
	≥ 16	32	11	18	61
Farm size (hectares)	0.4-2	44	30	29	103
	2.4-4	12	14	19	45
	4.4-6	1	6	5	12
	≥ 6.4	3	10	7	20
Access to extension service	Yes	21	36	36	93
	No	39	24	24	87
Land acqusition	Inheritance	51	25	28	105
	Shared cropping	6	24	25	55
	Leasehold	3	8	4	15
	Outright purchase	0	3	2	5

Table 2. Results on fertilizer application by farmers in their cocoa farms

Factors	Groups	Twifo-Heman Lower Denkyira district	Atwima-Mponua district	Bia district	Total frequency
Period of year of application	January-March	1	4	1	6
	April-June	11	6	13	31
	July-September	0	2	2	5
	October- December	2	0	0	2
Quantity apply/ha	1-3 bags	8	4	8	21
	1-3 L	5	9	7	21
	> 3 L	1	0	1	2
Method of application	Broadcasting	6	8	16	31
	Ring application	6	0	0	6
	Foliar application	2	5	0	7
Frequency of application per year	Once	11	10	13	21
	Twice	1	3	3	14
	Thrice	2	0	13	9
Type of fertilizer	*Asasewura*	11	6	3	21
	Cocofeed	0	1	13	14
	Sidalco	3	6	0	9

Table 3. Data on results of spraying of cocoa farms for control of capsids and black pod disease.

Factors	Group	Twifo-Heman Lower Denkyira district	Atwima-Mponua district	Bia district	Total frequency
Frequency of spraying insecticide against capsids	Once	5	3	1	9
	Twice	4	8	5	18
	Thrice	6	7	10	23
	> 4 times	5	1	2	8
Quantity of insecticides sprayed	1-3 L	14	14	18	47
	4-6 L	6	5	0	11
	> 6 L	5	1	1	2
Periods of year application of insecticide	April-June	10	11	15	37
	July-September	3	4	3	10
	October-December	1	2	0	3
	January-March	6	3	0	9
Frequency of spraying fungicide against black pod disease	Once	9	8	0	17
	Twice	8	3	2	13
	Thrice	0	4	11	16
	≥ 4 times	3	4	5	12
Period of application of fungicides	April-June	17	11	7	38
	July-September	3	8	11	22
	October-December	0	1	1	1

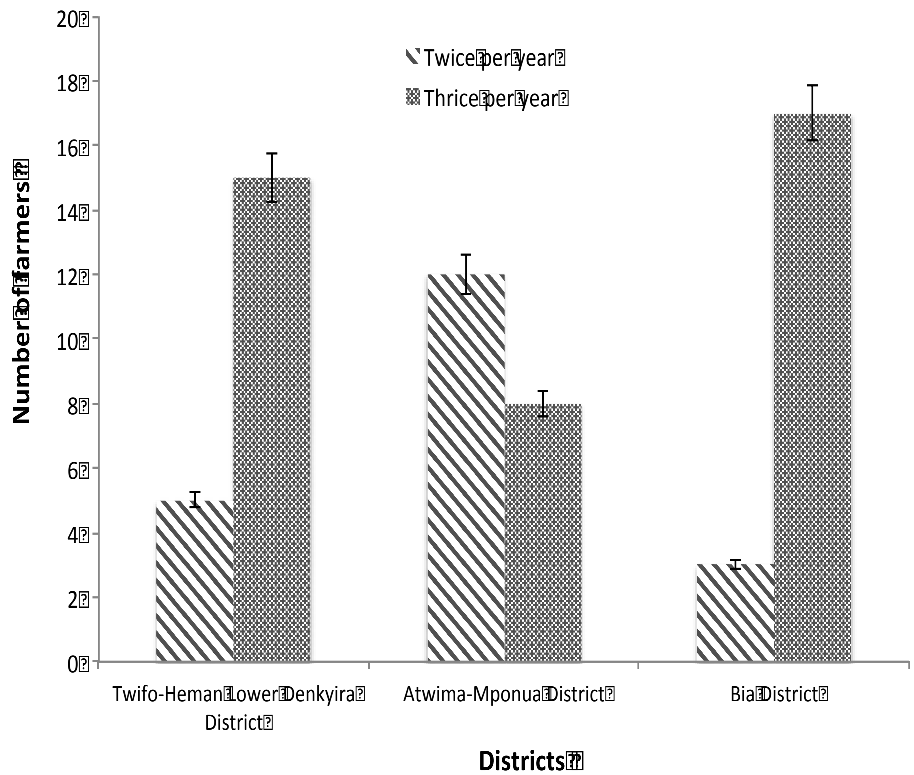

Figure 1. Comparison of frequencies of weeding cocoa farming farms in the three districts. Error bars represent ± 95% confidence limits.

district and Atwima-Mponua district spray once per year. The most common period of spraying against black pod disease was in April-June (63.3%), followed by July-September (36.7%). A few of the farmers spray in October-December. Frequency of spraying against capsid positively related to farmers age ($r^2 = 0.08$, $p < 0.05$), experience ($r^2 = 0.08$, $p < 0.01$) and farm size ($r^2 = 0.08$, $p < 0.001$). Means of land acquisition positively influenced the period of spraying against capsid ($r^2 = 0.08$, $p < 0.05$).

Weeds control and pruning

About 73.3% of farmers adopted manual means of weed control using hoes and cutlasses; 25% used both manual methods and herbicides and 2.2% used only herbicides. The 2.2% of the farmers who apply herbicides on their farms used mainly *Glyfos*. No significant difference in the methods of weeds control was detected in the three districts ($p > 0.05$); although, frequency of weeding varied ($\chi^2 = 14.8$, $p < 0.001$). In Bia district and Twifo-Heman Lower Denkyira district, farmers commonly control weeds in farms thrice in a year, whereas in Atwima-Mponua district, they mostly weed farms twice in a year (Figure 1). Significant difference ($\chi^2 = 15.4$, $p < 0.01$) was found in the frequency of pruning of cocoa trees in the three districts (Figure 2). With exception to educational status of farmers, none of the other socioeconomic variables correlated with weed control and pruning of cocoa farms. Educational status of farmers was positively related to the frequency of pruning ($r^2 = 0.14$, $p < 0.01$). The periods of pruning were the same in the three districts as 70% of the farmers prune cocoa trees between January and March (Figure 3).

DISCUSSION

The results of present study agree with previous studies that cocoa farming is a male dominated occupation (Aneani et al., 2012; Boateng et al., 2014; Osarenren and Emokaro, 2015; Taiwo et al., 2015). Generally, most of the farmers were in the middle age group suggesting the future of cocoa production in the study areas is blissful. More than half of the famers had received basic education and this however, may or may not guarantee for the adoption of research recommendations.

Household size was between 6 and 10 persons, which presuppose that farmers may have more family members to help in the daily routines of the farm. According to Effiong (2005), a relatively large household size enhances the availability of family labour, which reduces constraints on labour demand in agricultural production.

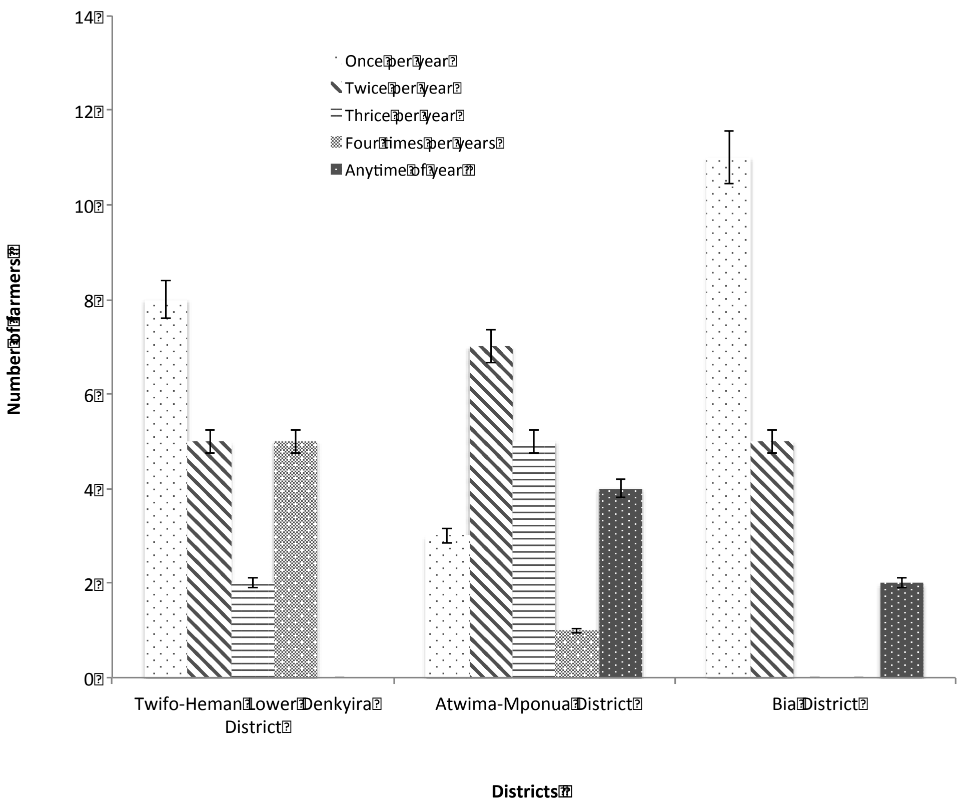

Figure 2. Comparison of frequencies of pruning cocoa trees in districts. Error bars represent ± 95% confidence limits.

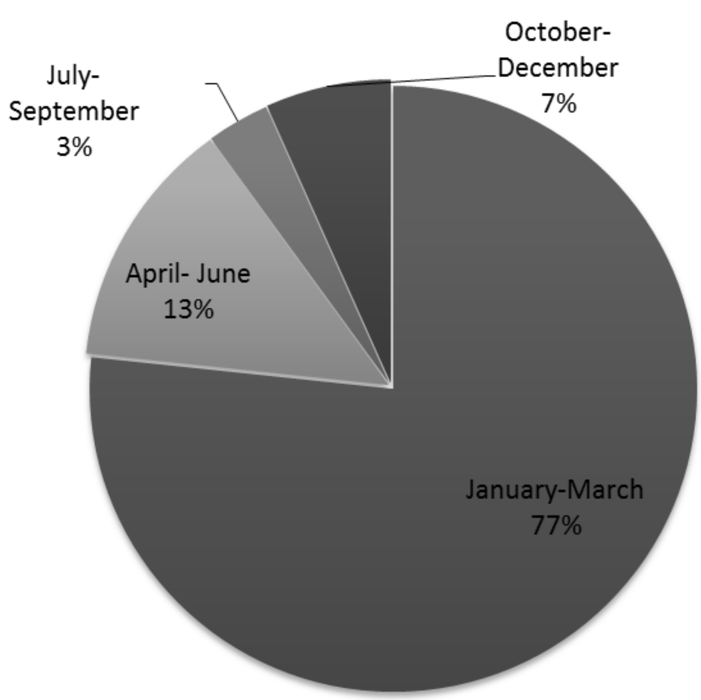

Figure 3. Proportions of farmers pruning cocoa trees in different periods of the year.

The maintenance of cocoa farms and subsequent increase in productivity is often associated with farmers' experience. In this study, majority of the farmers have gained experience in their quest to cultivate cocoa. For instance, farmers in Twifo Heman Lower Denkyira district have gained more experience regarding the variety to be cultivated and pattern of rainfall over time. It is of general opinion that experienced farmers have better knowledge about climatic conditions and market situations and are thus expected to run more efficient and profitable enterprise (Effiong, 2005). The farm size distribution of the cocoa farmers showed that most cocoa farmers were smallholders growing cocoa on 0.4 to 2.0 hectares of farmland. This observation agrees with previous report by Osarenren and Emokaro (2015), who observed majority of smallholders growing cocoa on less than 10 hectares of farmland. In this study, most of the farmers cultivate hybrid cocoa variety as recommended by Cocoa Research of Ghana (CRIG) for higher productivity. Wiredu et al. (2011) in a related study reported that the adopters of hybrid cocoa varieties gained an additional yield of 0.32 ton/ha. Land acquisition by farmers in the different districts was mostly by inheritance as some land owners tend to give out parcels of land for shared croppers to manage. Findings of the study showed that most farmers had access to extension service delivery. This assertion is in line with previous study conducted by Onumah et al. (2014) who reported that about 83.7% of cocoa farmers in Ghana have access to extension service.

The use of fertilizers on cocoa farms has been reported to boost production. For example, studies have shown that fertilizer application increased yields from 250 to 1,500 kg per hectare after the 4th year of application (Ghana Cocoa Board, 2002). The results of this study showed that most farmers have adopted the use of fertilizers on their farm for higher productivity whilst few do not apply due to financial difficulty. The type of fertilizer applied varied in the districts as majority preferred "*Asasewura* fertilizer to *"Cocofeed"* and *"Sidalco*" fertilizers since it was the first to be introduced by the Cocoa Research Institute of Ghana. The common method of fertilizer application in the different districts was broadcasting, while majority applied once in a year. This observation is in line with previous study by Baah et al. (2011), who reported that most farmers applied fertilizers once annually and preferred the broadcasting method of application. The recommendation of the Cocoa Research Institute of Ghana (CRIG, 1987) is that fertilizers should be applied once a year at the beginning of the rains (April-May) and the quantity of fertilizer applied should be three bags per acre. This recommendation had been adopted by majority of farmers in the study areas.

Smallholder cocoa farmers in Ghana use insecticides and fungicides to control capsid and black pod disease infestations. Of concern, however, is the fact that the amount of application differ in the different study sites. The use of agrochemicals is more common in the Bia district since most farmers perceived it as an efficient means of controlling weeds. The wrong use of chemicals on cocoa farms exposes farmers to some risks due to the hazardous effects. The residual effect of the chemicals on cocoa also constitutes concern if the chemicals are not properly handled. According to Atu (1990), pesticides are toxic and can have serious health hazards to human beings.

In this study, most of the farmers applied manual hand weeding of cocoa farms with only very few farmers using herbicides. Hand weeding of cocoa farms is labour intensive and could potentially limit the size of cocoa farms that a farmer can effectively managed. This could perhaps explain the reason why cocoa farming is a male dominated profession (Aneani et al., 2012). The difference detected in frequency of weeding cocoa farms could be a factor of vegetation type and climate. The use of herbicides could be an indication that cocoa farmers are adopting chemical means of weed control and this might increase in the future. The results of this study is similar to that of Aneani et al., (2007), who indicated that few cocoa farmers (5.7%) used weedicides to control weeds on their farms, with the majority (92.7%) relying on manual weeding. However, the improper use of herbicides especially at the seedling stage could affect cocoa plant and might have consequence on the ecosystem (Owusu-Manu, 1985). The use of herbicides may affect the activities of soil microbes and hence decomposition of plant litter. Pruning of cocoa trees has the potential of minimizing the incidence of diseases and increase aeration thereby improve yield quality. The study shows that most of the farmers prune their cocoa farms at least once in a year, which is line with CRIG recommendation (CRIG, 1987).

One of the major findings of this study is that it has revealed differences in factors of socioeconomic characteristics of farmers in the districts. For example, in this study, most farmers in Twifo Heman Lower Denkyira district were above sixty years, whereas farmers in other districts were between 41 and 50 years of age. The implication of this is that farmers in Twifo Heman Lower Denkyira district may not be as efficient and effective to adopt research recommendations since older people may not be able to adopt innovations (Baffoe-Asare et al., 2013). Experience largely influenced farmer's decisions regarding variety to be cultivated and time of planting. However, despite the rich experience gained by farmers in Twifo Heman Lower Denkyira district, this did not reflect on the performance of the cocoa farms compared to other districts where farmers has less experience. The reason could be that the farmers are older here. According to Oladele (2007), experience contributes to farmers' ability to improve on their farm operations or activities. Result of the study revealed differences in household size of farmers across the districts. That is while farmers in Bia district had more family members to contribute to cocoa cultivation, farmers in Atwima Mponua and Twifo Heman Lower Denkyira districts on the other hand had few family members to assist in the daily routines of the farm. The study also showed variations regarding farm size of cocoa farmers in the three districts. For instance farmers in the Bia district possess large farmlands compared to those in Twifo Heman Lower Denkyira district whose farmlands are small due to excessive fragmentation.

In this study, binary regression model was used to determine the effect of socioeconomic variables on farm management practices in the three districts. Generally, six variables out of twelve included in the model were significant in explaining the relationship between socioeconomic variables and farm management practices. The positive sign of age of farmers indicate that young cocoa farmers in the study areas have greater likelihood of investing more in agrochemicals and easily to understand and apply innovations as directed by cocoa extension agents. This observation confirms previous study by Nkamleu and Adesina (2000) who reported that young cocoa farmers are generally more likely to adopt new agricultural technologies than older ones. The positive coefficient sign of farm size and frequency of spraying indicates that farmers with larger farm sizes are also more likely to spend more in agrochemicals like insecticides and fungicides. This supports previous studies by Nkamleu et al. (2007) who documented positive correlation between total area cultivated and adoption of agrochemicals. The coefficient of educational status of cocoa farmers is positively signed and significant indicating that educated farmers are more likely to know when to prune their cocoa trees within the cropping season.

CONCLUSION AND RECOMMENDATIONS

It can be drawn from the study that the country's cocoa cultivation is greatly affected due to ageing of experienced cocoa farmers and other related factors. The vast majority of Ghanaian youth with the requisite knowledge and skills perceived cocoa farming as unattractive and longtime venture whilst they look for jobs with better remuneration. The present study also revealed significant differences in factors of socioeconomic profile and farm management practices of smallholder cocoa farmers which may have a serious implication for the attainment of cocoa production targets for the country. The relationship between farm management practices and socioeconomic characteristics of cocoa farmers were thoroughly investigated.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Aneani F, Anchirinah VM, Asamoah M, Owusu-Ansah F (2012). Adoption of some cocoa production technologies by cocoa farmers in Ghana. Sustainable Agric. Res. 1(1):103-117.

Aneani F, Anchirinah VM, Asamoah M, Owusu-Ansah F (2007). Baseline socio-economic and farm managements survey. A Final Report for the Ghana Cocoa Farmers' Newspaper Project. New Tafo-Akim: Cocoa Research Institute of Ghana (CRIG).

Appiah MR, Ofori-Frimpong K, Afrifa AA, Asante EG (1997). Prospects of Fertilizer Use in the Cocoa Industry in Ghana".Proc. Soil Sci. Soc. Ghana 14:15. Kumasi, Ghana.

Asare R (2005). Cocoa agroforest in West Africa.A look at activities on preferred trees in the farming systems.Forest and Landscape Working paper. Danish Centre for Forest, Landscape and Planning, Royal Agricultural and Veterinary University (KVL) Dennmark P. 89.

Atu OL (1990). Pesticide usage by Imo state farmers in 1983 and 1988. In Nigerian J. Plant Prot. 13:66-71.

Baah F, Anchirinah V (2011). A review of cocoa research institute of Ghana extension activities and the management of cocoa pests and diseases in Ghana. Am. J. Social Manage. Sci. 2(1):196-201.

Baffoe-Asare R, Danquah JA , Annor- Frempong F (2013). Socioeconomic factors influencing adoption of codapec and cocoa High-tech Technologies among small Holder Farmers in Central region of Ghana". J. Exp. Agric. 3:2.

Bisseleua HBD, Fotio D, Yede MAD, Vidal S (2013). Shade Tree Diversity, Cocoa Pest Damage, Yield Compensating Inputs and Farmers' Net Returns in West Africa". PLOS ONE | www.plosone.org 8(3):e56115.

Boateng DO, Codjoe FNY, Ofori J (2014). Impact of illegal small scale mining(Galamsey) on cocoa production in Atwima district of Ghana. Int. J. Adv. Agric. Res. pp. 89-99.

Boateng I (2008).The impact of agroforestry on the livelihood of rural farming households. Unpublished Bsc thesis. Kwame Nkrumah University of Science and Technology, Department of Agroforestry pp. 15-17.

Cocoa Research Institute of Ghana (CRIG) (1987). Guide to cocoa cultivation. Tafo: Cocoa Research Institute of Ghana (CRIG).

Cocoa Board (2002).Report of the Committee on Application of High Technology Method on Cocoa Production in Ghana. Ghana Cocoa Board. Accra, Ghana P 4.

Effiong EO (2005). Efficiency of Production in Selected Livestock Enterprises in Akwa Ibom State, Nigeria. Unpublished Ph.D Dissertation, Department of Agricultural Economics, Michael Okpara University of Agriculture, Umudike, Nigeria P 45.

Forestry commission (2010)."National forest plantation development programme". Annual report for 2010.

Ghana Statistical Service (2010). Analysis of incentives and disincentives for cocoa in Ghana.

Global Agricultural Information Network (GAIN) (2012). Cocoa Annual Report.

Gockowski J, Weise S, Sonwa D, Tchtat M, Ngobo M (2004). Conservation because it pays: shaded cocoa Agroforestry in West Africa Paper presented at the National Academy of Sciences in Washington DC on February 10, 2004 at a 84th symposium titled 'The Science behind cocoa's benefits'. Document available at:

http://www.chocolateandcocoa.org/Library/Document/NAS.doc
ICCO (2010). International Cocoa Organisation. Quarterly Bulletins and Annual Reports. http//www.internationalcocoaorganistion.net.
IITA (2002). Summary of Findings from the Child Labor Surveys in the Cocoa Sector of West Africa: Cameroon, Côte d'Ivoire, Ghana, and Nigeria. Ibadan: The International Institute of Tropical Agriculture.
ISSER (2011). The State of the Ghanaian Economy in 2010.Institute of Statistical, Social and Economic Research, University of Ghana, Legon.
Juhrbandt J, Barkmann J (2008). Yield determinants in cocoa agroforestry systems in Central Sulawesi : Is shade tree cover a good predictor for intensification? In: Grosse, M., Lorenz, W., Tarigan, S., Malik, A. (eds.) Tropical Rainforests and Agroforests under Global Change. Proceedings International Symposium, October 5-9, 2008, Kuta, Bali, Indonesia. Universitätsverlag Göttingen 2008.
Kolavalli S, Vigneri M (2011). Chapter 12: Cocoa in Ghana: Shaping the Success of an Economy. In Chuhan-Pole and Angwafo, M. (eds.) (2011), Yes, Africa Can: Success Stories from a Dynamic Continent, The World Bank Publications.
Larson AM, Petkova E (2011). An Introduction to Forest Governance, People and REDD in Latin America: Obstacles and Opportunities". Forest 2:86-111.
Mohammed D, Asamoah D, Asiedu-Appiah F (2011). Cocoa Value Chain - Implication for the Smallholder Farmer in Ghana" Department of Information Systems and Decision Sciences, KNUST School of Business, Kwame Nkrumah University of Sci. Technol. Ghana.
Nkamleu GB, Keho Y, Gockowask J, David S (2007). Investing in Agrochemicals in the cocoa sector of Cote d'Ivoire: Hypotheses, Evidence and Policy Implications .African. J. Agric. Resour. Econ. 1(2):145-166.
Nkamleu GB, Nyemeck J, Gockowski J (2010).Technology Gap and Efficiency in Cocoa Production in West and Central Africa : Implications for Cocoa Sector Development, Working Papers Series N° 104, African Development Bank, Tunis, Tunisia.
Oladele OI (2007). Indigenous Labour Sourcing: Subsistence Farming and Poverty Status among Farmers in Nigeria. Indian J. Tradit. Knowl. 7(3):4.
Onumah JA,William PA, Quaye W, Akuffobea M (2014). Smallholder Cocoa Farmers Access to On/Off-Farm Support Services and its Contribution to Output in the Eastern Region of Ghana. Asian J. Agric. Rural Dev. 4(10):484-495.
Osarenren CO, Emokaro CO (2015). Profitabilty of cocoa production ubder different management systems in Edo state, Nigeria. Niger. J. Agric. Food Environ. pp. 38-43.
Owusu-Manu E (1985). The evaluation of the synthetic pyrethroids for the control of Distantiella theobroma Dist. (Hemiptera, Miridae) in Ghana. Proc. 9th Int. Cocoa Res..Conf. 1984, Lome, Togo pp. 535-538.
Ruf F, Schroth G (2004). Chocolate forests and monocultures: a historical review of cocoa growing and its conflicting role in tropical deforestation and forest conservation. In: Schroth G, da Fonseca GAB, Harvey CA, Gascon C, Vasconcelos HL, Izac AMN (eds) Agroforestry and biodiversity conservation in tropical landscapes. Island Press, Washington, DC.
Taiwo O, Ogunlade MO, Ayegboyin KO, Famaye AO, Adeniyi DO, Oyedokun VA, Adeosun SA, Adejobi KB (2015). Factors affecting the practice of cocoa rehabilitation techniques in Nigeria": A case of South-West and South-South geo-ecological zone. Int. J. Adv. Agric. Res. pp. 25-30.
Vaast P, Somarriba E (2014). Trade-offs between crop intensification and ecosystem service: the role of agroforestry in cocoa cultivation. Agrofor. Syst. 88:947-956.
Wiredu AN, Mensah-Bonsu A, Andah EK, Fosu KY (2011). Hybrid cocoa and land productivity of cocoa farmers in Ashanti Region of Ghana. World J. Agric. Sci. 7(2):172-178.

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Full Length Research Paper

The effect of plant density on growth and yield of ‘NsukkaYellow’ aromatic pepper (*Capsicum annuum* L.)

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Nsukka yellow pepper is an important aromatic pepper that is highly valued for heat, spice and flavour in Eastern Nigeria. The study was initiated to investigate the effects of different plant population densities on the morphological and fruiting characteristics of Nsukka yellow pepper cultivar. Eight treatment combinations giving rise to different population densities were used. The data on the number of leaves, number of branches, canopy diameter, plant height, number of fruits and fruit weight were collected at different days after planting (DAP) covering the periods of growth, flowering and fruiting. The results of the study showed that the different morphological parameters in addition to the number of fruits and fruit weight were significantly affected by plant population densities. The number of leaves was highest in T1 at 129 DAP and least in T2 at 66 DAP. The number of branches ranged from 0.27 to 3.47 and 55.1 to 97.9 at 66 and 129 DAP, respectively. The canopy diameter ranged from 9.24 to 19.82 cm recorded at 66 DAP and 41.18 to 73.66 cm recorded at 129 DAP, while the least plant height (6.33 cm) was recorded in T7 and the highest (56.01 cm) in T1 at 66 and 129 DAP, respectively. The highest fruit number and fruit weight per plant were obtained at plant densities of 20689.66 plants/ha (T1) and 31034.48/ha (T3) under plant spacing of 75 × 60 and 45 × 60 cm, respectively. The highest weight of fruits per hectare was obtained at the highest population density of 77586.21 plants/ha (T8). Farmers aiming at the selling point of single fruits are encouraged to use low population densities which is achieved by higher plant spacing but cumulative yield per hectare was higher at high population density under low plant spacing.

Key words: Aroma, Nsukka, pepper, plant spacing, population density, spice.

INTRODUCTION

Indigenous vegetable production is an important component of the subsistence farming system generally practiced in West Africa (Maga et al., 2012). In Nigeria, pepper is regarded as the third in importance among the cultivated vegetable crops after onions and tomatoes (Uzo, 1984; Ado, 1998; Romain, 2001). It plays a vital role in the nutritional balance of the rural and urban dwellers by supplying vitamins and minerals in their diets (Leung et al., 1968; Uguru, 1999). The varieties of pepper produced in Nigeria include Bird peppers-atawere

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(*Capsicum frutescens*), Cayenne pepper or red pepper-sombo (*C. frutescens*), Atarado (*Capsicum annuum*), Tatase (*C. annuum*) and also Nsukka yellow pepper (*C. annuum*) (Olufolaji and Denton, 2000; Adetula and Olakojo, 2006).

Nsukka yellow pepper, a variety of *C. annuum*, is a popular crop, and is considered among the principal vegetable crops grown in the derived savannah agro-ecology for its fruits which are characterized by unique aroma, hotness due to the capsaicin content, nutritional values, adaptability to the existing cropping systems and potentials for wealth creation (Nwankiti, 1981; Uguru, 2000; Abu and Uguru, 2005). Asogwa (2006) noted that the distinctive aroma of Nsukka yellow pepper enhances its acceptability in the market. Consequently, it attracts higher price than other pepper types in the local and urban markets. Similarly, Ajayi and Eneje (1998) reported that the distinctive aroma of the cultivar makes it very much cherished in the diets of several homes and eateries. Nsukka yellow pepper is not widely cultivated in most states in the country, this may be because of its tendency to lose its pungency, aroma and colouring in other areas (Uguru, 1999). Nsukka agricultural zone is generally considered to be the home of Nsukka yellow pepper (maga et al., 2012). For many years, the inhabitants of Nsukka agricultural zone have been engaged in the cultivation of Nsukka yellow pepper (*C. annuum* L.) for its fruits which are characterized by unique aroma and yellow colour. It is peculiar to Nsukka hence it is called 'Nsukka Yellow Pepper'. Although, it is also cultivated in some parts of Kogi State which is also in derived ecological zone as Nsukka.

Ekwu and Okporie (2002) suggested that the best spacing for the plant is 30 × 60 cm while 150 kgN/ha was sufficient for the growth of Nsukka yellow pepper in Abakiliki. Meanwhile, Aliyu et al. (1990) and Indalsingh and Antomie (2006) reported that reducing the intra-row spacing of two pepper varieties from 50 to 40 cm significantly decreased plant height, number of fruits and diameter of fruits, while total fruits yield per hectare was conversely increased. Continuous flowering starts 60 to 90 days after sowing. Flowers open three hours after sunrise and are open for 1 to 3 days. In the bud stage, the stigma is receptive, but the pollen is not yet mature; under normal circumstances 40 to 50% of the flowers set fruits. Fruits begin to mature 4 to 5 weeks after flowering. The peak harvest period is 4 to 7 months after sowing (Govindarajan, 1985). Flowering is a vital physiological process in crop existence and assurance for reproduction (Marcelis et al., 2005). Time of flowering is particularly of great importance in annual crops, because it is a component of the adaptation of a cultivar to an environment. It also determines fruit set and crop yield (Ishiyaku et al., 2005; Ferrara et al., 2011). Plant growth and development, especially flowering, is dependent on the interaction of many complex processes which are influenced by both genetic and environmental factors (Uarrota, 2010).

Nsukka yellow aromatic pepper is grown widely in derived savannah agro-ecology for its cherished aroma and as a major cash crop, especially among women farmers. The aim of this study was to assess the effect of plant population densities on the morphological and fruiting attributes of Nsukka yellow pepper (*C. annuum*) cultivar.

MATERIALS AND METHODS

The experiment was conducted in the new botanical garden, Department of Plant Science and Biotechnology, University of Nigeria, Nsukka. The dry seeds of Nsukka yellow pepper were raised in nursery baskets in the old botanical garden in a cured nursery mixture of 3:2:1 top soil, poultry manure and river sand, respectively. The seedlings were transplanted to the field after four weeks. A field experiment, laid out in randomized complete block design (RCBD) of three replications was used to determine the effect of pepper plant population densities on the growth and fruit characteristics of Nsukka yellow pepper genotype. The plot size was 2 × 2.9 m (5.8 m^2).

Eight population densities of pepper were tested and the inter and intra row spacing are as shown on Table 1. Plates 1 and 2 show Nsukka yellow pepper plants at 77586.21 (T8) and 31034.48 (T3) plants/ha population densities. The study was done under rain-fed conditions and poultry manure was applied broadcast at 34.48 t/ha. The manure was manually hoed in and allowed to decompose for five days before transplanting. The seedlings were transplanted to the field at appropriate spacings.

Data were collected on the following parameters by numerical count, number of leaves, number of branches and number of fruits per plant. Others as canopy diameter and plant height were by metrical measurement, while fruit weight was by the use of weighing balance. All the quantitative data collected were subjected to multivariate analysis of variance following the procedure outlined for RCBD format in Obi (2002). The means were separated using least significance difference (LSD) at P ≤ 0.05 only when the F-value is significant.

RESULTS

The results of the number of leaves showed significant differences among treatments at different days after planting (DAP). At early growth stages of 66 and 73 DAP, T5 and T6 had significantly the highest number of leaves, however, at 80 DAP, T6 had the highest number of leaves which did not differ significantly from that of T5. At full fruiting stage (129 DAP), the widest spaced plant (T1) with low plant density had significantly the highest number of leaves of 789.3 per plant. This was followed by T2 which had a value of 722.6 per plant (Table 2).

T6 had significantly the highest number of branches per plant at 66, 73 and 101 DAP. Number of branches per plant at 129 DAP ranged from 52.2 to 107.7 in different population densities. At fruiting stage (129 DAP), the lower plant densities with wider spacing (T1) had the highest number of branches (Table 3).

The canopy diameter, measured in centimetres, across different plant densities ranged from 9.24 to 19.82, 14.61

Table 1. Plant spacing and population densities per plot and per hectare, respectively.

Treatment	Plant spacing (cm)	Plant population density/plot (5.8 m^2)	Plant population density/ha (10,000 m^2)
T1	75 × 60	12	20689.66
T2	55 × 60	15	25862.07
T3	45 × 60	18	31034.48
T4	35 × 60	21	36206.9
T5	55 × 30	25	43103.45
T6	45 × 30	30	51724.14
T7	35 × 30	35	60344.83
T8	15 × 60	45	77586.21

Plate 1. Nsukka yellow pepper at 77586.21 plants/ha (15 × 60 cm spacing) at fruiting (green stage).

Plate 2. Nsukka yellow pepper at 31034 plants/ha (45 × 60 cm spacing) at fruiting (green stage).

Table 2. Effect of different plant population densities on number of leaves per plant (NL/P) at different days after planting (DAP).

Plant population	NL/P at 66 DAP	NL/P at 73 DAP	NL/P at 80 DAP	NL/P at 101 DAP	NL/P at 129 DAP
T1	$7.87^{cd} \pm 0.62$	$16.20^{c} \pm 1.48$	$36.06^{bc} \pm 2.52$	$194.9^{c} \pm 3.25$	$789.3^{a} \pm 26.3$
T2	$5.60^{d} \pm 0.49$	$11.87^{c} \pm 1.11$	$29.73^{dc} \pm 3.42$	$187.1^{d} \pm 9.16$	$722.6^{c} \pm 9.29$
T3	$8.47^{c} \pm 0.60$	$15.60^{c} \pm 1.23$	$32.93^{bc} \pm 2.11$	$168.4^{cd} \pm 3.81$	$674.1^{c} \pm 10.4$
T4	$6.27^{cd} \pm 0.65$	$11.87^{c} \pm 1.51$	$23.13^{d} \pm 3.196$	$151.2^{e} \pm 2.51$	$493.9^{e} \pm 17.1$
T5	$22.80^{a} \pm 1.25$	$36.40^{a} \pm 1.77$	$52.40^{a} \pm 3.22$	$274.1^{a} \pm 12.35$	$515.9^{d} \pm 14.8$
T6	$20.73^{a} \pm 0.93$	$34.20^{a} \pm 1.37$	$57.27^{a} \pm 2.82$	$272.6^{b} \pm 12.38$	$592.3^{d} \pm 23.2$
T7	$18.73^{b} \pm 0.56$	$27.60^{b} \pm 1.27$	$39.87^{b} \pm 1.95$	$227.0^{c} \pm 12.84$	$393.0^{f} \pm 14.8$
T8	$8.47^{c} \pm 0.99$	$14.67^{c} \pm 1.85$	$28.33^{dc} \pm 3.52$	$122.2^{e} \pm 6.998$	$338.8^{g} \pm 9.97$
F-LSD (P=0.05)	2.33	4.12	8.18	30.82	79.81

Values are mean ± SE.

Table 3. Effect of different plant population densities on number of branches per plant (NB/P) at different days after planting.

Plant population	NB/P at 66 DAP	NB/P at 73 DAP	NB/P at 80 DAP	NB/P at 101 DAP	NB/P at 129 DAP
T1	$0.87^{c} \pm 0.22$	$2.27^{c} \pm 0.37$	$4.53^{c} \pm 0.496$	$30.00^{bc} \pm 1.82$	$97.9^{a} \pm 5.13$
T2	$0.40^{c} \pm 0.16$	$1.67^{c} \pm 0.37$	$3.93^{cd} \pm 0.54$	$26.87^{d} \pm 1.33$	$92.5^{a} \pm 3.30$
T3	$0.80^{c} \pm 0.2$	$2.07^{c} \pm 0.27$	$3.80^{cd} \pm 0.42$	$22.73^{d} \pm 1.04$	$84.5^{c} \pm 3.54$
T4	$0.27^{c} \pm 0.12$	$1.20^{c} \pm 0.31$	$2.67^{d} \pm 0.53$	$28.60^{cd} \pm 2.89$	$73.0^{d} \pm 5.93$
T5	$2.20^{b} \pm 0.2$	$5.40^{b} \pm 0.39$	$10.47^{b} \pm 0.49$	$34.87^{b} \pm 1.6$	$55.1^{d} \pm 3.62$
T6	$3.47^{a} \pm 0.4$	$8.13^{a} \pm 0.496$	$13.67^{a} \pm 0.80$	$40.33^{a} \pm 2.13$	$66.3^{d} \pm 4.42$
T7	$2.47^{b} \pm 0.26$	$4.67^{b} \pm 0.41$	$9.87^{b} \pm 0.43$	$35.20^{ab} \pm 1.31$	$57.2^{d} \pm 3.67$
T8	$1.00^{c} \pm 0.26$	$1.80^{c} \pm 0.38$	$3.20^{c} \pm 0.61$	$21.00^{d} \pm 2.31$	$63.4^{d} \pm 3.15$
F-LSD (P=0.05)	0.69	1.06	1.54	5.59	12.46

Values are mean ± SE.

Table 4. Effect of different plant population densities on canopy diameter (CD) (cm) at different days after planting.

Plant population densities	CD at 66 DAP	CD at 73 DAP	CD at 80 DAP	CD at 101 DAP	CD at 129 DAP
T1	$11.90^{cd} \pm 0.56$	$17.36^{c} \pm 0.63$	$23.61^{cd} \pm 0.797$	$44.08^{ab} \pm 1.09$	$73.66^{a} \pm 1.24$
T2	$9.24^{f} \pm 0.81$	$14.61^{d} \pm 1.00$	$20.68^{de} \pm 1.24$	$46.85^{bc} \pm 1.55$	$68.01^{b} \pm 1.50$
T3	$11.36^{cde} \pm 0.53$	$16.89^{cd} \pm 0.53$	$22.52^{cde} \pm 0.798$	$43.60^{ab} \pm 0.75$	$67.34^{b} \pm 1.54$
T4	$9.77^{ef} \pm 0.98$	$15.29^{cd} \pm 1.297$	$20.06^{e} \pm 1.32$	$40.52^{d} \pm 1.61$	$52.19^{d} \pm 0.98$
T5	$17.40^{b} \pm 0.48$	$23.23^{b} \pm 0.42$	$30.52^{b} \pm 0.83$	$42.85^{ab} \pm 1.21$	$53.24^{d} \pm 1.64$
T6	$19.82^{a} \pm 0.53$	$27.07^{a} \pm 0.62$	$38.41^{a} \pm 1.46$	$47.34^{a} \pm 1.39$	$59.13^{c} \pm 1.34$
T7	$16.76^{b} \pm 0.46$	$22.30^{b} \pm 0.50$	$28.60^{b} \pm 0.79$	$42.13^{c} \pm 0.83$	$52.74^{d} \pm 1.08$
T8	$10.21^{ef} \pm 0.85$	$15.52^{de} \pm 1.14$	$20.19^{e} \pm 1.11$	$30.13^{e} \pm 1.14$	$41.18^{e} \pm 1.01$
F-LSD (P=0.05)	1.82	2.38	2.94	4.16	4.98

Values are mean ± SE.

to 27.07, 20.19 to 38.41, 30.13 to 47.34 and 41.18 to 73.66 at 66, 73, 80, 101, and 129 DAP, respectively (Table 4). T6 had significantly the widest canopy diameter (19.82 cm) at the peak of vegetative growth (63 DAP) and also 27.07, 38.41 and 47.34 cm at 73, 80 and 101 DAP, respectively. At 129 DAP, full fruiting stage, the plant population of 12 plants/plot (T1) had the highest canopy diameter of 73.66 cm (Table 4).

The results of plant height at different growth stages of Nsukka yellow pepper showed variations at different plant spacing. Plant height ranged from 6.33 to 9.2 cm at 66 DAP. Plant density treatment (T6) had significantly the highest value for plant height at 73, 80 and 101 DAP. At 129 DAP which is the peak of fruiting T1, had the tallest plant which measured 56.01 cm (Table 5).

The number of fruits/plant showed significant variation across the treatments (Figure 1). The range of values was 39.3 to 136 fruits/plant in the different plant densities.

Table 5. Effect of different plant population densities on plant height (PH) (cm) at different days after planting.

Plant population densities	PH at 66 DAP	PH at 73 DAP	PH at 80 DAP	PH at 101 DAP	PH at 129 DAP
T1	$9.29^{a} \pm 0.39$	$11.89^{ab} \pm 0.395$	$14.99^{b} \pm 0.61$	$29.75^{d} \pm 0.53$	$56.01^{a} \pm 1.22$
T2	$7.07^{de} \pm 0.41$	$9.01^{e} \pm 0.499$	$12.09^{cd} \pm 0.66$	$21.85^{f} \pm 1.36$	$48.55^{c} \pm 0.96$
T3	$8.91^{ab} \pm 0.41$	$11.24^{abc} \pm 0.43$	$14.47^{b} \pm 0.45$	$27.16^{e} \pm 0.76$	$46.23^{c} \pm 0.87$
T4	$7.48^{cde} \pm 0.499$	$9.60^{de} \pm 0.67$	$11.63^{d} \pm 0.95$	$24.61^{f} \pm 1.55$	$42.06^{d} \pm 1.23$
T5	$6.35^{e} \pm 0.17$	$10.59^{bcd} \pm 0.30$	$18.49^{a} \pm 0.56$	$33.69^{b} \pm 0.88$	$44.91^{c} \pm 1.08$
T6	$7.99^{bcd} \pm 0.189$	$12.20^{a} \pm 0.21$	$17.33^{a} \pm 0.33$	$42.29^{a} \pm 1.01$	$50.55^{b} \pm 1.76$
T7	$6.33^{e} \pm 0.197$	$10.40^{bcd} \pm 0.35$	$13.75^{b} \pm 0.52$	$31.69^{de} \pm 0.93$	$39.42^{d} \pm 0.897$
T8	$8.65^{abc} \pm 0.74$	$10.78^{abcd} \pm 0.85$	$13.74^{bc} \pm 1.09$	$19.65^{f} \pm 0.75$	$37.73^{d} \pm 0.93$
F-LSD (P=0.05)	1.13	1.33	1.85	4.08	4.68

Values are mean ± SE.

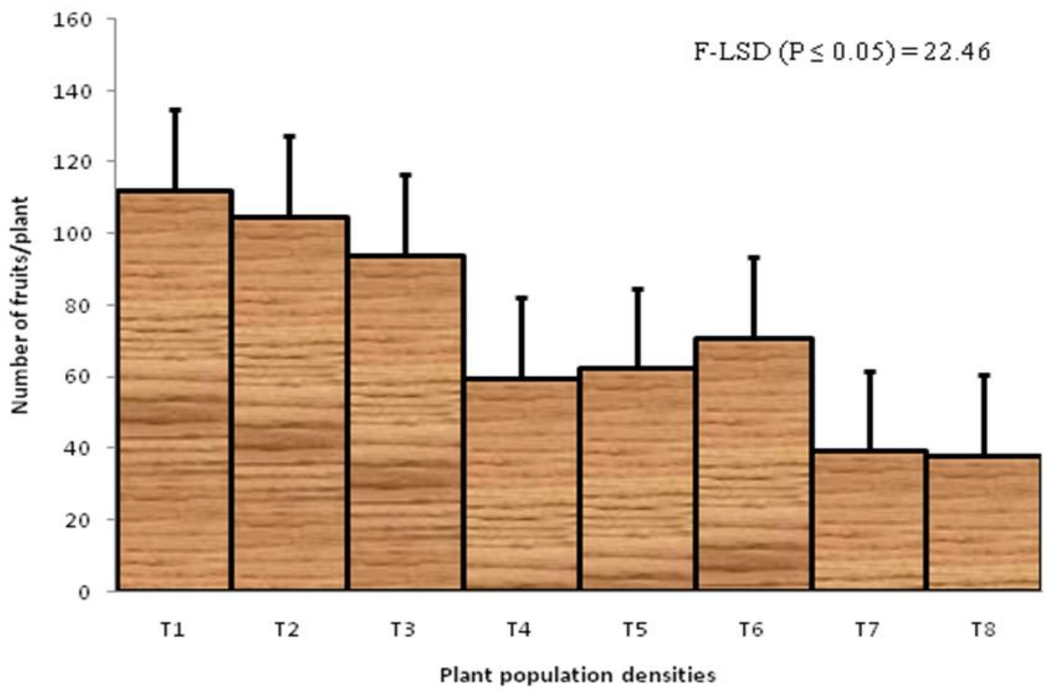

Figure 1. Effect of plant population density on number of fruits per plant.

The lowest plant population densities (T1) had the highest number of fruits/plant after three harvests. T1, T2 and T3 did not differ significantly in their number of fruits per plant. The least number of fruits per plant (39.3 and 38.1 fruits) was observed in T7 and T8, respectively, which did not vary significantly from each other.

The weight of fruits per plant was found to be highest in T3 population density. Fruits weight/plant was higher at low population densities (Figure 2). The three lowest population densities T1 to T3 had significantly the highest number of fruits per plant. The same treatments had significantly the highest values in fruit weight per plant. In considering the weight of fruit per plot, the higher plant population densities had more weight than those with low population (Figure 3). Equally, the estimated fruit weight in tonnes per hectare based on plant density of 77586.21 in 15 × 60 cm gave the highest fruit weight of 5.78 T/ha (Figure 4).

DISCUSSION

Pepper plants in this study behaved differently in the growth and fruiting attributes based on the plant densities. Plant population has been considered a major factor that determines the degree of competition between plants based on the observations on maize (Abuzar et al., 2011). So the observed variations in the growth and yield

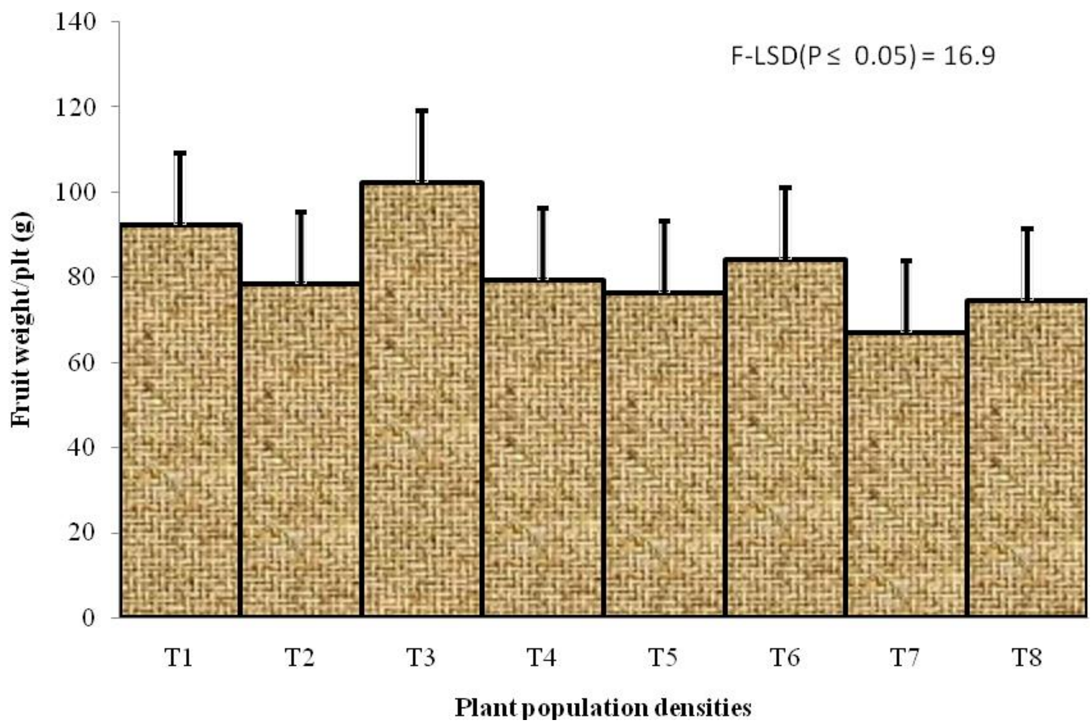

Figure 2. Effect of plant population density on fruit weight per plant.

characteristics of *C. annuum* L. var. Nsukka yellow could be attributed to the agronomic practice adopted which in this case are the plant population densities in the different plots. Nasto et al. (2009) also noted that modern vegetable production practices emphasize the need to use optimum plant population attained with appropriate spacing and plant arrangements. Adequate plant spacing could help farmers in maximizing yield (Ahmed, 1981; Stofella and Bryan, 1988; Adams et al., 2001).

The observed large canopy diameter (CD) in low population density could be an indication of numerous branches and leaves. It is a pointer that the wider the spacing, the higher the canopy diameter. This could equally be translated to higher yield if plant population is adequate. Plants with larger canopy diameter may also be pertinent in the metabolic activities of the plant by providing numerous leaves for photosynthetic activity as also was suggested by Aluko et al. (2014). It was observed that higher plant densities had lower number of leaves, branches and less canopy diameter, which was similar to the reports of Johnson and William (1997) and Islam et al. (2011). This may be due to competition among plants. Plants under high population compete for space, assimilates and sunshine. At the fruiting stage, plants with lower population densities were still more vigorous than those of higher population densities which may be, due to availability of space, assimilates and other micro-environmental components like air movements. It should also be noted that poultry manure was applied broad cast on equal measures per plot according to the suggestion by Echezona and Nganwuchu (2006). Therefore, plants with lower densities had more available nutrients which invariably were translated to higher vigor.

Higher number of leaves/plant is an indication of higher photosynthetic efficiency since the leaves are the major sites of photosynthesis in green plants. Therefore, it is expected that the high number of leaves/plant recorded at T1 will enhance high assimilate production which will promote growth, development and yield in that population. Number of leaves/plant increased as plant densities/hectare decreased from 77586.21 to 20689.66, similar to the observations of Aliyu et al. (1990).

The tallest and most profusely branched plants and those with the highest number of leaves were recorded in 75 × 60 cm plant spacing with 20689.66 plant density per hectare. This may be attributed to wider spacing between plants. Plant height increased as plant spacing increased from 15 × 60 cm to 75 × 60 cm. This was also reported by Nagdy et al. (1979) who observed that varying plant spacing and rates of nitrogen application increased plant height, number of branches and leaves on pepper plants. Increase in plant height may enhance the emergence of more branches, leaves and consequently increase the canopy diameter; it equally, could contribute in exposing the plants to higher sun intensity. The fruit weight per plant was highest at wider spacing with low plant population. This may suggest that there were less

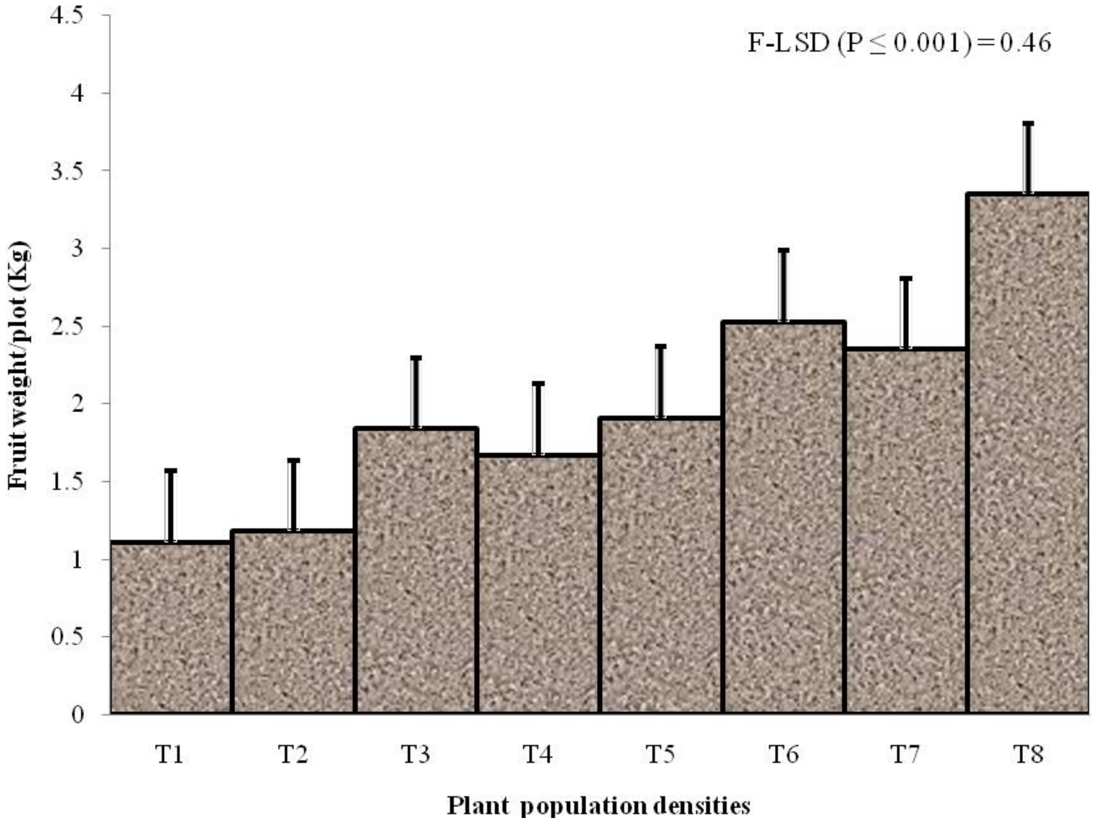

Figure 3. Effect of plant population density per plot on fruit weight.

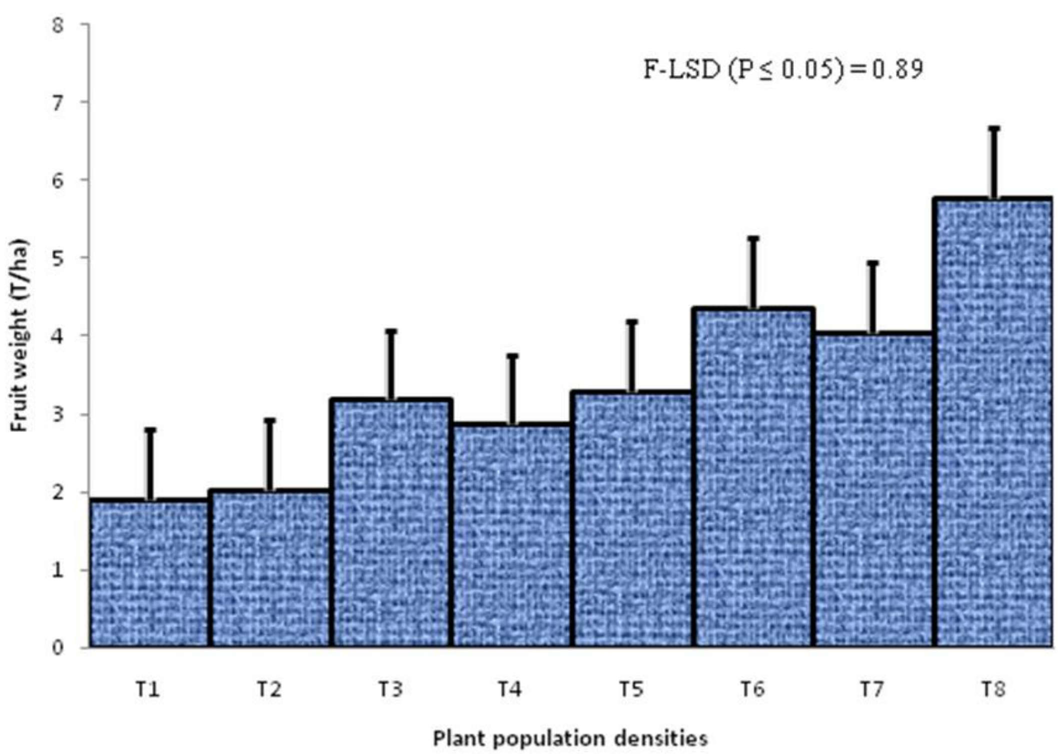

Figure 4. Effect of plant population density per hecter on fruit weight.

competition for nutrient and space among plants. Similar observation was made among Okra cultivars by Ekwu and Nwokwu (2012). Even though plants in low population densities, had higher values in most vegetative characters, which had been reported to have higher correlation with number of fruits and fruit yield (Abu et al., 2013), their cumulative yield were low based on lower plant population. The higher population densities due to competition for space and assimilate could not produce fruits as those with low population in both number and weight on single plant stand basis but on cumulative basis higher populations produced more number of fruits. This result contradicts the report on Okra, where widest plant spacing consistently gave least values in all vegetative parameters (Amjad et al., 2001). Number of fruits/plant and fruit weight per plant were more at the widest spacing. This also agrees with the reports of Ekwu and Nwokwu (2012).

Russo (2003), Nasto et al. (2009) and Khasmakhi-Sabet et al. (2009) had observed that the highest fruit yield of pepper was obtained when grown at the higher population densities. Therefore, the result is of interest to the farmer because it could be deceptive making conclusions based on fruit weight per plant which was recorded in wider spacing of 45 × 60 cm and plant population of 31034.48 per hectare. The spacing that gave the highest plant population per hectare equally had the highest fruit weight per hectare.

In conclusion, higher plant population density of 77586 plants per hectare (15 × 60 cm) gave the highest yield and within the scope of this work could be recommended for the cultivation of Nsukka yellow pepper. Higher population is of advantage to the farmer since the fruits of Nsukka yellow pepper are not sold based on single fruit weight basis but on fruit weight per basket in both local and urban markets. This could also translate to higher income for the farmer.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Abu NE, Uguru MI (2006). Evaluation of Genetic Variations in growth and yield Components of aromatic Pepper lines in the Derived Savannah Ecology of Nigeria. AgroScience 5(1):1-7.

Abu NE, Uguru MI, Obi IU (2013). Genotypic stability and correlation among quantitative characters in genotypes of aromatic pepper grown over years. Afr. J. Biotechnol. 12(20):2792-2801.

Abuzar MR, Sadozai GU, Balocha AA, Shah IH, Javid T, Hussain N (2011). Effect of plant population densities on yield of maize. J. Anim. Plant Sci. 21(4):692-695.

Adams HV, Lauckner FB, Sisnett DD (2001). Effect of high plant population densities on yields, plant and fruit characteristics of the hot Pepper Cultivar, West Indies red. Proc. Caribbean Food Crops Soc. 37:197-201.

Adetula AO, Olakojo SA (2006). Genetic characterization and evaluation of some pepper accessions (*Capsicum frutescens* L.): The Nigerian 'Shombo' collections. Am. Eur. J. Agric. Environ. Sci. 1(3):273-281.

Ado SG (1998). Evaluation of capsion in Nigeia PGRCLE. Newsletter 17:16-17.

Ahmed MK (1981). Optimum Plant Spacing and Nitrogen fertilizer of sweet Pepper in the Sudan Gezira. Soil Crop Sci. Fla. Proc. 32:85-96.

Ajayi AR, Eneje CN (1998). Preference of Nsukka Yellow Pepper Among Growers and Consumers in Nsukka agricultural zone of Enugu State,Nigeria. Proc. 15th HORTISON conf., Ibadan, 8th - 11th April. pp. 184-187.

Aliyu L, Found MK, Mohmoud WS (1990). Effect of Plant Spacing and Nitrogen on Pepper. *Capsicum* Newsletter 10:61.

Aluko M, Alabi EO, Ayodele OJ (2014). Growth and Yield Responses of Bell pepper (*Capsicum annuum*, Rodo variety) to in-row plant spacing. J. Agric. Biol. Sci. 9(11):1-9.

Amjad HK, Foysal HR, Hossain G (2001). Effect of plant spacing on growth and yield of okra production. Pak. J. Agric. Sci. 12(1):59-89.

Asogwa AC (2006). Effect of soil type and manure types on the growth yield and quantity characteristics on Nsukka Yellow pepper unpublished M. Ed. Thesis Department of Crop Science University of Nigeria, Nsukka.

Echezona BC, Nganwuchu OG (2006). Poultry Manure Application and Varietal Effects of Chilli Pepper (*Capsicum sp*) on Insect pests and diseases in humid – tropical environment. AgroScience 5(2):49-58.

Ekwu LG, Nwokwu GN (2012). Effect of plant spacing and planting date on the growth and yield of Okra (Abelmoschus esculentus L.) in Abakaliki. Int. J. Agric. Rural Dev. 15(2):1041-1048.

Ekwu LG, Okporie EO (2002). Effect of Plant Spacing and Nitrogen Fertilizer on the Growth and Yield of Pepper (*Capsicum annum L*.). AgroScience 3(2):22-26.

Ferrara A, Lovelli S, Di Tommaso T, Perniola M (2011). Flowering, growth and fruit setting in greenhouse bell pepper under water stress. J. Agron. 10:12-19.

Govindarajan VS (1985). *Capsicum* Produciton, technology, chemistry and quality. History, botany, cultivation and primary processing, Crit. Rev. Food Sci. Nutr. 22(2):109-176.

Indalsingh T, Antomie PB (2006). The effects of plant population on Yield and fruit quality of hot pepper cv. Local Red. Proc. Caribbean Food Crops Soc. XL11(2):370.

Ishiyaku MF, Singh BB, Craufurd PQ (2005). Inheritance of time to flowering in Cowpea (*Vigna unguiculata* (L.) Walp.). Euphytica 142:291-300.

Islam M, Saha S, Akand MH, Rahim MA (2011). Effect of spacing on the growth and yield of sweet pepper (*Capsicum annuum* L). J. Central Eur. Agric. 12:328-335.

Johnson GA, William CM (1997). Multiple Cropping in the Humid Tropics of Asia. IDRC Publication, Canada pp. 176-248.

Khasmakhi-Sabet A, Sedaghathoor S, Mohammady J, Olfati A (2009). Effect of plant density on bell pepper yield and quality. Int. J. Veg. Sci. 15:264-271.

Leung WTW, Busson F, Jardin C (1968). Food composition table for use in Africa. FAO, Rome, Italy 306 p.

Maga TJ, Uguru MI, Ogbonna PE (2012). Variability and correlation studies in agro-morphological traits of the aboriginal Nsukka yellow pepper (*Capsicum annuum* L.) genotypes. Nig. J. Hortic. Sci. 17:88-102.

Marcelis LFM, Heuvelink E, Hofman-Eijer LRB, Bakker JD, Xue LB (2005). Flower and fruit abortion in sweet pepper in relation to source and sink strength. J. Exp. Bot. 55:2261-2268.

Nagdy GA, Found MK, Mahmound WS (1979). Effect of Cycocel and Ethrel treatments on the anatomical structure of stems and leaves of pepper plant. Res. Bull. 115:14.

Nasto TH, Balliu A, Zeka N (2009). The influence of planting density on growth characteristics and fruit yield of peppers (*Capsicum annuum*). Acta Hortic. 830: 609-612.

Nwankiti OC (1981). Sterility in intraspecific hybrids of Capsicum. Indian J. Genet. 41:200-204.

Obi IU (2002). Statistical methods of detecting difference between treatment means for field and Laboratory. Experiments. AP Publisher Co. Nig. Ltd., Nsukka 117 p.

Olufolaji AO, Denton OA (2000). Vegetable Programme. In: Denton, OA

et al. (Eds). NIHORT: 25 Years of research into Horticultural Crops Development in Nigeria (1975-2000). National Horticultural Research Institute, Idi-Ishin, Ibadan, Nigeria. pp. 29-61.
Romain HR (2001). Crop production in Tropical Africa, DGIC, Brussels, Belgium pp. 462-467
Russo VM (2003). Planting date and plant density affect the yield of pungent and non-pungent jalapeno peppers. J. Hortic. Sci. 38:520-523.
Stofella PJ, Bryan HH (1988). Plant population Influences, growth and yields of bell pepper. J. Am. Soc. Hortic. Sci. 133:835-839.
Uarrota VG (2010). Response of cowpea (*Vigna unguiculata* L. Walp.) to water stress and phosphorus fertilization. J. Agron. 9:87-91.
Uguru MI (1999). Location effects on the growth, yield and flavour Expression of Nsukka aromatic yellow Pepper. J. Appl. Chem. Agric. Res. 6:84-87.
Uguru MI (2000). Expression of quality traits of Nsukka aromatic Yellow pepper in two agro – ecological zones. Plant Prod. Res. J. 5:6 -11.
Uzo JO (1984). The Genetics of on-Vein-Banding in Aromatic Pepper (*Capsicum annuum* L.). Soc. Hortic. 22:201-205.

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Full Length Research Paper

Physiological and behavioral responses of dairy heifers in an integrated-crop-livestock-forestry system

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The integrated crop-livestock-forestry system has been an option in tropics to mitigate the effects of heat stress on pasture-based system for dairy cows. We evaluate the effects of shade arrangements in integrated crop-livestock-forestry systems on physiological and behavioral responses of crossbred dairy heifers. Twenty-four crossbred European-Zebu heifers with 330.0±36.7 kg of body weight were assigned in three treatments: no shade, partial shade or total shade. Air temperature (34.4°C), black globe temperature (41.6°C), temperature humidity index (84) and heat load index (98) were higher ($P<0.05$) for the No shade treatment. Higher values of respiratory rate (99 mov.min^{-1}) and skin temperature (38.1°C) were also found for the no shade treatment. Shade availability affected the grazing time ($U = 246.5$, $P<0.05$). Heifers spent 10% more time in pasture on shade treatments. No difference was found on time spent in rumination, drinking or walking on shade treatments. Shade provision was an efficient strategy to reduce respiratory rate and skin temperature as well as to increase grazing time in integrated crop-livestock-forestry system.

Key words: Cattle, *Eucalyptus*, heat stress, integrated farming, pasture, shade.

INTRODUCTION

The integration of pastures with tree species in livestock-forestry systems (ICLF) has been an option to overcome the effects of thermal stress in tropics (Salton et al., 2014; Ainsworth et al., 2012). Heat stress affects the animal physiology and behavior and compromises their welfare (West, 2003; Schütz et al., 2010). Physiological responses include sweating, increase of body temperature, respiratory frequency and reduced rate of metabolism and feed intake (Collier et al., 2006). Also, cows spend less time lying in order to expose a greater surface area to lose heat by convection (Mader et al., 1997).

Shade provision by tree species protects animals against solar radiation and produces an environment with

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mild temperatures and consequently, better thermal comfort (Valtorta et al., 1997; Tucker et al., 2008; Rovira and Velazco, 2010). Ferreira et al. (2014) evaluated the shade availability in the paddock on physiological and behavioral response of crossbreed dairy cattle. Dairy cows spent around 57% of their time under the shade and the absence of shade on pasture caused heat stress. Treatment with insufficient shade helps to reduce stress at an intermediate level. These results show that shade should be available for all cows at the same time, as previously reported by Schütz et al. (2010).

Forage production may be reduced when shade levels exceed 50% of incident radiation. It occurs due to the decrease in a photosynthetic rate of C_4 grasses (Devkota et al., 2009; Paciullo et al., 2010). However, in moderate shade conditions, there is evidence of the maintenance or an increase in forage production at sunny conditions (Baruch and Guenni, 2007). Mello et al. (2017) assessed the influence of shade level (full sun, moderate shade, and intensive shade) on dairy heifer behavior during three seasons in Midwest of Brazil. The system with intensive shade shown negative effects on sward structure. On the other hand, the grazing activity was positively affected.

Additionally, an increase of forage nutritive value was found under shade, which could improve the performance of animals on a pasture-based system (Sousa et al., 2010; Yamamoto et al., 2007). Our objectives were to evaluate the effects of shade arrangements in integrated crop-livestock-forestry system on the respiratory rate, skin temperature and behavioral responses of crossbred dairy heifers.

MATERIALS AND METHODS

Location of the study, animals and treatments

The experiment was conducted in the experimental area in the ICLF of Embrapa Agrossilvopastoral, located in Sinop, Mato Grosso, Brazil (Latitude 11°51´43´´S, Longitude 55°35´27´´O) and all procedures involving animals were approved by the Animal Ethics Committee. The climate of the region corresponds to the Aw type (tropical climate with dry season), according to the Köppen classification, with dry winters and rainy summers. The data were collected during February and March 2013, and the evaluations were carried out on sunny and overcast days. Because of the safety standards of the Embrapa experimental field, collections were not held in rainy days.

Twenty-four Holstein x Zebu crossbred heifers (24.5±2.9 months; 330.0±36.7kg) were divided into group of eight in three treatments balanced by genetics groups. The treatments involved shade arrangements of *Eucalyptus camaldulensis* in the crop-livestock-forestry system: no trees (no shade); presence of trees (385 trees ha^{-1}) in two rows with 2.0 m distance between plants and 3.0 m between lines and with a distance of 49 m between the rows (partial shade); and trees arranged in three-line rows with 2.0 m distance between plants and 3.0 m among lines and with a distance of 49 m between the rows, resulting in a density of 720 trees ha^{-1} (total shade) (Figure 1).

A crop-livestock-forestry system was installed in January, 2011. It presented a 10 ha area formed by *E. camaldulensis* clone, pasture of Piatã grass (*Urochloa brizantha* cv. Piatã) in integration with corn for silage. Planting lines were oriented East to West and the *Eucalyptus* high was 12 m. All treatments approximately had the same pasture area formed by Piatã grass. Ten paddocks (0.25 ha) enclosed by electrified fences were used. Rotational grazing was carried out and the entry of animals in each paddock occurred when grazing reached 95% of light interception.

Environmental variables

Dry bulb temperature (DBT), relative humidity (RH) and black globe temperature (BGT) was monitored in 20-min intervals from 8:00 h to 16:00 h using an electronic system of data acquisition (HOBO®H8), installed at 1.60 m above the ground. For the no shade treatment, a sensor was placed in the center of the paddock, and for partial and total shade treatments, sensors were located in the middle of the rows of eucalyptus and set 0.5 m apart from the trees. The wind speed (WS) was measured with a digital anemometer (accuracy of ± 0.03 m s^{-1}) at the height of other sensors, at intervals of 2 h, between 8:00 h and 16:00 h.

Temperature humidity index (THI) was calculated hourly using the equation developed by Berry et al. (1964) and the heat load index (HLI) according to Gaughan et al. (2008) as follows:

$$THI = (1.8 \times DBT + 32) - [(0.55 - 0.0055 \times RH) \times (1.8 \times DBT - 26)];$$

$$HLI_{TGN>25} = 8.62 + (0.38 \times RH) + (1.55 \times BGT) - (0.5 \times WS) + [e^{2.4 - WS}];$$

$$HLI_{TGN<25} = 10.66 + (0.28 x RH) + (1.3 x BGT) - WS.$$

Where:
e = base of natural logarithm (approximate value e = 2.71828).

Physiological variables

Respiratory rate (RR) and skin temperature (ST, °C) were measured twice a day at 8:00 h and at 14:00 h. The RR expressed in movements per minute was obtained by counting number of rises of the flank. The ST was measured with a portable digital infrared thermometer (Instrutemp, ITTI 1000 model), equipped with laser sights, set with emissivity (ε)=0.95, 1.5% accuracy and optical resolution of 30:1. The measures were taken at approximately 1.5 m from the animal in the dorsolumbar region.

Animal behavior

Heifers were individually identified with colorful necklaces. Behaviors were recorded with focal sampling (Martin and Bateson, 1993) every 15 min from 8:00 to 16:00 h. The behavioral variables observed were the following: location of animals (under the shade or sun), posture (standing or lying down), and activities (grazing, resting, rumination, walking). Under the shade was considered when the animal was with 50% or more of the body under the eucalyptus' shade. Standing was considered to be an inactive posture (no locomotion). Lying behavior was considered to be when the flank was in contact with the ground. Heifers were considered to be grazing if grass was being consumed or could be seen in the mouth. Resting was defined when heifers have not shown apparent activity. Data were expressed as the percentage of the time in each behavior regarding the total time of observation.

Statistical analyses

The effects of the treatments on environmental variables (DBT, RH,

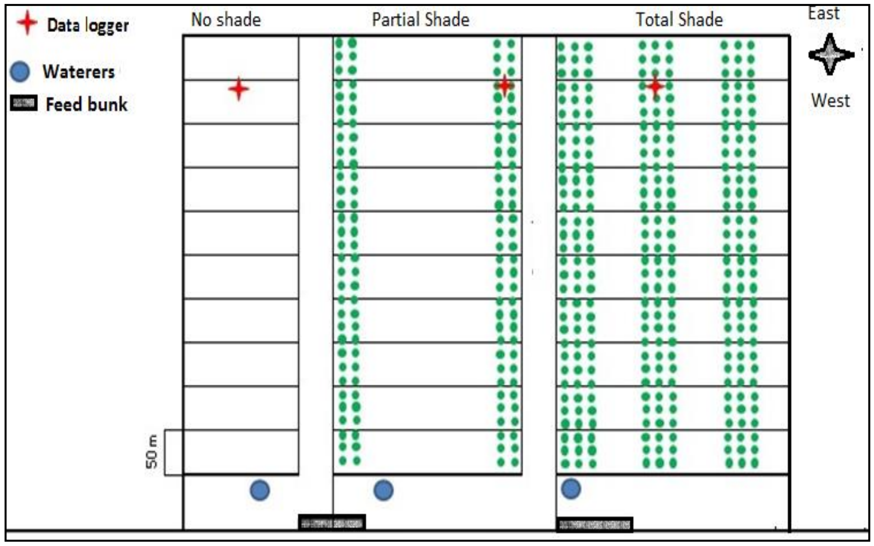

Figure 1. Schematic view of experimental area.

BGT and WS), thermal comfort indexes (THI and HLI) and physiological variables (RR and ST) were performed using the procedure for mixed models in SPSS® program version 16 (IBM Software). Treatments, day, time and interaction between treatments were considered as fixed effects. The normality of the variance was evaluated for all variables using the Kolmogorov-Smirnov test. The averages were adjusted for multiple comparisons by the method of least significant difference (LSD) being adopted with a significance level <0.05.

Pearson correlation coefficients ($r_{Pearson}$) were determined among physiological variables and HLI. The proportion of the shade usage, grazing activities, water intake, rumination, idleness, as well as the time spent standing, lying or walking were analyzed by Kruskal-Wallis non-parametric test (KS). Medians were compared by the Mann-Whitney test (U) when a significant difference among treatments was observed by KS.

RESULTS

Environmental variables

The shade availability affected the microclimate of the paddocks (Table 1). The DBT, BGT, WS, THI and HLI were higher (P<0.05) at no shade in comparison with partial shade or total shade. On the other hand, the RH was higher (P<0.05) in the total shade treatment in comparison with no shade and partial shade treatments.

No shade treatment presented higher DBT values (P<0.05) than those treatments with shade during the day-time. The maximum DBT (37.1°C) was observed at 15:00 h. At this time, shade treatments reduced the DBT by approximately 4°C (33.0°C).

Smaller values of RH (47.3% vs. 58.5%) were verified at 15:00 h respectively, for no shade and partial shade treatments. The values found for the BGT in the no shade treatment were higher (P<0.05) than those treatments with shade all day long. Both thermal comfort indexes THI and HLI showing highest values (P<0.05) for no shade treatment.

Physiological variables

Animals with shade availability showed smaller values (P<0.05) for RR and ST. The RR of the heifers was higher (P<0.05) in the no shade treatment (77 mov min^{-1}) followed by total shade (69 mov min^{-1}) and partial shade (64 mov min^{-1}). The RR in the afternoon was higher than in the morning. The treatments with partial shade (76 mov min^{-1}) and total shade (83 mov min^{-1}) showed lower values of RR compared with the no shade treatment (99 mov min^{-1}).

The ST was higher (P<0.05) in the no shade treatment in comparison with partial shade (31.8°C) and total shade (32.7°C) treatments, which did not differ from each other. ST in the afternoon was higher than in the morning. Partial shade (33.7°C) and total shade (34.1°C) treatments showed lower values of ST compared with No shade treatment (42.1°C).

The HLI showed a positive relationship with RR ($r_{Pearson}$=0.67) and ST ($r_{Pearson}$=0.51). As expected, RR and ST were increased when HLI was increased. No shade treatment animals were more vulnerable to this effect when compared with shade treatments (Figure 2).

Animal behavior

The shade availability affected the grazing time of the heifers (U=246.5, P<0.05, Figure 3). The animals grazed 10% more in shade treatments compared with no shade treatment. The animals in no shade treatment decreased the grazing activity from 12:00 h to 13:00 h time that

Table 1. Average values (minimum and maximum) of environmental variables and thermal comfort indexes during the trial period.

Environmental variable	No Shade		Partial Shade		Total Shade	
	Mean	Range	Mean	Range	Mean	Range
Dry bulb temperature (°C)	34.4[a]*	28.3-37.1	30.7[b]	27.0-32.9	30.6[b]	26.7-33.3
Relative Humidity (%)	55.7[c]	47.3-73.1	66.5[b]	58.6-82.0	71.9[a]	62.1-85.7
Black globe temperature (°C)	41.6[a]	33.0-45.9	32.6[b]	27.4-35.3	32.8[b]	27.4-36.3
Wind speed (m. s^{-1})	0.9[a]	0.7-1.2	0.6[b]	0.5-0.8	0.3[c]	0.1-0.4
THI[1]	84[a]	79-87	81[c]	78-84	82[b]	78-85
HLI[2]	98[a]	90-104	88[c]	82-93	93[b]	84-98

*Row with differing superscripts are significantly different (P<0.05); [1]THI= Temperature–humidity index; [2]HLI= Heat load index.

coincides with the highest values of HLI (HLI=100) and in the late afternoon (16:00 h) grazing activity was increased.

No differences were found among treatments for rumination time (KS= 0.60, P=0.74), displacement (KS=0.22, P=0.89) and water intake (KS=5.37, P= 0.07). The average time spent with the activities of rumination and displacement were 30 and 8% of the total time, respectively.

Heifers in no shade treatment remained longer (43.7%) on resting behavior (U=284.0, P=0.001, Figure 4) when compared with the heifers in partial shade (37.7%). Resting time differed (U=287.5, P=0.001) among treatments with 37.7 and 38.2% for partial and total shade, respectively.

Heifers of the total shade treatment were recorded more often (U=315, P=0.003) standing (68.6%) than those at no shade (58.2%). Time spent lying was higher (41.8%) for animals in the no shade treatment (U=315.0, P=0.01) when compared with heifers with access to total shade (31.4%).

No difference was found in the use of shade between partial and total shade treatments (U=513.5, P=0.69, Figure 5). This feature was effectively used by heifers and corresponding on average 60% of the time in the shade.

DISCUSSION

Shade provides by trees modified the microclimate of the pasture resulting in a reduction of approximately 4°C air temperature and increase of relative humidity. Trees introduction reduced the wind speed and the solar radiation, creating a mild temperature regime with higher humidity levels. This occurred because the aerial part of the trees (canopy) can become a physical protection for the pasture, reducing the wind speed, decreasing direct losses from the soil and its humidity evaporation (Franke and Furtado, 2001).

The microclimatic conditions in a silvopastoral systems and its effects on heifers grazing behavior were evaluated by Lopes et al. (2016). The average temperature were higher than 30°C during the experimental period, and the two strategies with *Eucalyptus* rows adopted were not able to mitigate the heat stress conditions. Although better conditions were found under the tree canopy in both silvopastoral arrangements.

Thermal comfort indexes THI and HLI were high in all treatments ranging from 78 to 87 for THI, and 82 to 104 for HLI. The values were higher than the recommended limits in all treatments showing stressful thermal environment conditions to dairy heifers. Maximum productive potential of heifers could be expressed under THI and HLI around 72 and 77 units, respectively. However, these limits are only a guide and may be higher or lower depending on other factors, such as diet, feed intake and breed. Also, we can recognize that shade environments reduced the heat load index.

Shade availability decreased the RR between 17 and 10%, respectively, for partial and total shade treatments. The RR can quantify the severity of heat stress: 40 to 60 frequencies mov min^{-1} animals are in mild stress, 60 to 80 mov min^{-1} in medium stress, 80 to 120 mov min^{-1} in high stress and over 120 mov min^{-1} in severe stress (Silanikove, 2000). All heifers experienced stress in our experiment; in partial shade (76 mov min^{-1}) they were under medium stress, while in total shade (83 mov min^{-1}) and no shade treatments (99 mov min^{-1}) they were under high stress. Even though crossbred heifers are considered to be higher heat tolerant than pure dairy-bred, we found that heat stress has a significant effect on physiological responses. Consequently, shade provided by trees could mitigate the heat stress on pasture-based systems in tropical areas.

Rovira and Velazco (2010) evaluated the effects of artificial and natural shade on the respiratory rate, behavior and development of steers during the summer, observed that animals under shade showed a lower respiratory rate average than animals without shade, 64 and 74 mov min^{-1}, respectively. Steers with access to natural shade showed 6 mov min^{-1} less than those with access to artificial shade.

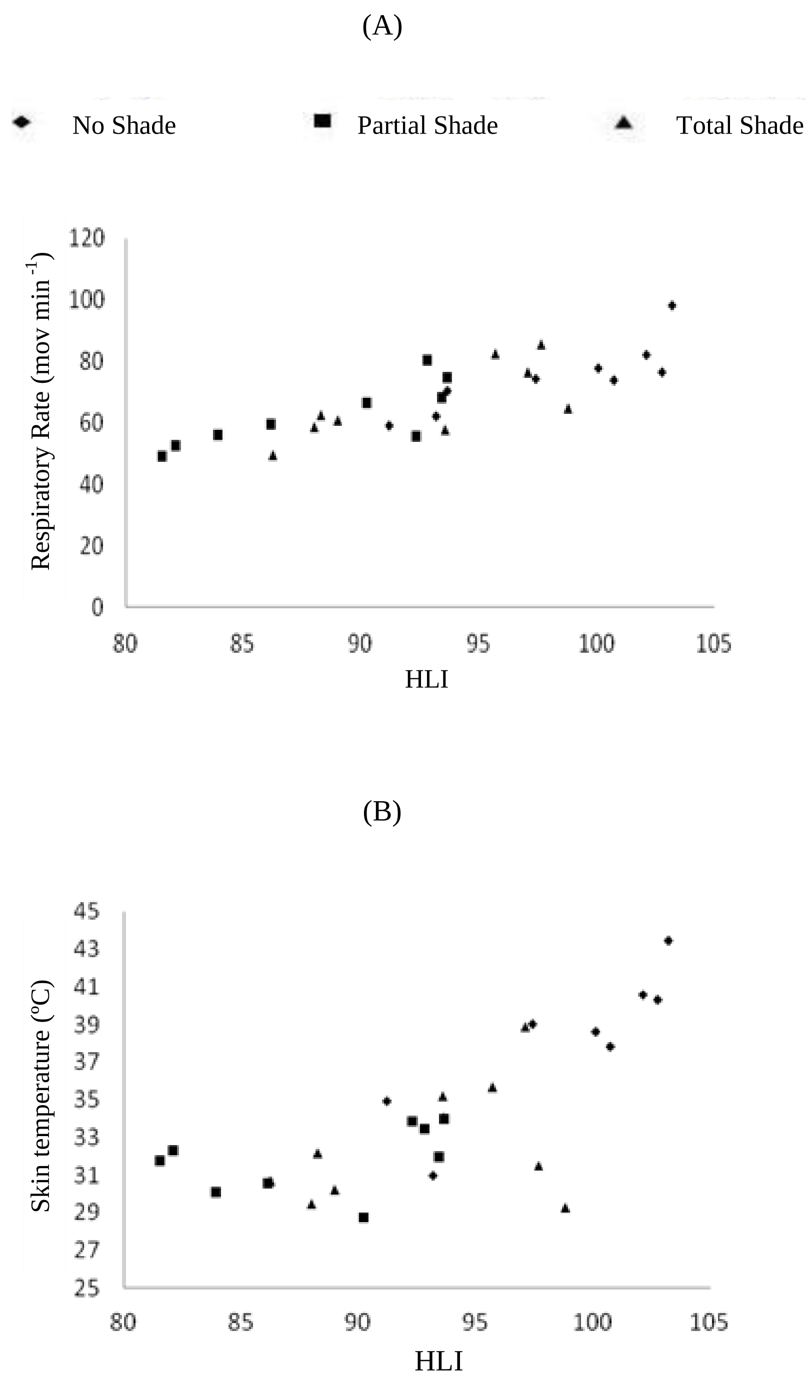

Figure 2. Relationship between (A) heat load index (HLI) and respiratory rate and (B) skin temperature of heifers in no shade, partial shade or total shade treatments.

High environment temperature could decrease the ability of cattle to dissipate body heat and it results in increased body temperature with negative influences on the productive performance. Thus, environmental modifications such as shade or evaporative cooling should be adopted to facilitate heat exchanges (West, 2003).

Heifers in shade treatments had lower ST with values of 31.8 and 32.8°C for partial and total shade, respectively. Shade reduced ST 5 to 6°C compared with no shade treatment. According to Collier et al. (2006) when skin surface temperature is lower than 35°C, the

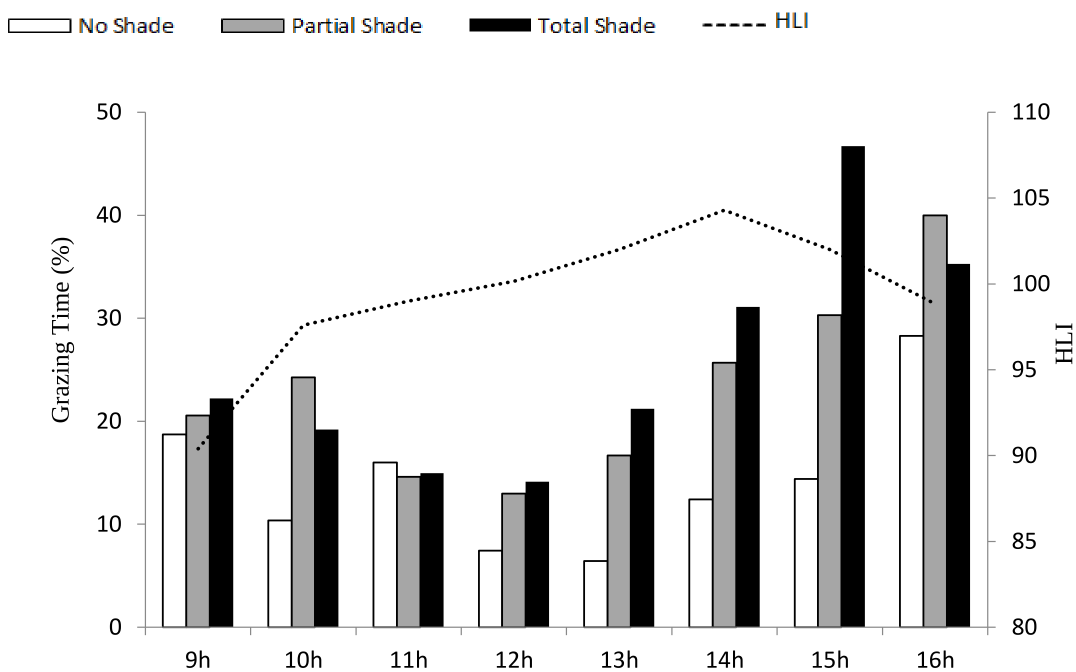

Figure 3. Percentage of grazing time of the dairy heifers from 9:00 h to 16:00 h in no shade, partial shade or total shade treatments.

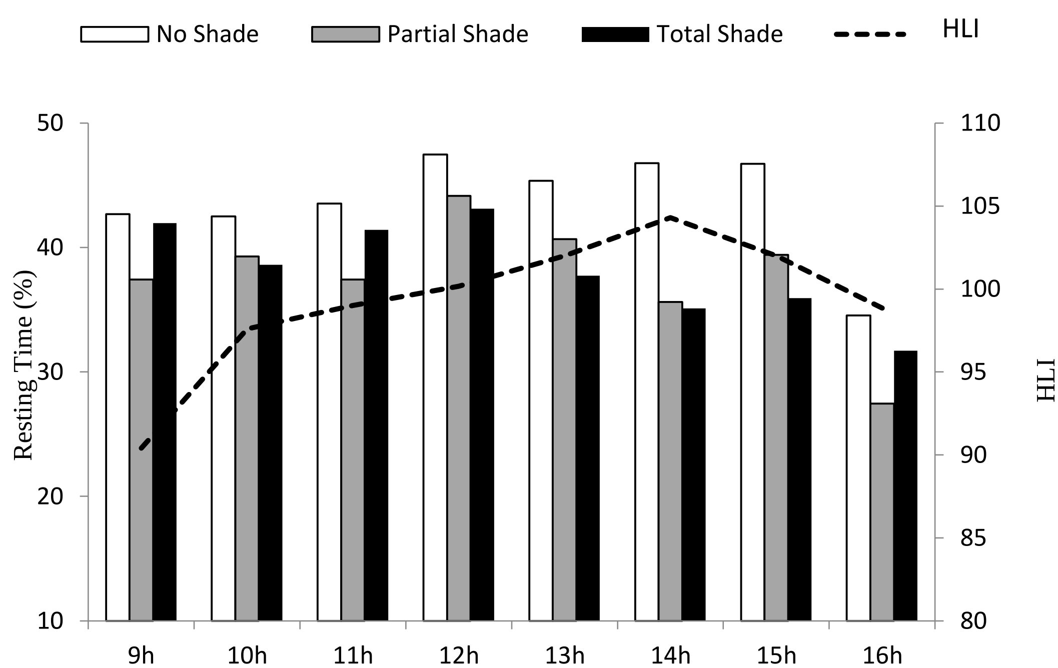

Figure 4. Percentage of the time spent in rest from 9:00 h to 16:00 h in no shade, partial shade or total shade treatments.

temperature gradient between body core and skin is enough for the animals to effectively use the four basic methods (conduction, convection, radiation and evaporation) of heat exchange. As a result, the shade provision reduced skin temperature showing that animals exposed to a partial shade had better thermal comfort.

Our findings shown heifers with shade access spent an average of 60% of the time using this resource. It was

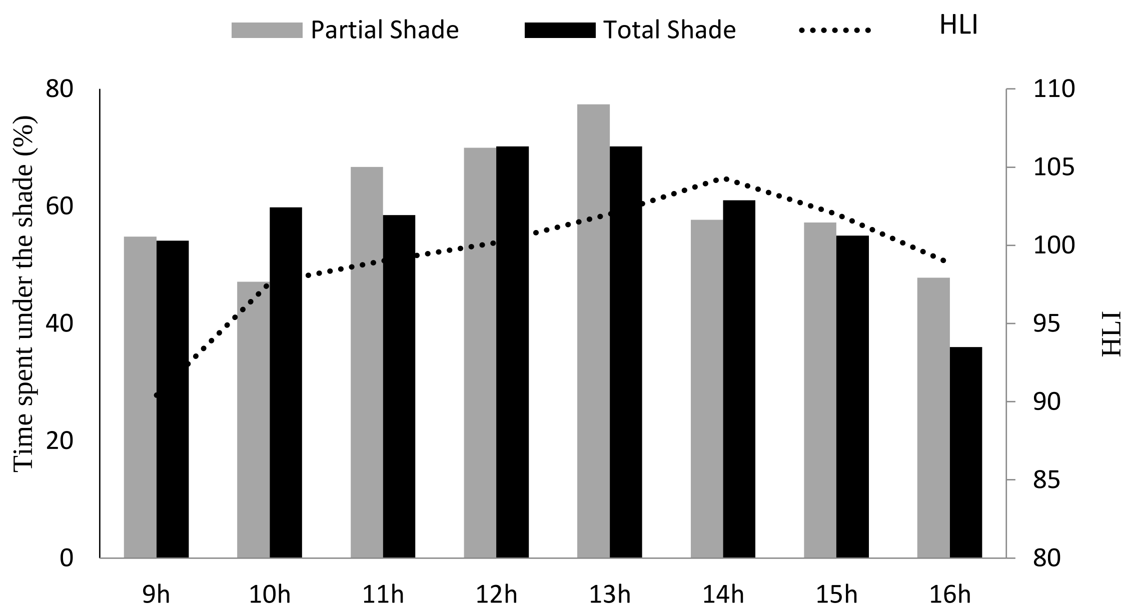

Figure 5. Percentage of time spent under the shade in partial and total shade treatments from 9:00 h to 16:00 h.

expected, since these cows tend to remain under the shade due to the coolest microclimate. Both treatments with trees had enough shade area where heifers were able to share it and not compete for it as recommended by Schütz et al. (2010).

Grazing behavior could be affected by daytime heat accumulation. Also, time spent under the shade is positively related to ambient temperature, solar radiation and rectal temperature (Sprinkle et al., 2000; Bennett et al., 1985). Shade availability increased the heifers´ grazing time even during the hottest hours. It was a beneficial response considering that dairy herds could reduce the feed intake to minimize the thermal imbalance and maintain the homeothermy (Yousef, 1985).

Previous research with livestock-forestry system found similar results with crossbred Holstein x Zebu and concluded this system could provide a thermal comfort for animals resulting in longer time on grazing (Paes Leme et al., 2005).

Heifers in shade treatments remained standing for a longer period (66.4%). However, as reported previously, this pattern was associated with the increase on grazing time. Specific environmental condition can stimulate more than one behavioral response and animal learns to employ the most efficient one (Curtis, 1981).

The longest resting time (43.7%) found in the no shade treatment might be associated as an endogenous strategy to reduce heat production. Although no difference was observed in the time spent on water intake, this was a frequent animal behavior in no shade treatment. These results supporting previous findings, where the time around the water trough was increased for animals with shade availability reduced or no shade treatment (Schütz et al., 2010; Mader et al., 1997). According to these authors, the water evaporation produces a microclimate that cools the animals.

Conclusion

Shade availability in a livestock-forestry increased the heifers´ grazing time and decreased respiratory rate and skin temperature.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Ainsworth JAW, Moe SR, Skarpe C (2012). Pasture shade and farm management effects on cow productivity in the tropics. Agric. Ecosyst. Environ. 155:105-110.
Baruch Z, Guenni O (2007). Irradiance and defoliation effects in three species of the forage grass Brachiaria. Trop. Gras. 41:269-276.

Bennett IL, Finch VA, Holmes CR (1985). Time spent in shade and its relationship with physiological factors of thermoregulation in three breeds of cattle. App. Anim. Behav. Sci. 116:28-34.

Berry IL, Shanklin MD, Johnson HD (1964). Dairy shelter design based on milk production decline as affected by temperature and humidity. Transac. ASAE. 7:329-331.

Collier RJ, Dahl GE, Vanbaale MJ (2006). Major advances associated with environmental effects on dairy cattle. J. Dairy Sci. 89:1244-53.

Curtis SE (1981). Environment management in animal agriculture. Animal Environment Services Illinois.

Devkota NR, Kemp PD, Hodgson J, Valentine I, Jaya IKD (2009). Relationship between tree canopy height and the production of pasture species in a silvopastoral system based on alder trees. Agrofor. Syst. 76:363-374.

Ferreira LCB, Machado Filho LCP, Hotzel MJ, Alves AA, Barcellos AO (2014). Respostas fisiológicas e comportamentais de bovinos submetidos a diferentes ofertas de sombra. Cadernos Agroecol. 9:1-14. (In Portuguese).

Franke IL, Furtado SC (2001). Sistemas Silvipatoris: Fundamentos e Aplicabilidade. Documento 74. Embrapa. Acre:Rio Branco.

Gaughan JB, Mader TL, Holt SM, Lisle A (2008). A new heat load index for feedlot cattle. J. Anim. Sci. 86:226-234.

Lopes LB, Eckstein C, Pina DS, Carnevalli RA (2016). The influence of trees on the thermal environment and behavior of grazing heifers in Brazilian Midwest. Trop. Anim. Health Prod. 5:755-761.

Mader TL, Fell LR, Mcphee MJ (1997). Behavior response of non-Brahman cattle to shade in commercial feedlots. Livest. Environ. 5:795-802.

Martin P, Bateson P (1993). Measuring Behaviour : An Introductory Guide. Second ed. United Kingdom.

Mello ACT, Carnevalli RA, Shiratsuchi LS, Pedreira BC, Lopes LB, Xavier DB (2017). Improved grazing activity of dairy heifers in shaded tropical grasslands. Cienc. Rural. 47:1-7

Paciullo DSC, Castro CRT Gomide CAM, Fernandes PB, Rocha WSD, Müller MD, Rossiello ROP (2010). Soil bulk density and biomass partitioning of *Brachiaria decumbens* in a silvopastoral system. Sci. Agricola. 67:401-407.

Paes Leme TMS, Pires MFÁ, Verneque RS, Alvim MJ, Aroeira LJM (2005). Behavior of holstein x zebu crossbreed cows grazing *Brachiaria decumbens* in a silvipastoral system. Ciênc. Agrotec. 29:668-675.

Rovira P, Velazco J (2010). The effect of artificial or natural shade on respiration rate behavior and performance of grazing steers. New Zeal. J. Agric. Res. 53:347-353.

Salton JC, Mercante FM, Tomazia M, Zanatta JA, Concenço G, Silva WM, Retore M (2014). Integrated crop-livestock system in tropical Brazil: Toward a sustainable production system. Agric. Ecosyst. Environ. 190:70-79.

Schütz KE, Rogers AR, Poulouin YA, Cox NR, Tucker CB (2010). The amount of shade influences the behavior and physiology of dairy cattle. J. Dairy Sci. 93:125-133.

Silanikove N (2000). Effects of heat stress on the welfare of extensively managed domestic ruminants. Livest. Prod. Sci. 67:1-18.

Sousa LF, Maurício RM, Moreira GR, Gonçalves LC, Borges I, Pereira LGR (2010). Nutritional evaluation of “Braquiarão” grass in association with “Aroeira” trees in a silvopastoral system. Agrofor. Syst. 79:179-189.

Sprinkle JE, Holloway JW, Warrington BG, Ellist WC, Stuth JW, Forbes TD, Greene LW (2000). Digesta kinetics energy intake grazing behavior and body temperature of grazing beef cattle differing in adaptation to heat. J. Anim. Sci. 78:1608-1624.

Tucker CB, Rogers AR, Schütz KE (2008). Effect of solar radiation on dairy cattle behaviour use of shade and body temperature in a pasture- based system. Appl. Anim. Behav. Sci. 116:28-34.

Valtorta SE, Leva PE, Gallardo MR (1997). Evaluation of different shades to improve dairy cattle web-being in Argentina. Int. J. Biometeorol. 41:65-67.

West JW (2003). Effects of heat-stress on production in dairy cattle. J. Dairy Sci. 86:2131-2144.

Yamamoto W, Dewi IA, Ibrahim M (2007). Effects of silvopastoral areas on milk production at dual-purpose cattle farms at the semi-humid old agricultural frontier in central Nicaragua. Agric. Syst. 94:368-375.

Yousef MK (1985). Stress Physiology in Livestock. Basic Principles. CRC Press: Florida.

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Full Length Research Paper

Utilization of wheat bran and dried *Acacia saligna* *(*Labill) H.L.Wendl leaves by highland rams

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This study was conducted to evaluate body weight gain, feed intake and digestibility of highland sheep supplemented with wheat bran and dried *Acacia saligna* leaf five treatments, namely grass hay as a control (T1), 100 g per day *A. saligna*, (T2), 200 g per day *A. saligna* (T3), 300 g per day *A. saligna* (T4) and 400 g per day *A. saligna (*T5) with a fixed amount (200 g per day) of wheat bran was provided to the supplemented groups. Ram lambs in the control group gained 7.8 g/day while ram lambs placed under T2, T3, T4 and T5 gained 42.8, 63.9, 62.2 and 57.8 g/day. Thus, supplementation of 200 g/day dried *A. saligna* and 200 g/day wheat bran is biologically more efficient and economically more profitable and thus recommended for highland ram lambs fattening.

Key words: *Acacia saligna*, digestibility, grass hay, highland sheep, Mekelle Agricultural Research Centre, wheat bran.

INTRODUCTION

Acacia cyanophylla Lindl. (Syn. *A. saligna* (Labill.) H. Wendl) is a leguminous shrub which provides large amounts of fodder for ruminants in arid and semi-arid regions (Ben Salem et al., 1999; Safinaz et al., 2010). *A. saligna* is one of the introduced browse shrub or tree species, which is widely grown and evergreen in different agro-ecological zones of Tigray (Shumuye and Yayneshet, 2011). *A. saligna* has reasonably large amount of crude protein (Moujahed et al., 2000), which has the potential to supplement the predominantly poor quality fibrous feeds widely used by smallholder farmers. As with other acacia species, the major limiting factor in the use of *A. saligna* is the presence of high concentration of tannins (Moujahed et al., 2005; Shumeye and Yayneshet, 2011). The low protein digestibility of *A. cyanophylla* in sheep was due to the high level of condensed tannins (CT) in its foliage (Degen *et al.,* 1995). Although the use of polyethylene glycol (PEG) to deactivate tannin has been recommended (Ben Salem et al., 1997; Moujahed et al., 2000; Ben Salem et al., 2005b; Olivares et al., 2013; Rojas et al., 2015a; Rojas et al., 2015b), its wider use under smallholder

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farmers is constrained not only by its cost (Moujahed et al., 2005) but also its availability in the market. Air drying improves palatability, intake and digestibility (Shumuye and Yayneshet, 2011; Olivares et al., 2013). Sun-drying was slightly more efficient in reducing CT levels in the acacia foliage (Ben Salem et al., 1999).

Like other tropical forages, *A. saligna* is deficient in energy and could be provided to ruminants with other energy sources (Silanikove et al., 1997; Nicholas et al., 2007; Safinaz et al., 2010). With the flourishing of agro-processing plants (Yayneshet, 2010), the availability and price of wheat bran make it tone of the best energy sources under the smallholder socioeconomic context. Beside to improving the feeding value of *A. saligna* the appropriate level to supplement sheep is not yet studied in our country. Hence, the objectives of this study were to: (1) Evaluate the nutrient contents of the experimental diets; (2) Measure body weight gain, feed intake and digestibility; (3) Evaluate the nitrogen balance in highland rams fed wheat bran and *A. saligna* in different proportions.

MATERIALS AND METHODS

Study area description

The study was conducted at Mekelle Agricultural Research Center (MARC) 13°31'N latitude and 39°58'E longitude. Average annual rainfall is 475.5 mm and altitude fall in 2000 m.a.s.l (Siyoum and Yesuf, 2013).

Experimental feeds

A. saligna leaves were collected from 2 to 3 years old stand by hand plucking. The harvested leaves were air dried for five days. A total of 500 kg dried *A. saligna* leaves were collected and packed in waterproof sacks. Native grass hay (*Cynodon dactylon*) was harvested from MARC's experimental fields at 50% heading. Wheat bran was purchased from a private flour milling industry, and mixed with *A. saligna* leaves.

Experimental animals and their management

Twenty yearling highland sheep rams with an average initial body weight of 21.9±1.86 kg were purchased from the local market in Atsbi district in the study region. Age was estimated from the presence of milk tooth. The experimental animals were tagged for identification and treated against internal and external parasite using anti-helminths Albendazole (7.5 mg/kg weight ingested through mouth) and Ivermaectin (0.2 mg/kg weight, administered through subcutaneous injection), respectively (DACA, 2013). The housing was made of concrete floor, aerated from the sides, roofed with corrugate sheet and had good drainage for ease of cleaning. Clean water and salt were provided freely throughout the experiment period on individual bases.

Experimental design and treatments

A randomized complete block design (RCBD) with four blocks and five treatments/block was used. The experimental treatments were (1) T1: Grass hay *ad libitum*; (2) T2: T1+ 100 g of air dried *A. saligna* leaves + 200 g wheat bran; (3) T3: T1+ 200 g of air dried *A. saligna* leaves+ 200 g wheat bran; (4) T4: T1+ 300 g of air dried *A. saligna* leaves + 200 g wheat bran and (5) T5: T1+ 400 g of air dried *A. saligna* leaves + 200 g wheat bran. The supplementation was scheduled at two equal portions (8:00 am and 16:00 pm).

Measurements

Chemical composition

Nitrogen (N) content of the feed, feces and urine were analyzed according to Kjeldahl method (AOAC, 1990). The CP was calculated N x 6.25. The apparent nutrient digestibility coefficient (DC) was calculated total amount of nutrients in feed minus the total amount of nutrient in feces divided by the total amount of nutrient in the feed and finally multiplied by 100. Digestibility of the dry matter (DDM), digestibility of the organic matter (DOM) and digestible organic matter in dry matter (DODM) was analyzed according to MAFF (1975). The fiber content (dry matter (DM), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) and Ash) of the experimental feeds was examined according to (Van Soest et al., 1991) and the condensed tannin content was determined according to (Burns, 1971).

Feed intake and feed conversion efficiency

The amount of feed offered and refused for each sheep was measured every day for the whole 90 days of the experimental period. The feed intake was calculated by subtracting the refusal from the offered feed. Feed conversion efficiency was calculated by dividing daily live weight gain by daily feed intake.

Live weight change

Live body weight record was taken every Friday for each animal for the whole experimental days. The live weight change and daily live weight gain were calculated initial body weight subtracted from the final live weight and the daily live weight gain was a result of final body weight minus initial body weight divided by the 90 days the trial undertaken.

Digestibility

Feces and urine were collected for 7 days following 3 days adaptation trial. The daily fecal excretion of each ram was mixed thoroughly according to their treatment and 10% was sampled and kept in air tight plastic containers and stored at -4°C refrigerator. About 100 mL urine was mixed with 10% H_2SO_4 to maintain pH value below 3.0 (Osuji et al., 1992). Urine was collected twice a day in the morning and evening. Out of the total collected urine 10% of urine was sampled from each sheep and stored frozen for each treatment prior to determine N yield (Chen et al., 1990).

Statistical model and data analysis

The following statistical model: $Yij = \mu + \tau i + \beta j + \epsilon ijk$ was used in analyzing the data. Where; Yij = the overall response; μ = overall mean; τi = ith treatment effect (i= 1,2,3,4,5); βj = jth block effect (j= 1, 2, 3, 4); ϵijk = overall treatment and block effect. Data on the nutrient and dry matter intake, nutrient digestibility, nitrogen balance and live weight change were subjected to analysis of variance (ANOVA) using JMP5 (SAS Institute Inc, 2002) and mean

Table 1. Chemical composition of experimental feeds and treatments.

Feeds	Chemical composition (%)										
	DM	OM	CP	NDF	ADF	ADL	Ash	SM	H	C	CT
GH	94.71	91.77	6.55	76.15	50.62	10.43	8.23	23.85	25.53	31.96	-
WB	93.58	93.73	16.20	48.01	15.52	3.52	6.27	51.99	32.49	5.73	-
AS	92.03	84.91	14.84	43.39	30.56	8.04	15.09	56.61	12.83	7.43	13.78
Trt	**Chemical composition (g d^{-1})**										
	DM	**OM**	**CP**	**NDF**	**ADF**	**ADL**	**Ash**	**SM**	**H**	**C**	**CT**
T1	751.7	690	49.2	572	380	78.4	62	428	193	240	-
T2	981.5	898	90	515	317	106	83.4	485	198	128	12.7
T3	1095	996	105	721	451	97	99	279	270	255	25
T4	1168	1057	117	749	471	103	111	251	278	258	37
T5	1227	1106	127	769	468	107	121	231	283	258	47.5

GH = grass hay; WB = wheat bran; SM = soluble matter; H = hemicelluloses; C = cellulose; Trt = treatment; DM = dry matter; OM = organic matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL = acid detergent lignin; AS = *Acacia saligna*; [a'] = 100%-NDF; [b'] = NDF-ADF; [c'] = ADF-(ADL+Ash); CT = Condensed Tannin; - = value not found.

Table 2. Daily dry matter and nutrient intake of highland sheep rams.

Parameters (g days^{-1})	Treatments T1	T2	T3	T4	T5	SEM	SL
DMI	751.73^{d}	981.47^{c}	1095.29^{bc}	1167.92^{ab}	1226.88^{a}	28.988	***
OMI	689.86^{d}	898.05^{c}	996.21^{bc}	1057.13^{ab}	1105.95^{a}	26.511	***
CPI	49.24^{e}	89.98^{d}	105.04^{c}	116.72^{b}	126.98^{a}	2.0569	***
NDFI	572.44^{c}	664.56^{b}	721.19^{ab}	749.14^{ab}	768.77^{a}	21.692	***

$^{a, b, c, d, e;}$ means within a row not bearing a common superscript letter significantly differ. ***= (p<0.0001); NS = not significant; DMI = Dry matter intake; SEM = Standard error of mean; OMI = Organic matter intake; CPI = Crude protein intake; NDFI = Neutral detergent fiber intake; SL = significant level.

comparison was done using Tukey's (Honest Significant Difference) HSD test at P<0.05 (Sokal and Rohlf, 1981).

RESULTS

Chemical composition

The chemical composition of *A. saligna*, wheat bran and grass hay is presented in (Table 1). The nutrient content of experimental feeds varied as they came from different sources. Wheat bran contained the highest CP content followed by *A. saligna* and grass hay. The NDF content of *A. saligna* was lower than wheat bran and grass hay. The CT content of treatment feeds rose progressively from T2 to T5.

Dry matter and nutrient intake

The dry matter intake and nutrient intake data are presented in (Table 2). The highest total DMI (1226.88 g days^{-1}) and OMI (1105.95 g days^{-1}) were recorded for rams placed under T5. Total DMI and OMI significantly (P<0.001) higher in the supplemented rams than the control rams. The daily grass hay dry matter intake was not affected by supplementation and showed no significant difference (p>0.05) between the supplemented and control group.

Nutrient digestibility

Nutrient digestibility in rams supplemented with wheat bran and different levels of *A. saligna* leaves were significantly (P<0.001) higher in nutrient digestibility from the control group (Table 3). DCP values were significant (P<0.0001) higher at supplemented rams and pronounced at rams assigned to T4. *A. saligna* supplementation did not impose any negative effect on digestibility as the supplemented groups had higher digestibility than the control group.

Nitrogen balance

Nitrogen (N) intake and retention was efficiently utilized in T4 rams as that group had significantly (P<0.05) higher in

Table 3. Nutrient digestibility in highland sheep fed on grass hay and supplemented with wheat bran and graded level of *A. saligna.*

Nutrient (%)	Treatment					SEM	SL
	T1	T2	T3	T4	T5		
DMD	64.89[e]	75.51[d]	78.34[c]	80.54[a]	79.98[b]	0.0613	***
DOM	69.99[e]	78.34[d]	80.58[c]	81.99[a]	81.31[b]	0.07533	***
DCP	58.56[e]	75.48[c]	73.81[d]	77.38[a]	76.75[b]	0.10273	***
DNDF	58.51[e]	63.29[d]	69.60[a]	68.81[b]	67.12[c]	0.07922	***
DADF	57.61[c]	61.11[b]	68.88[a]	68.87[a]	68.90[a]	0.08847	***

[a, b, c, d, e;] means within a row not bearing a common superscript letter significantly differ. ***= (p<0.0001); DMD = Dry matter digestibility; SEM = Standard error of mean; OMD = Organic matter digestibility; CPD = Crude protein digestibility; NDFD = Neutral detergent fiber digestibility; ADFD = Acid detergent fiber digestibility; SL= Significance level.

Table 4. Nitrogen intake, excretion and retention in highland sheep rams feed on hay and supplemented with wheat bran and graded level of *A. saligna.*

Parameter ($g\ days^{-1}$)	Treatment					SEM	SL
	T1	T2	T3	T4	T5		
Total N intake	7.44[b]	10.91[ab]	13.97[ab]	14.86[a]	13.42[ab]	1.662	*
N voided in feces	2.41[b]	2.68[ab]	3.52[a]	3.50[a]	3.36[ab]	0.23775	*
N voided in urine	1.62	0.89	1.05	0.69	1.08	0.274	Ns
Total N voided	4.03[ab]	3.57[b]	4.57[a]	4.19[ab]	4.44[a]	0.1994	*
N retention	3.41[b]	7.34[ab]	9.40[ab]	10.66[a]	8.98[ab]	1.5262	*

[a, b]means within a row not bearing a common superscript letter significantly difference; *= (p<0.05); Ns = not significance; $g\ days^{-1}$ = gram per day; SEM = Standard error mean; SL= Significance level.

Table 5. Body weight change and efficiency of highland sheep fed on basal diet grass hay and supplemented with wheat bran and graded level of *Acacia saligna.*

Body weight	Treatments					SEM	SL
	T_1	T_2	T_3	T_4	T_5		
Initial body weight (kg)	21.80[a]	21.9[a]	22.45[a]	21.6[a]	21.95[a]	1.0323	Ns
Final body weight (kg)	22.5[b]	25.75[ab]	28.2[a]	27.2[a]	27.15[a]	1.1805	*
ADBWG (g/d)	7.78[b]	42.78[ab]	63.89[a]	62.22[a]	57.78[a]	8.5515	*
FCE (g LWG/ g DMI)	0.007[b]	0.04[ab]	0.065[a]	0.061[ab]	0.066[a]	0.01255	*

[a, b]Mean in the same row with different superscript differ significantly; * = (P<0.05); SEM = standard error of mean; SL = Significance level; Ns = not significance; FCE = feed conversion efficiency; ADBWG = average daily body weight gain; (g/d) = gram per day); DMI = dry matter intake; LWG = live weight gain; kg = kilogram; g = gram; SL = significance level.

N intake and retention, but not to the other supplemented group and control group (Table 4). Rams assigned to T3 and T5 was higher (P<0.05) in N excretion, but T2 rams excrete less N (P>0.05).

Live weight changes

Rams of the supplemented group (T3, T4 and T5) had better (P<0.05) in their final weight and daily live weight gain (DLWG) (Table 5). However, the DLWG increased till T3 and start to decline even with an increase level of *A. saligna* in the highest supplemented rams (T4 and T5). This implies rams satisfy their requirement with supplemente of 200 g/days *A. saligna* and 200 g/days wheat bran. Adding more *A. saligna* means they excrete either in the form of urine or feces. The feed conversion efficiency (FCE) also varied significantly (P<0.05) between T1 and T3 and T5. However, for economic reasons T3 was best suited to the rams.

DISCUSSION

Chemical composition

DM, OM and CP of A. *saligna* used in this study contained 92.03, 84.91 and 14.84%, respectively. The

OM content found in this study is comparable with other authors (Ahmed, 2007; Moujahed *et al*., 2000; Mousa, 2011; Shumuye and Yayneshet, 2011). The CP content of *A. saligna* was comparable to 13.8, 13.76 and 15.7% CP (Krebs et al., 2007b; Safinaz et al., 2010; Chentli et al., 2014) and higher than the value reported by others (Shumuye and Yayneshet, 2011; Moujahed et al., 2000; Ahmed, 2007; Mousa, 2011). This variation arises from age and species of the Acacia plant, soil fertility where the Acacia plant grown and the season of the leaf harvest. Different studies also suggested this idea the differences in CP content between these browse plants are probably due to differences in protein accumulation in them during growth (Salem et al., 2006). Some differences might also have been due to stage of plant growth and/or season of collection (Ben Salem et al., 2005a). Nutritive value difference in *A. saligna* were primarily the result of change in maturity (Abdel-Fattah, 2005). Inconsistencies could also be due to sampling site and climatic influences on foliage growth and plant nutrient accumulation (Salem, et al., 2006). Abdel-Fattah (2005) also explains season of production affects the CP content of *A. saligna* that is CP content was lower in summer compare to autumn, winter and spring. Overall, the environment in which the plant grow had high impact on the plant characteristics and composition (Abdel-Fattah, 2005; Ben Salem et al., 2005a) also insisted soil type, fertility and water supply affect nutrient concentrations in plants.

The NDF, ADF and ADL content are less than the value reported by Shumuye and Yayneshet (2011). Similar to the CP content of *A. saligna* its fiber content also affected by different factors like production season and soil type, age of the plant and the like. In agreement with this (Abdel-Fattah, 2005) reported NDF, ADF and ADL content of *A. Saligna* had lower in winter compared to other seasons. The Acacia leaf used in this study was at the young age this may contribute to low fiber content. As the plant get older the fiber content rise and vice versa. Abdel-Fattah (2005) described the nutritive value variation of Acacia leaves were primarily due to maturity variation.

Condensed tannin content of dried *A. saligna* found in this study is lower than the value reported by (Abdel-Fattah, 2005) 63 g/kg DM to 113 g/kg DM in summer and winter, respectively for fresh *A. saligna*, 63.1 g/kg DM CT for fresh *A. saligna* (Chentli et al., 2014), 24.6 g/kg DM CT for *A. saligna* (Krebs et al., 2007b) and 18.67% of CT for *A. saligna* reported by Shumuye and Yayneshet (2011). The CT value of this study is within the beneficial category of 20 to 40 g/kg DM reported by Thi et al. (2005) of the variability in condensed tannin content contribution of many factors. According to Abdel-Fattah (2005), variation in CT appear because of soil type, fertility and water supply affect tannin concentrations in plants. CT content varied from source of plant parts and growing stage (Getnet et al., 2008) and plant age (Krebs et al., 2007a). Beside to the above variation treatment effect also one of the main factors in reducing the condensed tannin content of *A. saligna*. Drying of acacia foliage under shade or sun reduced their CT content (Ben Salem et al., 1999). Season of harvest, which collected in spring for this study also contributed in reducing tanning effect. According to Abdel-Fattah (2005), explains the high temperature effect in summer contributes to the concentration of tannin that change because of physiological maturity.

Dry matter intake

The daily total DM, OM, CP and NDF intake in this study was 24, 23.6, 44 and 14%, respectively. Similar to this study, Tamir and Asefa (2009) and Shumuye and Yayneshet (2011) reported that different forms of *A. Saligna* supplementation significantly increased the total DMI, OMI and CPI.

When animals exposed to tannin rich feeds they try to control their intake, this may affect further performance of the animal. Adverse effect of tannin rich feeds control animals by restricting their intake (Ben Salem et al., 2005a). As negative effect of tannin in *A. saligna* leaf can be healed by treating the intake of nutrient improves. Salem et al. (2006) reported that PEG treatment of *A. saligna* increased intake of DM and its components in sheep and goats. Ben Salem et al. (1999) brief treatment of *A. saligna* with PEG increase DCP intake. Similar to this Moujahed et al. (2000) also reported 195 g DM intake improvement observed when sheep feed on dry *A. saligna* and supplement with mineral block. In this study highest intake contribution of *A. saligna* in (T5) to the total DM intake reach 22%. This result was less as compared to 46% share of *A. saligna* from the total DM intake of sheep feed on lucerne hay based diet (Ben Salem et al., 1997). This variation may arise from the supplemental effect of wheat bran and the basal diet grass hay (Moujahed et al., 2000) insisted Acacia intake is somewhat related to the associated forage. Different A. saligna state improve the intake of animals when mixed with good quality roughage (Ben Salem, et al., 1997). Beside treatment methods in reducing the tannin effect of *A. saligna,* feeding to sheep is also beneficial than other livestock as sheep are more resistance to tannin rich feed. Abdel-Fattah (2005) supported this idea; it may be possible to use sheep as models for cattle to characterize tanniniferous feeds (Abdel-Fattah, 2005).

Nutrient digestibility and nitrogen balance

In this study nutrient digestibility increment was observed when moving from control to the supplemented group. Similar to this result, Ben Salem et al. (1999) and Krebs et al. (2007b) reported treatment of *A. saligna* with PEG improves DM and OM digestibility compare to feeding *A.*

saligna in fresh form. Ben Salem et al. (2005b) also insisted wood ash treatment have no effect on intake and OM digestibility of the diet rather it increase crude protein and NDFom digestibility. Similar to this study, Rojas et al. (2015) reported *Acacia* supplemention in sheep diet do not affect the digestibility rather it improves the intake and weight gain of sheep. Increase level of *A. saligna* in ewe supplementation improves digestibility (Maamouri et al., 2011).

Not only the *Acacia* treatment improves the digestibility in this study the supplemental wheat bran also contribute its own share. In agreement to this Moujahed et al. (2000) presented comparism between sheep fed on oat hay and dried *A. saligna* sheep fed on a similar basal diet supplemented with mineral block improves CP digestibility and nitrogen retention. The DCP value found in this study at the supplemental group 73.81 to 77.38% was comparable to 72.8% DCP reported for sheep fed *A. saligna* treated with PGE (Ben Salem et al., 1999). Further mineral block supplementation on *Acacia* based diets have a positive effect (Moujahed et al., 2000). Unlike to this result, Ben Salem et al. (1997) reported field drying, do not have an effect on nutrient digestibility till the DM 150 g whereas with exceeding this level negatively affect nutrient digestibility. The problem pronounced when supplement 300 g DM level of Acacia as it decreases OM, CO and NDF digestibility by 9, 12 and 15% respectively. At the highest level it can also decrease digestibility by 36% (Ben Salem et al., 1997). Air-drying of *A. saligna* has no effect on fiber digestibility (Ben Salem et al., 1999). The disparity of the results with respect to the effect of tannins on cell wall digestibility, suggests that the interaction between CT and cell wall carbohydrates may vary with plant species, animal species, tannin levels and possible tannin structure (Ben Salem et al., 1999). Ben Salem et al. (2005a) reported animals exposed to tannins early in life exhibited higher digestible crude protein intake. The differences in DM intake could affect diet digestibility (Ben Salem et al., 1997).

N intake was higher by 20 to 33% in the supplemented group than the control group. Similarly, N retention was higher in the supplemented group by 32 to 36% of the control group. However, the total N voided was not significant difference between the supplement and control group. This result agreed with Ben Salem et al. (1999) increased urinary N excretion, though not significant. This implies the N consumed was converted to desired hvoided through the wastes Ben Salem et al. (1999) explained, although sheep ingested equal amounts of nitrogen (N), N excretion in feces and urine was similar in sheep fed fresh or air-dried acacia foliage. Hence, *A. saligna* treatment with shed drying had significant impact in reducing the protein binder tannin as the supplemental group display higher N intake but similar in voided N. This may arise from the early adaptation of the rams to the *A. saligna* as the digestibility trial undertaken following the growth evaluation trial. In agreement to this idea. Ben Salem et al. (2005a) reported animals exposed to tannins early in life exhibited higher retained more N than the inexperienced lambs. Over all in this study the N balance was positive this helps all the rams in this study display weight gain. The positive N balance in this study may arise from the treatment applied to *A. saligna* as Ben Salem et al. (1999) reported PEG treatment of *A. saligna* had positive effect on N balance. Ben Salem et al. (2005b) also insisted feeding untreated acacia resulted in negative N balances but with treatment, N balance resulted in positive N balance. Overall, supplementation of *A. saligna* had posetive effect on N balance and improves digestibility in sheep feeding (Safinaz et al., 2010).

Live weight changes

The daily live weight gain was increased as level of *A. saligna* increased to 183.8 g DM day in T3 and declined gradually when the level of *A. saligna* was increased to 267.3 and 344.4 g DM day in T4 and T5, respectively. *A. saligna* leaves could be best included in the grass hay based feeding in dried form at the rate of 183.8 g DM day for improved nutrient utilization and growth performance of yearling lambs.

Live weight gain found in this study was comparable to 73 g/day gain for Barbarine and Queue Fine de l'Ouest sheep fed on ad libitum dried *A. saligna* and supplemented with 400 g barely and 30 g mineral and vitamin supplement (Ben Salem et al., 1999). Similarly Ben Salem et al. (2005a) also reported 50 g day gain for Barbarine lambs early experienced to dried *A. Saligna* leaf. Unlike this finding, Mousa (2011) reported daily weight gain of 186.31$\pm$19.28 g/day for Awassi fed *ad libitum* dried *A. salina* supplemented with concentrated ration. However, Ben Salem et al. (2005a) reported weight loss of Barbarine lamb in-experienced to dried *A. saligna* leaf. The daily live weight gain found in this study was the result of the supplemental feed of wheat bran and the treatment applied to *A. saligna* leaf. Ben Salem et al. (1999) described an increase in the rate of gain for growing sheep given PEG-treated acacia reflects the positive effect of PEG on the availability of nutrients, mainly proteins, in the diet. Ben Salem et al. (2005b) also insisted higher growth performance of lambs probably results from the higher intake and better provision of available nutrients to these animals.

Conclusions

The present result suggested that supplementation of highland sheep with wheat bran and graded level of *A. saligna* had a positive effect on the feed intake, live weight gain and digestibility. The effects were relatively more pronounced for sheep supplemented with 183.8 g DM day dried *A. saligna*.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Abdel-Fattah ZS (2005). Impact of season of harvest on in vitro gas production and dry matter degradability of Acacia saligna leaves with inoculum from three ruminant species. Anim. Feed Sci. Technol. pp. 67-79.

Ahmed MEW (2007). Nutritive Value Assessment of Ensiling or Mixing Acacia and Atriplex Using In Vitro Gas Production Technique Research. J. Agric. Biol. pp. 605-614.

AOAC (1990). *Official Methods of Analaysis.* Washington D.C.: Assocition of Office Analaytical Chemists.

Ben Salem H, Nefzaoui A, Ben Salem L, Tisserand J (1997). Effect of Acacia cyanophylla Lindl. foliage supply on intake and digestion by sheep fed luceme hay-based diets. Anim. Feed Sci. Technol. pp. 101-113.

Ben Salem H, Nefzaoi H, Ben Salem L, Tisserand J (1999). Intake, digestibility, urinary excretion of purine derivatives and growth by sheep given fresh, air-dried or polyethlene glycolsoaked foliage of acacia cynophylla Land. J. Anim. Feed Sci. Technol. pp. 297-311.

Ben Salem H, Nefzaoui A, Makkarb H, Hochlef H, Ben Salem I, Ben Salem L (2005) (a). Effect of early experience and adaptation period on voluntary intake, digestion, and growth in Barbarine lambs given tannin-containing (Acacia cyanophylla Lindl. Foliage) or tannin-free (Oaten hay) diets. J. Animal Feed Sci. Technol. pp. 59-77.

Ben Salem H, Sourour A, Makkar H, Nefzaoui A (2005) (b). Wood ash treatment, a cost-effective way to deactivate tannins in Acacia cyanophylla Lindl. foliage and to improve digestion by Barbarine sheep. Animal Feed Sci. Technol. pp. 93-108.

Burns R (1971). Method for estimation of tannin in grain sorghum. Agron. J. pp. 511-512.

Chen X, Hovell F, De B, Oskov E, Brown D (1990). Excretion of urine derivatives by ruminants: effect of exogenous nucleic acid supply on purine derivative excretion by sheep. British J. Nutr. pp. 131-142.

Chentli A, Gillmann L, Bouazza L, Medjkal S, Limami A M, Le Paven M M, Bousseboua H 2014. Effects of secondary compounds from cactus and acacias trees on rumen microbial profile changes performed by Real- Time PCR. Int. J. Adv. Res. 2:660-671.

DACA (2013). Standard treatment guidelines for veterinary practice. Drug administration and control authority of Ethiopia (DECA), For veterinary practice (first eddition) P 504.

Degen A, Becker K, Makkar H, Borowy N (1995). Acacia saligna as a fodder tree for desert livestock and the interaction of its tannins with fibre fractions. J. Sci. Food Agric. 68:65-71.

Getnet A, Sonder K, Wink M, Kijora C, Steinmueller N, Peters K J (2008). Effect of variety and harvesting management on the concentration of tannins and alkaloids in tagasaste (Chamaecytisus palmensis). Anim. Feed Sci. Technol. Article 144:242 -256.

Krebs GL, Howard DM, Dods K (2007) (a). The effect of feeding Acacia saligna on feed intake, nitrogen balance and rumen metabolism in sheep. Asian Australia J. Anim. Sci. 20:1367-1373.

Krebs G L, Howard D M, Dods K (2007) (b). Feeding Acacia saligna to sheep and goats with or without the addition of urea or polyethylene glycol. Asian-Australasian J. Anim. Sci. pp. 101-112.

Maamouri NA, Kraiem K, Mahouachi M (2011). Effects of concentrate and Acacia cyanophylla foliage supplementation on nitrogen balance and milk production of grazing ewes. J. Livest. Sci. 139:264-270

MAFF (Minister of Agricultyre, Fisheries and Food) (1975). Tech. Bull.33: Energy allowances and feeding systems for ruminants. H.M.'s Stationery Office, London.

Moujahed N, Kayoulib C, Thewis A, Beckers Y, Rezgui S (2000). Effect of multinutrient blocks and polythylene glycol 4000 supplies on intake and digestion by sheep fed Acacia cyanophylla lindl. foliageibased diets. J. Anim. Feed Sci. Technol. pp. 219-238.

Moujahed N, Ben Salem H, Kayouli C (2005). Effects of frequency of polyethylene glycol and protein supplementation on intake and digestion of *Acacia cyanophylla* Lindl. foliage fed to sheep and goats. Small Rumin. Res. 56:65-73.

Mousa M (2011). Effect of feeding acacia as supplements on the nutrient digestion, growth performance, carcass traits and some blood constituents of awassi lambs under the conditions of North Sinai. Asian J. Anim. Sci. pp. 102-117.

Nicholas G, David H, Guijun Y, Margaret B (2007). Variability in feed quality between populations of Acacia saligna(Labill.) H. Wendl. (Mimosoideae)—implications for domestication. Anim. Feed Sci. Technol. pp. 109-127.

Olivares PJ, Avilés NF, Albarrán PB, Castelán OOA, Rojas HS (2013). Use of three fodder trees in the feeding of goats in the subhumid tropics in Mexico. Trop. Anim. Health Prod. 45:821-828.

Osuji P, Nsahlai I, Khaalili H (1992). Feed evaluation. Addis Abeba (Ethiopia): ILCA (International Livestock Center for Africa).

Rojas HS, Olivares PJ, Aviles NF, Villa MA, Reynoso PA, Camacho DLM (2015) (a). Productive response of lambs fed Crescentia alata and Guazuma ulmifolia fruits in a tropical region of Mexico. Trop. Anim. Health Prod. 47:1431-1436.

Rojas HS, Olivares PJ, Elghandour MMMY, Cipriano-Salazar M, A´vila-Morales B, Camacho-Dı´az L M, Salem AZM, Cerrillo Soto MA (2015) (b). Effect of polyethylene glycol on in vitro gas production of some non-leguminous forage trees in tropical region of the south of Mexico. J. Agrofor. Syst. 89:735-742.

Safinaz MS, Ahmed MH, Ibrahim MA (2010). Impact of feeding atriplex halimus and acacia saligna with different sources of energy on lambs performan. Egyptian J. Sheep Goat Sci. 5(1):191-208.

Salem A, Salem M, El-Adawya M, Robinson P (2006). Nutritive evaluations of some browse tree foliages during the dry season: Secondary compounds, feed intake and in vivo digestibility in sheep and goats. Anim. Feed Sci. Technol. 251-267.

SAS Institute Inc. (2002). JMP 5 Statistical Software. NC, USA: Cary.

Shumuye B, Yayneshet T (2011). Effect of feeding treated Acacia Saligna (Labill.) H.L. Wendl. leaves on growth performance and digestibility in goats. J. Dryland Agric. 4(2):341-347.

Silanikove N, Gilboa A, Nitsan Z (1997). Interactions among tannins, supplementation, and polyethylene glycol in goats fed oak leaves. Anim. Sci. 64:479-483.

Siyoum Z, Yesuf M (2013). Searching and Evaluating of Cost Effective Management Options of Garlic White rot (Sclerotium cepivorum Berk) in Tigray, Northern Ethiopia. J. Plant Pathol. Microbiol. http://dx.doi.org/10.4172/2157-7471.1000189.

Sokal R, Rohlf F (1981). Biometry. San Francisco, USA: W,H, Freeman.

Tamir B, Asefa G (2009). Effects of different forms of Acacia saligna leaves inclusion on feed intake, digestibility and body weight gain in lambs Fed grass hay basal diet. Anim. Feed Sci. Technol. pp. 39-47.

Thi MU, Dinh VB, Ørskov ER (2005). Effect of foliages containing condensed tannins and on gastrointestinal parasites. Anim. Feed Sci. Technol. 121:77-87.

Van Soest PJ, Robertson JB, Lewis BA (1991). Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74(10):3583-3597.

Yayneshet T (2010). Feed Resource Availability in Tigray Region, Northern Ethiopia, for production of Export Quality Meat and Livestock. Ethiopian Sanitary and Phytosanitary Standards and Livestock and Meat Marketing Program (SPS-LMM), Mekelle University, Ethiopia.

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Full Length Research Paper

Impacts of deforestation on the livelihood of smallholder farmers in Arba Minch Zuria Woreda, Southern Ethiopia

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The ever increasing demand of farmland, fuel wood and charcoal production coupled with population growth has accelerated the rate of forest reduction in Ethiopia. This has resulted in soil erosion and land degradation. This study was conducted at Arba Minch Zuria Woreda Gamo Gofa Zone, Southern Nations and Nationalities Peoples' Region (SNNPR), with the aim of assessing impacts of deforestation on the livelihood of small holder farmers. Both qualitative and quantitative data were collected from primary and secondary data sources. Data on the socio-demographic variables as well as farmers' perception towards impacts of deforestation, were collected using structured questionnaire from 180 randomly selected households from each study sites. The overall average age of respondents was 46.29, where the highest age was recorded in Mille site as compared to other sites (P<0.001). The average household (HH) size of each site was 6.62, 5.52 and 4.82, respectively (P<0.001). About 89.4% of the respondents from all study sites indicated the existence of unwise utilization of forest resources which led to environmental degradation of the area. The result indicated that 27.2% of the forest resources are common woodland, while 72.8% was open access. All the respondents (100%, N= 180) across the study sites reported that the increased trends of degradation of forest resources. Generally, the results of the study indicated that the effects of deforestation on land productivity; agriculture and livestock production had a negative effect on livelihoods of the community. Based on the present study, it is appropriate to undertake the large-scale natural resource management by incorporating community-based watershed management, thereby reducing the adverse impact of deforestation.

Key words: Deforestation, farmers perception, land degradation, livelihoods.

INTRODUCTION

Forests play an important role in the environment like providing the basic necessities, providing habitat for the variety of wildlife species, contribute to the control and moderate climate, prevent soil erosion and flooding;

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despite the benefits obtained from forest ecosystem goods and services, the clearing of forest and deforestation have contributed to the continued decline of forest resources in Ethiopia.

According to FAO (2000), tropical forest covers 814 million ha, of which 110 million ha is located in Africa, 168 million ha in Asia and the Pacific, and 536 million ha in Latin America. However, only 25 million ha are exploited in a sustainable way and 11 million ha of tropical forests are conserved with an effective political protection. All the tropical humid forests in Africa suffer from a massive deforestation (Soury, 2007). Loss of biodiversity of tropical forests is mainly due to degradation and destruction of habitat by anthropogenic activities. Currently, it is a global problem (Sukumaran and Jeeva, 2008) because the annual rate of global deforestation is about 13 million hectares, most of which occurs in the developing world. Forest loss in Africa is particularly troubling, however, two-thirds of the continent’s population depends on forest resources for income and food and 90% of Africans use fuel wood and charcoal as sources of energy. Despite, or perhaps because of this dependence on forest resources and non-timber forest products, deforestation in Africa is estimated at about 3.4 million hectares/year (CIFOR, 2005; FAO, 2010). However, most of these species have been vulnerable to different factors that led to the devastation of natural forest resources and diminishing of the forest cover. In relation to the causes of deforestation in Ethiopia, several factors have been mentioned. According to Tadesse and Demel (2001), deforestation usually followed human resettlement patterns.

In sub-Sahara Africa, majority of the population derives its livelihood from agriculture. Smallholder agriculture accounts for 75% of agricultural production of which the majority constitutes of rain fed farming. Drought is Africa’s principal form of natural disaster which often affects rain fed agriculture dramatically. The impact of population growth in rural areas is pushing communities into unsustainable farming practices such as burning and razing of tropical forests in order to plant crops, planting in steep slopes, moving into fragile marginal eco-system, over cropping and over grazing and subsequent depletion of fragile arable land and over-utilization of ground water resources. It has been estimated that a sixth of the world’s land area, nearly 2 billion hectares, is now degraded as a result of overgrazing and poor farming practices. Water resources for agricultural purposes are getting scarce, and there are hardly any land reserves to be brought into production to widen the agricultural base. By 2025, close to three billion people in 48 countries will be affected by critical water shortage for all or part of the year. Gebremarkos and Deribe (2005) pointed out that, lack of proper forest management and utilization, land tenure policy, lack of compatible forest proclamation and other legislations, and extensions of cultivation to marginal lands were indicated as major causes of deforestation. According to Demel et al. (2003), the underlying causes of deforestation are, closely linked with the vicious cycle of mutually reinforcing factors that means poverty, population growth, poor economic growth and the state of the environment. With regard to the effects of deforestation, Legesse (2003) argued that the decimation of natural forests results in the loss of a large number of forest products, drought, flooding, interrupts water flow, declines in land productivity and exacerbates misery and poverty of the rural people. Moreover, as illustrated in Ermias (2003), in Amhara regions alone, about 2 to 3.5 billion tons of fertile top soil is washed away per annum and deposited into rivers. Demel et al. (2003) argued that the reduction of vegetation cover and the associated negative impact on land, threaten ecosystems, flora and fauna by depleting genetic resources as well as loss in biodiversity. Considering the longitudinal profile of deforestation in Ethiopia, it should be clear at the outset that there have been no reliable records on the extents of the country’s forest prior to recent times (Yigremew, 2001). Mooney, the modern forestry expert, as noted by Pankhurst (1992), has argued that Ethiopia was densely wooded in ancient and not so remote times. But, it appears that there is no way of establishing how much of the country was actually forested, or at precisely what period and at what rate deforestation was occurred (Pankhurst, 1992). However many authors, based on existing indigenous remnant forests available in portions of the country and ecological settings, have tried to reconstruct the forest cover in remote and recent pasts. The various estimate made by different authors show that once in the remote past, about 30-48% of the country and as much as 87% of the highlands, were covered by forests vegetation (Yigremew, 2001). According to Tewolde (1996), most of the high lands had been deforested at least by the 16th century, and probably as early as the 16th century. Towards the beginning of the 1900s, however, the forest cover of the country was estimated at 40% of the area of Ethiopia. Depletion of forests had been 6-20% in 1950-1960, and had accelerated since the late 1960 and early 1970, the rate in this period, was estimated in the range of 2-6%. The acceleration of forest degradation in this particular period, according to Edessa (1993), was due to changes in climate of the country. On the other hand, Dessalegn (1996) largely attributes it to change in government and land use policy.

In the previous years, the Gamo-Gofa people used to protect remnant forests for varieties uses such as: traditional assembly places, production of household equipment’s, energy sources and others. The Gamo people are bound intimately with the land and land resources, which frequently contributes to environmental disruption and thereby maintaining an overall ecological equilibrium. In the highlands, the Gamo have protected sacred forests along waterways and on the tops of hills, these being the remnant forests of formerly vast

Afromontane woodlands (Desalegn, 1996). Within the groves, the people keep their ritual relics and perform sacrifices, healings, harvest rituals and fire ceremonies that symbolize the connection between the past and the future. All of which recognize the peoples' dependence on the earth and its resources to sustain their livelihoods.

The distribution of the land use in Arba Minch Zuria Woreda has been changing greatly over time because of subsequent cultivation after deforestation due to high population and economic pressures, and infrastructure and irrigation development (Tuma, 2007). Currently, a small part of the border area near Lake Abaya is covered with forest, whereas the highland that was once covered by forest is now deforested. In the escarpment between lowland catchments and highland areas, the scattered trees were also disappearing from those places. However, nowadays these important traditions which are tourist attraction sites and sources of country economy have been changed in other land use system Thus, this study attempts to assess the perception of local community to the impact of deforestation. The current research was to explore local community perception towards deforestation and decreased income, thereby livelihood. Specifically, it attempted to determine the impacts of deforestation on the livelihood of the community. The identification of the perception of local community towards deforestation and the local knowledge and their roles in forest management activities were also key specific objectives of the study.

MATERIALS AND METHODS

Description of the study area

Arba Minch Zuria woreda is in the Southern Nations, Nationalities and Peoples' Region is located between 6°05´N to 6° 12´N and 37°33´E to 37°39´E, it is a part of Gamo Gofa zone 400 km south of Addis Ababa (Figure 1). It is bordered on the south by the Dirashe woreda, on the west by Bonke, on the north by Dita and Chencha, on the northeast by Mirab Abaya, on the east by the Oromia National Regional State, and on the southeast by the Amaro special *woreda* (Defaru, 2006).

The total population of the study area is 164,529. Out of the total population, 82,199 are men and the rest 82,330 are women (CSA, 2007). The family size of each house hold is an important factor to determine the nature of supply and consumption of forest product by respective house hold. Thus, family size of each house hold was considered. Family size is another demographic aspect which shows the status of family. The average family size of the area is 6 which are more than district's family size. Therefore, the density of population in the area is 9-10 persons per ha (Defaru, 2006).

Topographically, the study area is characterized by escarpment and narrow valleys. The slope ranges between 20 to70% which resulted in massive soil erosion and altitude lies between 1190-3200 masl. The drainage patterns follow the general topographic orientation so that small rivers rising from Gamo highlands drain to Lake Abaya and Chamo. Among these, Hare and Baso drain to Lake Abaya whereas Kulfo, Sile and Sego rivers drain to Lake Chamo (Arba Minch Zuria Woreda Rural Development Office, 2008/09). The geology of the lower part of the study area is of recent or quaternary volcano which serves as a substrate for the dry Afromontane vegetation (Friis and Mesfin, 1992).

Accordingly, it is mainly quaternary volcanic alluvial deposits and lacustrine clay, Mateos (2003) stated that the soils under the forest and the state farm are composed of three main types: Fluvisols, Gleysols and Vertisols. Fluvisols consist of soil materials developed in alluvial deposits and flood plains.

The mean monthly temperature is 23.9°C varying between 22.7 (July) to 25.7°C (March). Rainfall distribution in the study area is bimodal with a long rainy season from the beginning of March to the end of May with maximum rainfall around the month of April (228 mm), and a short rainy season from mid-August to mid-October. The minimum rainfall is recorded in January (18 mm) (FAO, 2010). The 25 years maximum average temperature trends of the study area were displayed (1987-1999 and 2000-2011), average maximum temperature difference in the years were 30.3 and 30.6°C, respectively (Table 1 and Figure 2). The minimum temperature trends showed variation before and after 1996.

The land use land cover is combined with open space and readily available pasture, means that high agricultural yields and livestock production are possible. Most of the people in the area use traditional system of crop production. This includes, ploughing with oxen and with traditional hand tools in areas of steep slopes like Meche kebele. This was also one factor for the rapid destruction of forest resources which was followed by population growth of the area (Defaru, 2006). Varieties of food crops and fruits are grown: Maize is the primary food crop followed by sorghum, teff and barely, respectively. Irrigated banana, mango and cotton are primary cash crops, Livestock production, including the fattening of oxen, is another important income source. Much of the Woreda land was under settlement, hilly areas and gorge escarpments (Table 3).

Land holding size

According to the farmers associations administration, the range of land holding for the sampled households head in Mille 0.25-0.5 ha, in Meche 1.0-1.5 ha and in Kanchama 0.5- 2.0 ha was recorded. Majority of the people depend on rain-fed agriculture and cultivate maize and sorghum as their main crops. During the early and late dry period of the year, the people burn vegetation to clear bushes for agricultural purposes.

Methods

Research design

Survey was carried out to collect primary data to generate reliable information on the intended topic. Three representative *kebeles* namely, Mille, Meche and Kanchama which are among the major areas where selected for their forest area coverage. The fieldwork for this study was carried out from mid-November to January 2014. Face to face interview using questionnaires was adopted to gather information based on the prepared questionnaires. The questionnaire was developed with the objective of obtaining meaningful information and views from the household members living within the study area and from the key informants. The key Informants including community representatives and elders, experts at district office of Agriculture and development agents who are assigned at community level were considered in the survey. Data was collected by well-trained personals who are well acquainted with each kebeles and trained before the start of the data collection. The first two days of the survey period was devoted to training the data collectors by which they were tolerant to how to handle the respondents and fill the questionnaires.

Sampling techniques

A simple random sampling method was used to select sample

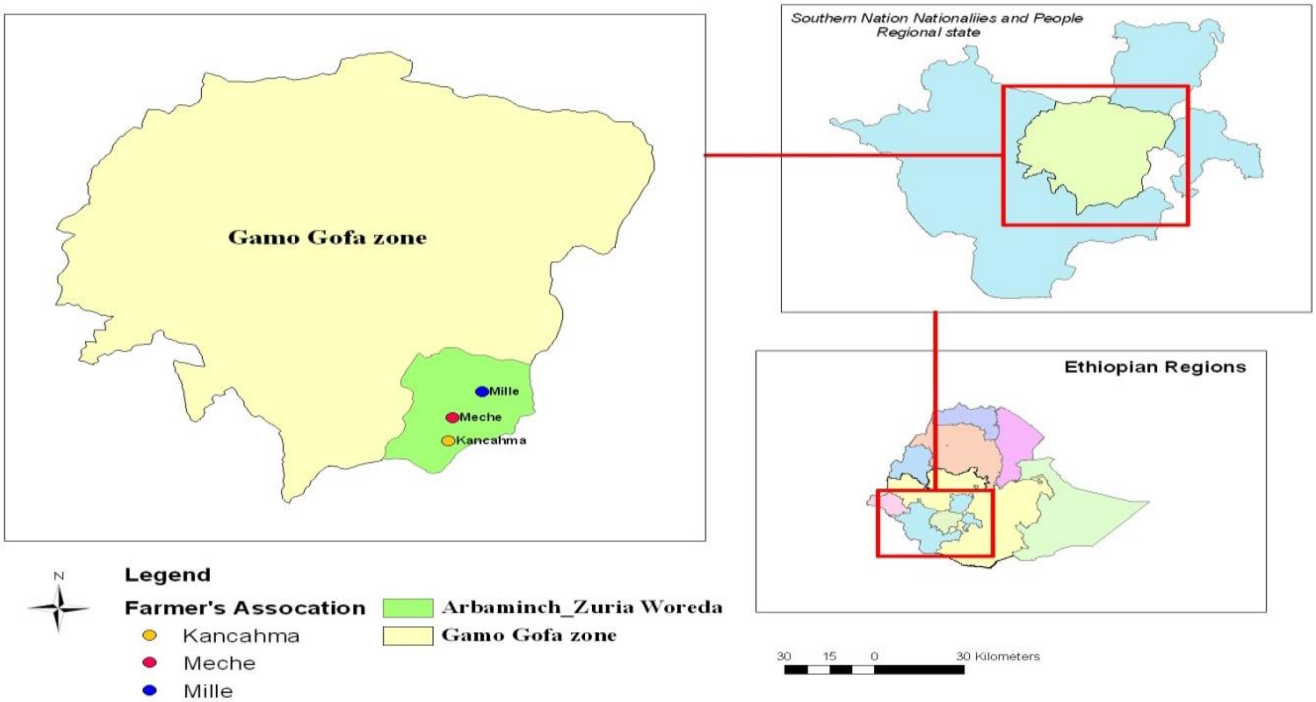

Figure 1. Map of the study area.

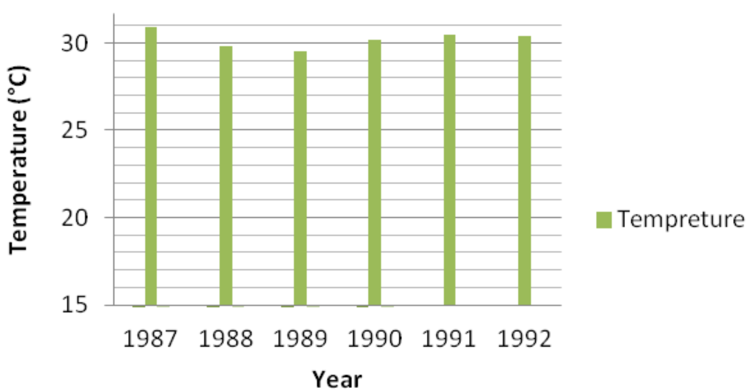

Figure 2. The variability of average annual temperature in AZW (1987-2011). Source: GGZRDO (2012)

households for the household survey; three Farmers Associations (Mille, Meche and Kanchama*)* were selected purposively. At this stage, the researcher took great care to ensure that the selected kebeles sufficiently represented the district in terms of socio-economic and physical characteristics. Secondly, the sample household heads were selected from each kebeles using simple random sampling method. This was carried out based on the list of households registered in the respective farmer's associations obtained from Keble Experts and administration. These were 1034, 460 and 1195 registered households identified from Mille, Meche and Kanchama kebeles, respectively. At this stage, the development agents (DAs) and kebeles officials were consulted to identify the location of each household's residence within kebeles. The sample respondents were then taken. Respondents were selected at uniform intervals from the prepared alphabetical list of the whole household heads living in each Keble near the forest patches. To determine the sample size of households to participate in the study, large sample approach was selected following Wooldridge (2000).

According to data obtained from Kebeles Administrative and Development Agents (2006), there are about 1034, 460 and 1195 household units in Mille, Meche and Kanchama kebeles, respectively. And a total of 2689 household heads live in the Kebeles. From this, 250 households (P) are town inhabitants and out of the total households, 180 where selected for interviews. Therefore, 60 is the minimum sample size of housing units for reliable result. However, to be safe in the cases of some absences of household and unexpected problems during data collection and other cases, the sample size was increased to 180 randomly selected households. The sample size taken from each study sites

Table 1. Twenty five years mean monthly tempreture of Arba Minch Zuria Woreda (Source: GGZRDO (2012).

Year	Average T° in C°	Year	T° in C°
1987	30.9	2000	30.6
1988	29.8	2001	30.0
1989	29.5	2002	31.1
1990	30.2	2003	30.5
1991	30.5	2004	30.7
1992	30.4	2005	30.3
1993	29.8	2006	30.2
1994	30.7	2007	30.0
1995	30.4	2008	31.0
1996	30.1	2009	31.7
1997	30.6	2010	30.0
1998	30.4	2011	30.8
1999	30.9	-	30.6

near the forest patches (*Kebeles*) was sixty (60). Focus group discussions and field observations were also made to validate the data obtained by interviews and questionnaires. Discussions were made within three groups of different individuals in the community. Field observations were made and tried to grasp knowledge on some of the environmental and socio-economic conditions of the kebeles. Literature review, covering past research studies and relevant documents was carried out to gather secondary data. This include, journal articles, performance reports and research papers prepared and presented for policy discussions and conferences, and other relevant documents from the concerned administrative offices. The primary data were collected from selected households using structured questionnaires, interviewing guides and key informants and FGD. The questionnaires were filled by sample household heads living in three Farmers Associations and the interview was held with many individuals ranging from the elder group of community to the officials and experts in the field. Some of the interviewees were elderly persons, kebeles officials, youngsters, women, development agents (DAs) and experts at the districts office of agriculture and rural development. Focus Group Discussion (FGD) was also conducted to gather information related to historical records of forest resources utilization and management.

Data analysis

All quantitative and qualitative data were analyzed using Statistical Package for Social sciences (SPSS versions 20, 2012). The chi-square and one-way ANOVA procedures were followed for the data analysis. The analyzed data were presented by percentage and arithmetic means in the form of tables and figures.

RESULTS AND DISCUSSION

Demographic characteristics of the respondents

The overall average age of respondents in the study areas was 46.29%, where the highest was recorded in Mille farmers' association (55). All age groups of the present study are categorized under productive groups of age between 15 and 65 (World bank, 2012). Such age group is believed to have advantages of forest resources management or conservation activities; however, certain people in these age groups might have lacked the knowledge of wise use of natural resources and the low opportunity of training on forest conservation activities resulted in competition for forest land cultivation and crop production in order to feed large family members as well as for fire wood and charcoal production.

The average household size of each farmers association is 7 in Mille, 6 in Meche and 5 in Kanchama respectively; the overall average is 6. This is close to Ethiopian national average household size of 5 (MoH, 2014). The land holding size of the households ranges from 0.375-1.75 ha (Table 2). Additionally, owning land by the households enables generation of information in relation to the impact of deforestation. This is because households can clearly see what the causes for deforestation on their farm plots and the associated problem in affecting land productivity.

As shown in the Table 2 among the respondents, in Mille, Meche and Kanchama 98.33, 96.70 and 88.33%, respectively were male and the rest female. The religious composition, 83.33% of the respondents in Mille, 70% in Meche and 81.70% in Kanchama were protestant and the rest orthodox. In the case of educational status, 66.70% in Mille, 48.33% in Meche and 25% in Kanchama of the respondents are illiterate in each farmers association; the highest illiteracy level was recorded in Mille farmers' Association; whereas the lowest was in Kanchama. As mentioned in Table 2, the number of oxen owned by farmers in the three farmers association was recorded as highest (2) in Mille whereas the lowest (1.00) was in Kanchama. The overall average recorded in the study area was (2). Community elders explained that oxen are most important animals in the area. In such a way that they are indicators of wealth, focus group discussion with elders revealed that they used to have large number of cattles some 30-40 years ago, however, due to climate change related factors such as, land degradation which have an impact on the livestock and their livelihood is now affected, in association with feed shortage, poor access to improved extension services, lack of improved cattle breeds and distance to marketing points and poor administrative mechanisms to restore the ecosystem was also the other factor which decreases the number of cattles in the area.

Analysis of farmer's livelihoods and their relation with forest

Most of the farmers depend on farm and off-farm activities to generate sufficient income in order to sustain their life (Figure 3 and Table 4). Forest is one of the resources on which most of the community depend to generate income and household usage. As shown

Table 2. Mean of demographic information of the respondents.

Demographic situation		Farmers association		
		Mille	Meche	Kanchama
Age (year)		55.00	43.00	42.00
Family size (No.)		7.00	6.00	5.00
Land holding size (ha)		0.375	1.25	1.75
Oxen (No.)		2	2	1
Sex	Female	1.70 (1)	3.33 (2)	11.70 (7)
	Male	98.33 (59)	96.70 (58)	88.33 (53)
Marital status	Married	100 (60)	97.00 (58)	88.00 (53)
	Widowed	-	3.33 (2)	11.70 (7)
Language	Gamo	100 (60)	100% (60)	100 (60)
Educational level	Illiterate	66.70 (40)	48.33 (29)	25.00 (15)
	Grade 1-4	33.33 (20)	46.70 (28)	71.70 (43)
	Grade 5-8	0	5 (3)	3.33 (2)
Religion	Protestant	83.33 (50)	70 (42)	81.70 (49)
	Orthodox	16.70 (10)	30 (18)	18.33 (11)

Numbers in bracket indicates frequencies.

Table 3. Land cover of Arba Minch Zuria Woreda.

Crop types	Area covered (ha)	Percent
Annual crops	33,847	15
Permanent crops	39,610	18
Grazing areas	2,713	1
Forest and bush land	10,058	5
Uncultivable Land	50,668	23
Cultivable Land	11,421	5
Water body	18,197	8
Settlement, hilly areas and gorge escarpments	56,403	25
Total	222,917	100

Source: SNNPR (2005).

in Figure 3, integration of crop and livestock system was the main source of income for the farmers; on the other hand, some of the farmers (15-25%) in Meche and Kanchama areas depend on selling of firewood and charcoal.

Major livelihood sources

As respondents of households of different age groups indicated (Table 4) due to effect of deforestation, crop was sources of income for households. The interview result showed that, Mille, 10% and in Kanchama 7.25% of the respondents responded that crop production is the major income source for households. On the other hand, respondents in Mille, 25.8%, in Meche, 22% and in Kanchama 23.8% of the respondents indicated that crop-livestock production is the major source of household income (Table 4). The remaining 6.8% of the respondents in the study areas income source depend on sale of charcoal and firewood. From this result, it is possible to say that forest resources are one of the main income and livelihood sources to the local community in the area (Culas, 2006). The study areas are believed to represent the household socio-economic characteristics of the whole Farmers Associations in the Woreda, mixed crop-livestock farming systems are the major sources of household's income; followed by crop production. The

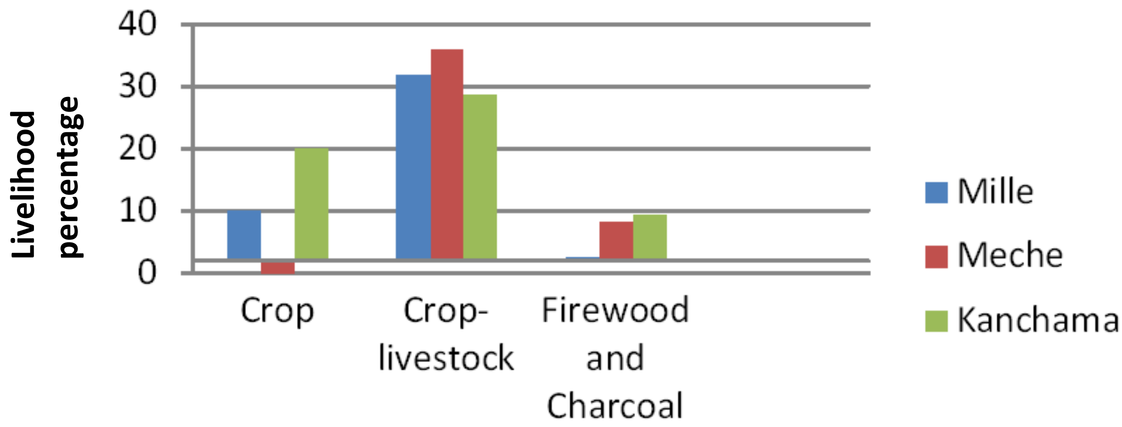

Figure 3. Sources of income for the selected households.

Table 4. Household income source and dependency on forest resources.

Source of incomes		Farmers association			Overall mean	*P-value*
		Mille	Meche	Kanchama		
Crop		10 (18)	5 (9)	7.25 (13)	22 (40)	
Crop-livestock		25.8 (46)	22 (40)	23.8 (43)	71.6 (28)	***
Sale of wood and charcoal		0.61 (1)	2.5 (4.5)	3.3 (6)	6.8 (12)	
Selling of FP	Own farm	9 (15)	12.6 (21)	5.4 (9)	27 (45)	**
	Community forest	27 (45)	23.4(39)	30.6(51)	75 (135)	

FP = forest product.

income generated from the above sources is used to cover other household expenses, government and social obligations such as clothing, school fees for children, payments of fertilizers and other. The variation is statistically significant (*P*<0.004) (Table 4). According to the results of the study, livestock production is considered for a source of income and survival. Ownership of oxen has the base for crop cultivation as the major tool for preparing land. Households who do not own oxen make an agreement with households who own oxen in exchange for labor. Some of the households traditionally lease out their land as a result of lack of oxen for land cultivation. The proportion of income generated in the study area is smaller than reports of central highlands of Ethiopia (NRoE, 2012).

Farmer's access and utilization of forest

The result indicated that, households accessibility and utilization of forest resources did not change their income or livelihood assets (*P*<0.001). In the study area, some of the farmers' association leaders explained that 40 years ago the main source for house construction and farming equipment was made from forest products but now they buy materials from the market which are not forest products.

Most of the farmers have an access to forest resources for different purposes: fire wood, charcoal production, poles, local house construction, farming tools and household furniture (Table 5). However, each farmer's association didn't have an equal access. As indicated in Table 5, statistically significant difference (*P<0.001*) was observed between farmers association towards forest resource access. In Mille, about 36.00%, Meche 28.80% and 24.00% of the farmers have an accesses to forest resources (Table 5). About 82.20% of the farmers in the study sites have an access to forest resource but the remaining 17.77% of farmers who live at distance from the forest in Meche and Kanchama area did not have relatively less accesses to forest resource utilization for different purposes. These farmers instead use trees around home garden, and crop residues for cooking and source of light energy. This means that even though they are far form the forest they deplete the agroforestry vegetation near their home. Based on the statistical result, the observed accessibility and increased utilization of the remaining forest, is evident that there has been further deterioration of forests and other natural resources and contribute to increase in temperature.

Table 5. Farmers access to forest, utilizations, and ownership in the study area.

Variables		Farmers association			Overall mean	P-value
		Mille	Meche	Kanchama		
Access	Yes	36 (60)	28.8 (48)	24 (40)	82.2 (148)	***
	No	0	7.2 (12)	12 (20)	17.7 (32)	
Unwise use (Utilization)	High	36 (60)	31.8 (53)	28.8 (48)	89.4 (161)	***
	Low	0	4.2 (7)	7.2 (12)	11.4 (19)	
Owners	Govern	26.4 (44)	25.8 (43)	26.4 (44)	72.8 (131)	NS
	Common	9.6 (16)	10.2 (17)	9.6 (16)	27.2 (49)	
Fuel source	Forest wood	27.6 (46)	31.8 (53)	35.4 (59)	87.8 (158)	***
	Farm stead	8.4 (14)	4.2 (7)	0.6 (1)	12.2 (22)	
Percep to forest role	Shade and fence	17.4 (29)	3 (5)	21 (35)	38.3 (69)	***
	Income source	14.4 (24)	13.2 (22)	4.8 (8)	30 (54)	
	Soil conservation	4.2 (7)	19.8 (33)	10.2 (17)	31.7 (57)	

Numbers in bracket indicates frequencies and NS indicates non-significant.

Forests in the study site belong to the government. The Woreda and farmers association officials attempted to conserve the resource by restricting the inhabitants from using forest resources through awareness creation and punishment when necessary. However, some farmers feel that they not practically feel responsible. According to the respondents, about 72.80% of the forest land was owned by the government and the rest was the community forest.

According to the data taken from Keble and Woreda Agricultural offices in the previous 30-40 years, the area was covered by dense forest but at present, it was not more than 10 ha. This is attributed to the increase in population followed by high agriculture expansion. Most of the rural poor maintain diversified livelihood strategies, because they cannot obtain sufficient income from a single source to survive and to reduce risks. This is why the largest part of smallholder farmers is not really depending only on agriculture but also utilize forest products to increase their household income. As summarized in Table 4, majority of the households in the study area indicated that their main sources of household consumption of energy was forest wood (P<0.001). This finding was close to the situation in which forest wood is the main source of fuel for cooking in most part of Ethiopia (FAO, 2012). Figure 4a and b, shows that the source of energy in the study area is largely biomass energy, particularly trees. Fuel wood is used as energy for both cooking and lighting. Consequently, vast numbers of trees are cut each year, adding significantly to the rate of deforestation. Physical collection of fuel wood, which is the responsibility of women and children, is one of the factors affecting livelihoods negatively.

According to community elders, few of the households in the area depend on cow dung, crop residues, and dried woods of trees around home garden as fuel wood sources; the use of cow dung and crop residue for cooking purpose can depletes soil fertility and cause soil degradation in the area which results to low productivity. Some of the key informants mentioned that some years ago, the area was dominated by dense forests and different varieties of wild animals however, currently, only few trees are still standing and the area is severely degraded.

Perception of the role of forests and the importance of trees varies from community to community; in the Table 5, 17.4, 3 and 21% of the respondents in Mill, Meche and Kanchama, respectively, confirmed that forests are useful and important forest shading and fence; some households 14.4% in Mille, 13.2% in Meche and 4.8% in Kanchama indicated forest as source of income. The last groups explained that 4.2% in Mille, 19.8% in Meche and 10.2% in Kanchama perceived that forest was important in the conservation of soil. The sense of environmental protection is not well known by many household in the area. Even though there are development agents (DA) experts who have responsible of teaching the inhabitants about the environmental role of forests, the respondents in the study area have low perception of this role.

Forest degradation and conservation efforts

As indicated in Table 6, fire wood and charcoal production as a cause of deforestation was assessed in Mille 0.61%, Meche 2.5% and Kanchama 3.3%, the

A B

Figure 4. Deforestation activities in Kanchama.

Table 6. The major cause of forest degradation and its trends in the study area.

Degradation cause		Farmers association			Overall mean	P-value
		Mille	Meche	Kanchama		
Fire wood and charcoal		0.61 (1)	2.5 (4.5)	3.3 (6)	6.8 (12)	**
Agri. Expansion		27 (45)	33 (55)	31.8 (53)	85 (153)	
Intrusion of Investors		0	0	12 (20)	11.1 (20)	***
Pop, growth		36 (60)	36 (60)	24 (40)	88.9 (160)	
	High	36 (60)	36 (60)	36 (60)	100 (180)	
Trend of degradation ion	Moderate	0	0	0	0	***
	Low	0	0	0	0	

increasing human population from time to time in the area and the household's different social and governmental obligations, such as children's school fee, tax, to mention a few, exacerbated the rate of deforestation. However, household income was not covered; moreover, it resulted in excessive forest clearing for agricultural activities. In Kanchama, one of the communities elder explained that 30 years ago government policy towards awareness creation to the community was strong and consecutive especially from Woreda sector, however with time, the follow up gradually lessened which led to unsustainable utilization of forest resources for agricultural expansion by some illegal individuals. This is believed to be one of the major factors responsible for degradation of forest resources. It accounts for 27% in Mille, 33% in Meche and 31% in Kanchama. The overall mean of the three farmers association was 85%, and the traditional method of land cultivation is another factor which is responsible for the removal of the productive top-soil, hence a decline in land productivity, which has negative economic and environmental impacts. The most important cause of deforestation in all the study areas was found to be crop land expansion followed by cutting of trees for fuel wood and construction materials. The result showed that agricultural expansion took the largest share for forest destruction in the study areas ($P<0.026$). It is known that deforestation may expose the land to erosion which affects fertility of the soil, and also have significant impact on local and/or global climate.

Population increase have resulted in extensive forest clearing for agriculture, overgrazing by domestic animals, utilization for fuel wood, fodder and construction materials (Sands, 2006). New settlers are engaged in the conversion of forested area into crop production fields. According to the respondents, those who hold small land and those who totally do not have land were often involved in cutting trees for sale of firewood, for local house construction and for crop cultivation as income generation strategy. This condition which exists in the study area is similar to the causes at national level.

Figure 5. Deforestation and land degradation in Kanchama and Meche, respectively.

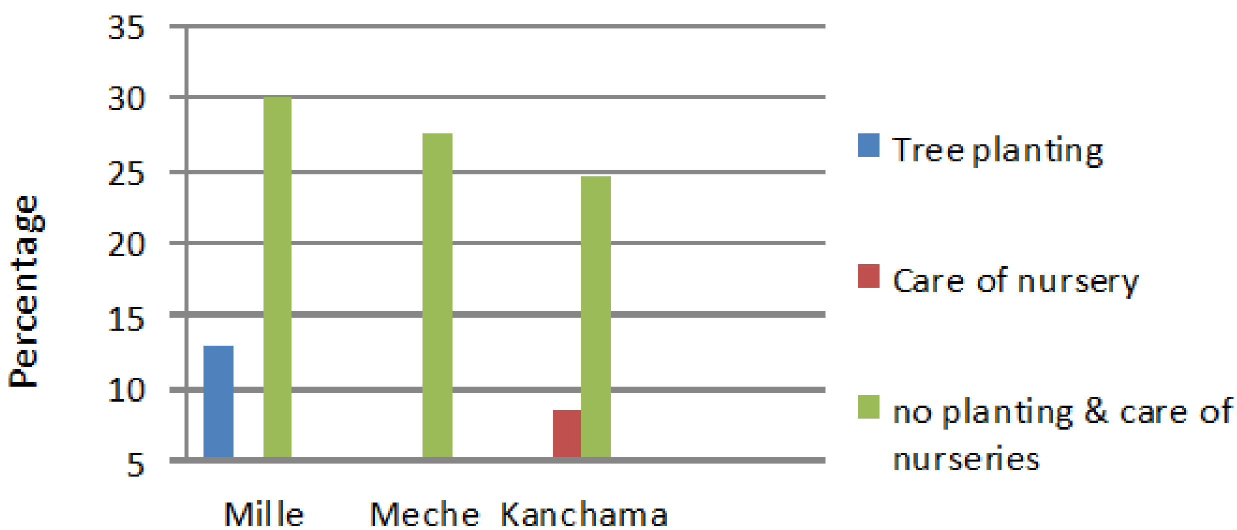

Figure 6. Forest Conservation Activities in the study area.

Most of the households (*P*<0.001) confirmed that the degradation of forest resources was a serious threat. During discussion with household heads, the occurrence of climate change in the area especially increase in temperature was one of the challenges which affected day to day activities of the people. According to the discussion, the effect of climatic change is accentuated by high population growth, land scarcity and depletion of forests resources. The household heads/members also mentioned that as population increases, there is expansion of crop land, which definitely leads to the forests depletion in the area.

Forests are being cleared at an alarming rate for the purpose of acquiring more agricultural land for food production and to meet the demand for fuel wood and house construction materials, within less than forty years almost all of them have been cleared and leaving scattered patches of forest remains. The remaining natural forests are found in gorge escarpment and protected areas (millennium parks) (Figure 5a) of Meche and some mountain areas of Mille which are not physiographically suited for arable farming. Some of these forests do exist because they are inaccessible. The most common effects of deforestation are soil erosion, loss of soil fertility, increase in temperature, loss of biodiversity, rainfall variability and water and fuel wood scarcity. The result of this finding is in line with the work of Defaru (2006). The rate of deforestation at national level was 1% per hectare.

Forest conservation efforts

From the information gathered during field survey, it was evident that there was lack of awareness creation on the need to apply/utilize local knowledge in the conservation

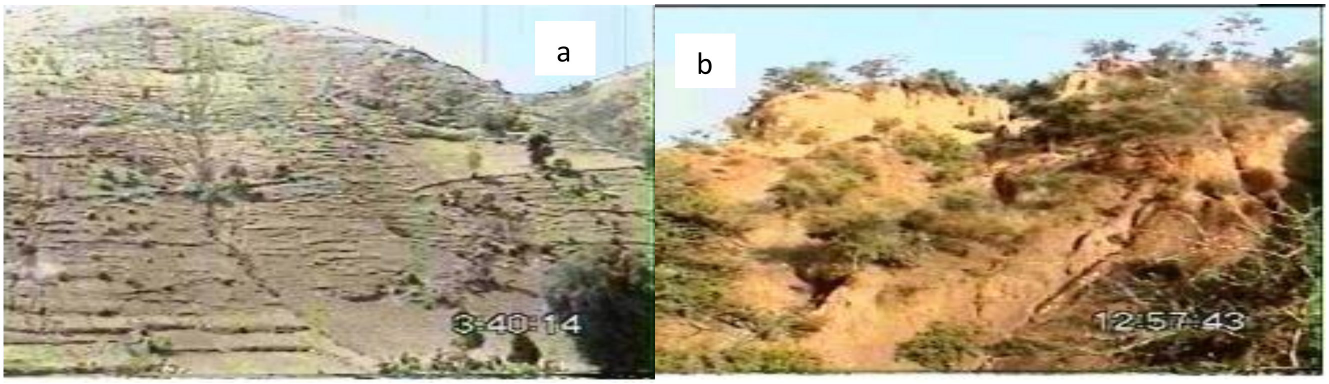

Figure 7. 'a' and 'b' indicates deforestation and gully formation in Meche.

Table 7. Forest conservation efforts in the farmers' association.

Activities		**Farmers association**			**Overall mean**	**P-value**
		Mille	**Meche**	**Kanchama**		
Tree planting		5 (3)	3 (5)	2.4 (4)	7.2 (12)	
Care of nursery		2.4 (4)	6.6 (11)	8.4 (14)	16.11 (29)	NS
No training		30.6 (51)	27.6 (46)	24.6 (41)	76.7 (138)	
Using fuel saving stove	Yes	1.8 (3)	2.4 (4)	2.4 (4)	6.11 (11)	NS
	No	34.2 (57)	33.6 (56)	33.6 (56)	93.9 (169)	
Awareness on forest law	Yes	29.4 (49)	27 (45)	28.2 (47)	78.3 (141)	NS
	No	6.6 (11)	9 (15)	7.8 (13)	21.7 (39)	

NS indicates non significance.

of forests, However, use of local knowledge in the study area alone cannot sustain the management of forests and environment unless it is supported by scientific methods and information (Figure 6). This is because, integration of both forms of knowledge create conducive condition to enhance environmental, ecological, social and economic sustainability. It was established that the selected household heads had low training opportunities in Mille (30.6%), Meche (27.6%) and Kanchama (24.6%) (Figure 7 and Table 7). Nevertheless, some of the respondentshad taken some training on tree planting (7.2%) and care of nursery (16 %). This finding was also in conformity with the result at national level of Ethiopia (NCS, 2012).

Respondents perception towards the laws and rules of forest resources indicated that the majority of the households in the study areas knows about the effects of deforestation and conservation practices through experience and from different sources of Knowledge (P<0.675) (Table 7). The community elders from each of the farmers associations share ideas and information that they had learned from their ancestors and villages. This is also a common practice in Ethiopia environmental conditions.

Focus group discussion and key informant perspectives on forest and livelihood activities

Focal group discussion with the planning team (a team with twenty members comprising 50% of both genders who are in charge of leading the community level development activities and elders of the community) established that deforestation is the major causes of land degradation in the area as far as the change in vegetation cover is concerned, it was confirmed that within 30-40 years ago there has been a significant decrease in forest cover, with a decline in soil fertility as a result of soil erosion.

It was evident that the study area was close to Arba Minch town which aggravated the scale of demand for fire wood, charcoal and wood materials for construction, and farm implements. Furthermore, the expansion of wood markets in the farmers' association and Arba Minch town also aggravated over utilization of forests. Lack of alternative energy sources is one of the major problems which enhance deforestation; this was due to high dependency of the majority of households on forest wood rather than the use of other alternative energy sources. According to the community leader's perception, there was a significant difference in the land holding size among the households. The result of the study revealed that those households with relatively small land but large family size exhibited the tendency of getting involved in firewood selling and collection of forest wood for other different purposes. Among the drivers, population growth and agricultural expansion took the highest percentage in enhancing deforestation; this view of the group was in line with the result of household survey (Table 6). The results of the study show that majority the respondents use local knowledge and traditional conservation practices. Only few of the respondents use some modern conservation approaches/practices such as; tree planting and tree nursery management which is in line with the results of household survey. Although, the application and practice of modern soil and water conservation approaches/methods are low, within the last four and three years, there has been a mass movement/drive by the government to restore degraded land and watershed development, reforestation of degraded areas and gully protection activities such as check dam (a physical structure constructed in gullies to reduce flow of water, thereby reducing soil erosion). In addition, conservation education and awareness campaigns were being implemented. Despite agriculture being the main economic activity in the study area, for the last three decades, the food production has consistently continued to decline due to deforestation, soil erosion and loss of soil fertility.

As far as the participation of conservation partners and agencies is concerned, apart from government agencies, there was no active non-governmental organization (NGO) involved in conservation education. The presence of committed individuals, organization and the like in educating the local people on the importance of forest was important in minimizing the ongoing deforestation and consecutive deterioration of the forest land escape to take urgent and appropriate actions to the local contexts such as efforts to mobilize the local communities and all other concerned stakeholders to maintain and improve vegetation cover of the study area. In order to mitigate soil erosion and decline of soil fertility, improving forests cover which contributes to stop direct impact of rain fall intensity and increase water infiltration and decrease soils credibility through improving the soils resistance by means of improving soil structure through using compost and mulching (add crop residues to protect the soil from rain fall drop effect and improve soil fertility), is important in planting trees and practicing agro forestry in the study area. Finally, protection of the ecosystem was a precondition for leading agricultural production as creating social, economic and environmental sustainability. So, it was better to conserve and protect forests and other natural resources to ensure environmental sustainability and to get various benefits from forests resource. So, any responsible body, especially stakeholders like, government organizations, local institutions, NGOs, local investors should make decisions concerning the alleviation of deforestation and should create conducive environment promoting indigenous knowledge and scientific information to enhance environmental sustainability.

Contribution of different institutions towards forest conservation

Regarding the role of NGOs in minimizing the impact of deforestation on the livelihood of the community, often there has been a local doubt of the government and government institutions due to the past policies, legislation/laws and practices that placed foresters and local communities in conflict. For example, the group reported that there is no organization in the area which supports the conservation of forest resources. The key informants explained that if they were in the community, they would be able to facilitate/cause change at the local level by providing training, extension and advisory services, strengthening the conservation structures for food for work or payments; this will encourage and promote the rural community livelihood options.

The other role of NGO would be marketing and promotion of local community conservation initiatives as well as advocacy at the local, national and international levels (Arnold, 2001). External organizations such as NGOs can strengthen the positions of local actors (Stevenson, 1996; IPCC, 2003). And they may be as powerful as the state, but their power often originates from the money that they control (Stevenson, 1996; IPCC, 2003). From these perspectives, the discussion builds up by reporting that, this was the time for NGOs, and other organizations to look at the natural resources of the area.

The negative effect of deforestation on livelihoods of rural community is also reported by different individuals such as Kanel et al. (2004). The decreasing natural forest in the study area is a critical problem, has negatively affected the livelihoods of the people that depend on forest products and services for survival.

Conclusion

The results of the study show that over time, the magnitude and rate of deforestation in the study area have intensified due to increased human population, poverty, expansion of agricultural land and unsustainable exploitation of forest resources. This has not only led to land degradation and scarcity of forest products but has accentuated the effects of climatic changes on the natural resources and people's livelihoods in the area. Soil erosion as a form of land degradation is widespread phenomena in the study area especially in Meche farmers' association. This condition has negatively affected soil fertility, food security and the livelihoods of the community members.

RECOMMENDATIONS

Based on the results of the study, the following recommendations are suggested to strengthen the sustainable utilization of forest resources in the study areas

1. Local communities and other stakeholders at all levels should be sensitized and educated on the values of forests. This will require a comprehensive conservation education and communication strategy.
2. Promote the implementation of population, health and environment programs that will support the delivery of reproductive health services, ensure that people living in the vicinity of the forests are living in a healthy environment and forests are protected.
3. Effective and efficient land use management practices should be implemented.
4. Government and nongovernment originations need to enhance the introduction and promote improved energy saving stoves types and other affordable alternative technologies which save biomass.

Conflict of Interests

The authors have not declared any conflict of interests.

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REFERENCES

Arnold JEM (2001). 25 years of Community forestry. Rome, FAO.

CIFOR (2005). Contributing to Africa's development Through Forests Strategy for Engagement in Sub-Saharan Africa. Center for international forestry research, Bogor, Indonesia. Circumpolar Conference, Canada.

Culas RJ (2006). Deforestation and environmental Kuznets Curve, an international, perspective. Ecol. Econ. 61(2):429-437.

CSA (2007). Census, the Ethiopian statistical agency country wide population number count.

Defaru D (2006). Land Use Patterns and its Implication for Climate Change: The Case of Gamo Gofa Zone, SNNPR.

Demel T (2001). Deforestation, wood famine and environmental degradation in highland ecosystems of Ethiopia: urgent need for actions. International Conference on African Development Archives. Paper 3. Available at: http://scholarworks.wmich.edu/africancenter_icad_archive/3

Demel T, Fetene M, Abate A (2003). The state of the environment in Ethiopia: Past, present, and future prospects. Environ. Environ. Change Ethiopia.

Desalegne R (1996). Land, Population and Environment: What is at Issue? Paper Presented at the Environment protection Agency, MONRD, Addis Ababa.

Edessa S (1993). The decline of forests and natural resources in Ethiopia. Ekologia(Bratislava)/Ecology(Bratislava) 12(2):215-222.

Ermias B (2003). Causes and Consequences of Environmental Degradation in Ethiopia. In Environment and Environmental Change in Ethiopia. Consultation Paper on Environment 1. Forum for Social Studies, Civil Society, and Environmental Policy Dialogue, Addis Ababa.

Food and agriculture organization (FAO) (2000). Global Forest Resources Assessment. FAO Forestry Paper 140, Rome, Italy.

Food and agriculture organization (FAO) (2010). Global forest resources assessment. Food and agriculture organization of the United Nations, Rome.

Food and agriculture organization (FAO) (2012). Food and Agricultural Organizations of the United Nations Rome.

Friis IB, Mesfin T (1992). The evergreen forests of tropical northeast Africa. Dk-1123 Copenhagen K, Denmark. Opera Botanica 63:1-70.

Gebremarkos W, Deribe G (2005). Problems of Forestry Associated with Institutional Arrangement. In Biological Society of Ethiopia, Imperative Problems Associated with Forestry in Ethiopia: Proceeding of a Workshop, Faculty of Science, AAU, and Addis Ababa. Gedion A (Ed.). Environment and Environmental Change in Ethiopia, FSS, Consultation Paper on Environment No. 1.

Intergovernmental Panel on Climate Change (IPCC) (2003). Intergovernmental Panel on Climate Change. Good Practice Guidance for Land Use, Land-Use Change and Forestry; The Intergovernmental Panel on Climate Change (IPCC): Hayama, Japan, 2003.

Kanel KR, Niraula DR (2004). Can rural livelihood be improved in Nepal through community forestry. Banko Jankari 14(1):19-26.

Legesse N (2003). Environmental Changes of Contemporary Ethiopia and the Indispensable Role of Indigenous Trees, FSS Consultation Paper on Environment No. 7.

Mateos E (2003). Inventory of wood species diversity in Arba Minch. Technical Report No. 23, Addis Ababa, Ethiopia. Memorial Christian College, Marthandam-629165, Kanyakumari, Tamil Nadu, India.

Ministry of Health (MOH) (2014). Controlling and protection of STD and viral and bacterial distributions in the central Ethiopia.

NCS (2012). Ethiopia national conservation strategy. National Conservation Secretariat, Office of Population, February 1 Addis Ababa.

Pankhurst A (1992). The his tom of Deforestation and Deforestation in Ethiopia Prior to World War II. Ethiop. J. Dev. Res. 14(2):59-77.

Sands R (2006). Forestry in a Global Context. CABI Publishing Agency.

Soury A (2007). Sacred forests: a sustainable conservation strategy. The case of sacred forests in the Ouémé Valley, Benin. Netherland: Wageningen University.

Stevenson G (1996). Indigenous knowledge in environmental assessment. Arctic 278-291.

Sukumaran S, Jeeva S (2008). A floristic study on miniature sacred forests at Agastheeshwaram, southern peninsular India. Eurasian J. Biosci. 2:66.

Tewolde G (1996). Environmental Policy and Population Explosion in Ethiopia. Paper the Himalaya: International Centre for Integrated (Mountain. Fisheries and aquaculture department).

Tuma A (2007). Effect of Fruit Based Land Use Systems on Soil Physicochemical Properties: The Case of Smallholders Farming Systems in Gamo Gofa, Southern Ethiopia; MSc thesis, Hawassa University, Hawassa, Ethiopia.

Jeffrey M. Wooldridge (2000). Introductory Econometrics: A Modern Approach, South-Western College Publishing, 2000, 2006, 2009.

World Bank (2012). Age dependency ratio; young (% of working-age population) in Ethiopia.

Yigremew A (2001). Rural Organization in Ethiopia: Their Condition's and Role in sustainable Natural Resource use and in Promoting Food Productions. In Food Security through Sustainable land use. Policy on Institutional, Land Tenure, and Extension Issues in Ethiopia, Edited by Taye A., Addis Ababa: Novib partners Forum References.

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Impact of land use and management practice on soil physical and chemical quality indicators of Vertisols at Pawe, Northwestern Ethiopia

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Soil quality is a function of inherent and dynamic properties of soil which determines the sustainability of crop and animal production. Based on this fact, the study was aimed to investigate the effects of land use systems and management practices on soil physical and chemical quality indicators of Vertisol at Pawe district, Northwestern Ethiopia. The result revealed that most of the soil physical and chemical properties were significantly ($p \leq 0.05$) affected by the land uses and respective management practices. The land uses and respective management practices were selected as the cultivated homestead land (CHL), cultivated research farm (CRF), cultivated fertilized land (CFL) and cultivated unfertilized land(CUL) and native vegetation land (NVL) as a control. The cultivated land with application of farm yard manure (FYM) at the homestead area had higher soil porosity, aggregate size, organic matter (OM), total and mineral nitrogen, available phosphorus (AvP), cation exchange capacity (CEC), exchangeable cations, and micronutrients than the native vegetation land. On the other hand, most of these soil physical and chemical properties found to be declined in the research farm, fertilized and unfertilized cultivated lands. Therefore, integrated use of chemical fertilizer, farmyard manure application and reduced tillage are important soil management practices for sustainable agricultural use of soil in the study area.

Key words: Soil quality, vertisol, land use, cultivated land, management practices.

INTRODUCTION

Soil quality in agricultural system depends on the inherent and dynamic nature of soil which determines the soils suitability for sustainable crop production. There are different factors that influence soil quality in agricultural system which include soil type, climate, tillage, crop rotation and type of soil fertilizer and manure (Imaz et al., 2010). In Ethiopia, due to intensive cultivation of soils without proper management practices such as a removal of crop residues from farm lands, low levels of fertilizer application (Nigussie et al., 2015), use of animal manure

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as a source of fuel (IFPRI, 2010) and the absence of appropriate soil and water conservation practices, result in degradation of soil quality. The core constraints in relation to this improper land use management include: depletion of organic matter due to widespread use of biomass as fuel, depletion of macro and micro-nutrients, removal of topsoil by erosion, change of soil physical properties, and increased soil salinity (IFPRI, 2010; Ayele et al., 2013). These will undoubtedly contribute to exacerbate soil quality decline leading to soil degradation, which may ultimately lead to complete loss of land values. Research in different parts of Ethiopia (Kiflu and Beyene, 2013; Nega and Heluf, 2013; Muche et al., 2015; Takele et al., 2015; Wasihun et al., 2015; Abegaz et al., 2016; Tesfahunegn, 2016) confirm that inappropriate agricultural land management has resulted in the deterioration of soil quality.

Cultivations started in Pawe district in 1985 following the National Resettlement Program in Ethiopia. Since then the natural vegetation of this area had gradually decreased due to deforestation by cutting trees and burning the forest area to use the land for cultivation without any management practice. These had undoubtedly contributed to soil quality degradation in Pawe district. In addition, Vertisols are the largest soil group in this area (Viezzoli, 1992) which affect soil's inherent quality for plant growth, have poor soil physical quality due to high smectite clay mineralogy, very hard and crack when dry, sticky and plastic when wet and poor in drainage. On the other hand, they have relatively high inherent fertility while it requires a careful management in order to tap the potential for crop productivity. Assessment of soil quality based on inherent and dynamic aspects of soil system, is an effective method for evaluating the environmental sustainability of land use and management activities (Nortcliff, 2002). In this regard, soil quality changes in the study area were inferred by measuring the relative changes in soil physical and chemical properties upon the conversion of native woody grass land to cultivated lands with different management practices including organic and inorganic fertilization history. Currently, only little scientific information is available on different land uses and its management impacts with regard to magnitude of soil quality changes under sustainable crop production in the country in general and in the Pawe district in particular. Therefore, this study was initiated to investigate the effects of land use systems on soil physical and chemical quality indicators of Vertisol at Pawe areas.

MATERIALS AND METHODS

Description of the study area

Geographically, the study area is located in Pawe district (11° 18´ 40" to 11º 19´ 29" north latitude and from 36º 24´ 26" to 36º 25´ 27" east longitude) Metekel Zone, Northwest Ethiopia (Figure 1). The district covers an area of about 150,000 ha and the altititude varies

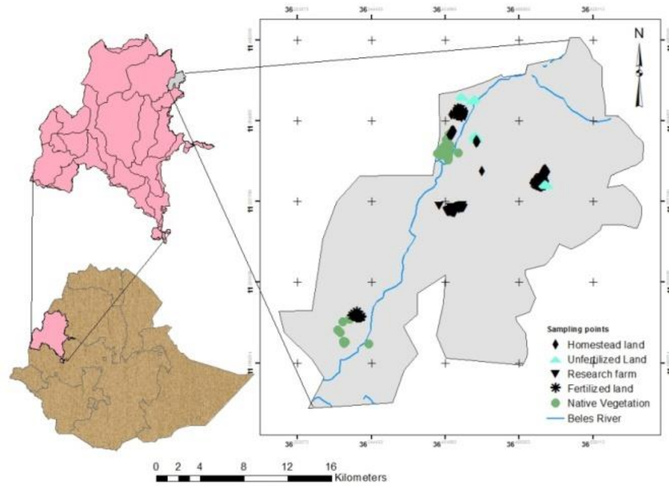

Figure 1. Location map of the study site, Pawe district, Northwestern Ethiopia.

from 1,000 to 1,200 m above sea level (masl) with much of the area falling in nearly flat to gently undulating topography. it is slightly undulating towards the Beles River. The geology of the area consists of metconglomerate and quartzite of the Precambrian basement complex (Mengesha et al., 1996). The dominant soil types in the Pawe district are broadly categorized as Vertisols, which account for 40–45% of the area (Viezzoli, 1992).

The climate of the study area is hot humid with annual mean temperature of 25ºC. It is characterized by a unimodal rainfall pattern with annual mean of 1587 mm.

Land use and management practices

The natural vegetation in Pawe districts consists of thick shrub, scattered trees and different grass species were currently survived from deforestation along the sides of Beles main river and its sub tributaries. The majority of the farming system is oriented towards grain production which depends on the use of oxen for land preparation. Cultivation of crops without much application of fertilizer is also a common practice in the study area. However, local farmers usually use farm yard manure (FYM) as soil management at nearby homestead fields. In contrary to the most farmers cultivate crops without much application of chemical fertilizers, the research station fields in the study area use different acid forming fertilizers and mechanized farming for land preparation. Therefore, this study considered the effect of tillage, fertilizer and farmyard manure application management practice in cultivated lands with comparison of natural forestland.

Field survey, site selection and soil sampling

Field observation and soil sampling were carried out with the help of topographic map of the district. Prior to the actual field work, preliminary soil survey and field observations were carried out using the topographic map (Scale 1:50,000) produced by the Ethiopian Mapping Authority (1994). However, the information about the actual soil condition and management practices of specific sites was gathered by observation of the actual soil condition and interviews with farmers and local agriculture experts. The sampling

Table 1. Effects of land use and soil depth on selected soil physical properties of Vertisols at study area.

Land use	Sand (%)	Silt (%)	Clay (%)	Textural class	BD (g cm^{-3})	PD (g cm^{-3})	Porosity (%)	FC (%)	PWP (%)	AWHC (%)
NVL	13.83	17.34	68.83	Clay	1.19^{a}	2.44	51.35^{a}	45.15^{a}	33.58^{ab}	11.57^{b}
CHL	11.50	18.67	69.83	Clay	1.12^{b}	2.45	54.29^{a}	48.80^{a}	35.16^{a}	13.64^{a}
CFL	10.67	17.50	71.83	Clay	1.22^{a}	2.43	50.69^{b}	44.36^{ab}	34.01^{ab}	10.36^{c}
CRF	8.17	20.83	71.00	Clay	1.21^{a}	2.45	49.78^{b}	38.26^{c}	29.67^{b}	8.60^{d}
CUL	7.67	21.50	70.83	Clay	1.24^{a}	2.49	50.06^{b}	40.13^{bc}	31.12^{ab}	9.01^{d}
LSD (0.05)	NS	NS	NS		0.05	NS	2.89	4.2952	4.4595	0.914
0-15	9.87	19.47	70.67	Clay	1.14^{b}	2.44	53.17^{a}	43.41	32.47	10.94^{a}
15-30	10.87	18.87	70.27	Clay	1.25^{a}	2.46	49.30^{b}	43.27	32.94	10.33^{b}
LSD (0.05)	NS	NS	NS		0.04	NS	1.75	NS	NS	0.59

*Means within a column and the same factor followed by same letter are not significantly different from each other at $p > 0.05$. NS = Not significant; LSD = Least significant difference.

sites were selected based on the land use system and management practices which are expected to affect soil physical and chemical quality. Accordingly, soil samples were collected from five land uses (NVL, CHL, CFL, CUL and CRF) in the Vertisols dominant area of Pawe district. From each sampling sites, three composite soil samples were augured at 0-15 and 15-30 cm depths and taken to the laboratory for analysis. For determination of bulk density and aggregate size distribution undisturbed soil samples were also separately taken from the selected sites.

Soil sample preparation and analysis

The disturbed soil samples that were collected from the study area were air dried, crushed and passed through 2 mm mesh sizes and analyzed in the soil laboratories of Pawe and Deberzeit agricultural research centers. Total porosity was calculated from the bulk and particle density. Soil texture was determined using the Bouyoucos hydrometer method, soil bulk density (BD) by the core method and aggregate size distribution by the dry sieving method (Jaiswal, 2003).The soil water contents at field capacity (FC -1/3 bar) and permanent wilting point (PWP -15 bars) were determined using the pressure plate apparatus and the plant available water holding capacity (AWHC) of the soils was calculated as the difference between the water contents at FC and PWP (Klute, 1965). Soil pH was measured using a digital pH-meter in 1:2.5 soils to water ratio (Peach, 1965). The soil OC content was determined by Walkley and Black method. Total nitrogen(TN) was determined by the micro-Kjelda CHL digestion, while NH_4^+ and NO_3^- were determined by steam distillation of ammonia (NH_3), using heavy MgO for NH_4^+ and Nevada's Alloy for NO_3^- (Bremner and Keeney, 1965). Available P was determined using the Bray II extraction method as described by Bray and Kurtz (1945). Exchangeable cations (Ca, Mg, K and Na) and Cation exchange capacity were determined after leaching the soil samples with 1 M ammonium acetate solution at pH 7 (Chapman, 1965). The micronutrients (Fe, Mn, Zn and Cu) were determined by extracting the soils with the DTPA method as described by Lindsay and Norvell (1978).

Data analysis

The soil analysis data were subjected to analysis of variance (ANOVA) using SAS software (9.3) to assess the significance of differences in soil parameters due to land uses and soil depths. Correlation coefficient (r) was also computed to determine the magnitude and relationship between selected soil quality indicators.

RESULTS AND DISCUSSION

Physical soil quality indicators

The data shows that there were no differences in textural classes among the land use system and corresponding management practices (NVL, CHL, CRF, CFL and CUL). Accordingly, the soils in the study area were clayey in texture; with the clay fraction accounting for more than 50% of the soil separates. Relatively higher sand contents were observed under the native vegetation followed by homestead lands, whereas relatively higher clay contents were observed under the remaining cultivated lands (Table 1). This indicated that the long-time cultivation process could be contributed to increase the clay size soil separates through the process of ploughing and other management practices. Adugna and Abegaz (2016) also suggested that the lower content of sand and higher content of clay fractions in the cultivated land may be attributed to the process of ploughing, clearing, and the levelling of farming fields. The soil bulk density (BD) and total porosity values were significantly ($p \leq 0.05$) different for the land use types and the corresponding management practices (Table 1). Numerically, it was ranged from 1.12 in the CHL to 1.24 g cm^{-3} in CUL. Contrary to BD, total porosity was highest (54.29%) in the CHL while it was the lowest (49.78%) in the CRF. The observed lowest BD in CUL and highest total porosity figures in the CHM are largely attributed to its highest soil OM content due to continuous application of FYM. On the other hand, the lowest total porosity in CRF and the highest BD in CUL are attributed to the continuous and intensive cultivation of the soil without much application organic and inorganic fertilizer inputs in UCL and heavy farm machinery compaction in CRF.

Previous studies reported that land use systems had significantly affected BD and soil porosity because of intensive cultivation without appropriate soil management which resulted in OM degradation and soil compaction (Bahrami et al., 2010, Bezabih et al., 2016). However,

Table 2. Aggregate size distribution (%) and mean weight diameters under different land use system on Vertisols of study area.

Land use/use	Aggregate size (mm)*								
	> 5	2-5	1-2	0.5-1	0.15- 0.5	0.125-0.15	0.053-0.125	≤ 0.053	MWD
Vertisols									
NVL	16.94[a]	42.98[ab]	26.34	6.57[ab]	2.62[bc]	1.68[b]	1.64[b]	1.24	4.11[ab]
CHL	21.42[a]	43.89[a]	23.78	4.59[b]	1.87[c]	1.62[b]	1.50[b]	1.33	4.44[a]
CFL	15.99[ab]	36.97[b]	28.71	10.14[ab]	3.71[b]	1.58[b]	1.67[b]	1.24	3.83[bc]
CRF	9.72b[c]	26.62[c]	29.83	17.91[a]	9.47[a]	2.47[a]	2.57[a]	1.41	2.94[c]
CUL	8.09[c]	41.64[ab]	31.71	10.50[a]	3.13[b]	1.77[b]	1.72[b]	1.44	3.49[d]
LSD (0.05)	6.68	6.78	NS	4.69	2.66	0.52	0.50	NS	0.50
Depth (cm)									
0-15	14.80	37.56	28.14	10.30	4.24	1.86	1.81	1.29	3.77
15-30	14.06	39.28	28.00	9.58	4.09	1.79	1.83	1.37	3.75
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

application of manure to the soil counteracted soil compaction by decreasing soil compatibility and improved porosity (Shirani, 2002), had impacted on soil quality by improve root growth, nutrient and air balance and water retention (Jamil et al., 2016).

Water contents at FC, PWP and AWHC were significantly (p ≤ 0.05) affected by land use types and soil management practices (Table 1). The observed results generally showed that the soil water contents at all three conditions were highest in the CHL while lowest in the CRF. This was attributed to the improved OM and total porosity of the soils in the CHL and declined in the remaining cultivated lands. Yuksek et al. (2010) also reported that as the amount of organic materials decrease, soil water retention at FC, PWP and AWHC of the soil decrease as well.

The aggregate size distributions was also significantly (p ≤ 0.05) affected by land use and management practices at all aggregate size classes except the 1-2 mm and ≤ 0.053 mm which has not affected by soil depth (Table 2). The CHL and NVL lands had a good soil structure as a result of having the greater proportion of macro aggregates (> 1 mm) and a lower proportion of micro-aggregate (≤ 1 mm) (Table 2). In contrast to homestead land, the percentage of macro- aggregates (> 5, 2-5 and 1- 2 mm) and the calculated mean weight diameter (MWD) decreased in the research farm while the micro- aggregates(0.5-1, 0.15-0.5, 0.125-0.15, 0.053-0.125 and ≤ 0.053 mm) increased as a result of using heavy farming machinery and intensive cultivation in the research farm. This indicated that the lower OM contents in the cultivated lands have hastened the decomposition of humus and the deterioration of soil aggregates while in homestead land, the application of FYM might be responsible for increased OM content and the stabilization of aggregates as well as higher MWD. In agreement with this result Bidisha et al. (2010) observed that cultivation without fertilization or manuring over control soil showed abundant micro aggregates.

Soil chemical quality indicators

The effects of land use and the corresponding management practice on soil chemical quality indicators (Tables 3 and 5). The result revealed that most of soil chemical quality indicators; pH, OM, TN, Av.P, exchangeable cations, CEC and micronutrients were significantly (p ≤ 0.05) affected by soil management practice in the study area. Based on the result, the soil pH was ranged from 6.71 in NVL to 6.07 in CRF. This could be due to the ameliorating effect of FYM on soil acidity by reducing the activity of aluminum ions in CHL and the continuous use of acid forming fertilizers (urea and DAP) and depletion of basic cations in the CRF. Similarly, Wakene and Heluf (2003) also attributed the lowest pH values recorded in the soils of the Bako Research Station due to intensive cultivation and use of acidifying inorganic N and P fertilizers.

The soil organic matter content of of the study area was significantly (p ≤ 0.01) varied from 2.25% in the CUL to 3.82% in the CHL. In addition, the soil under NVL also had relatively higher OM values (2.91%) next to the CHL in study area. According to Tekalign (1991), the amount of OM recorded in the CFL and CUL cultivated lands of the study area were found to be low, whereas the remaining cultivated lands and NVL in the study area had moderate OM content. Similarly, Bidisha (2010), recorded low organic carbon for unfertilized soil compared to the fertilized and manure amended soil. With regard to soil depth, the amounts of OM in the subsurface (15-30) soils were lowered 34.66, 45.44, 26.44, 20.32 and 14.08% under the NVL, CHL, CFL, CRF and CUL respectively as compared to their respective surface (0-15 cm) soils in

Table 3. Main effects of land use and soil depth on some chemical properties of Vertisols in the study area.

Landuse/use	pH	EC (dS m^{-1})	OM (%)	Total N (%)	C:N	NO_3^{-1}	NH_4^+	AvP
							(mg kg^{-1})	
NVL	6.71^a	0.58^b	2.91^b	0.132^b	12.78	15.63^{ab}	6.73^{bc}	3.48^b
CHL	6.70^a	0.89^a	3.82^a	0.169^a	13.21	19.75^a	10.63^a	18.91^a
CFL	6.40^b	0.45^{bc}	2.56^{bc}	0.118^b	12.96	14.73^{ab}	7.72^{bc}	2.97^b
CRF	6.07^c	0.33^c	2.64^{cb}	0.127^b	12.04	18.52^{ab}	8.01^{ab}	2.82^b
CUL	6.28^b	0.41^{bc}	2.25^c	0.110^c	11.86	13.38^b	5.22^c	2.31^b
LSD (0.05)	0.20	0.17	0.633	0.033	NS	5.950	2.72	7.09
Depth (cm)*								
0-15	6.46	0.59^a	3.35^a	0.15^a	12.87	21.26^a	8.58	8.89^a
15-30	6.40	0.48^b	2.32^b	0.11^b	12.27	11.55^b	6.74	3.31^b
LSD (0.05)	Ns	0.10	0.40	0.02	NS	3.76	NS	4.48

*Main effect means within a column of the same factor followed by the same letter are not significantly different from each other at P > 0.05.

the study area. This could be due to the mechanical tillage practice in the research farm uniformly mixing the surface and the subsurface soil. However, under the CHL, the OM was accumulated in the surface soil because the use of traditional tillage practices had significantly mixed the surface and subsurface soils.

The total N contents of the soils in the study area were also varied from 0.110% in the CUL to 0.169% in the CHL. According to Tekalign (1991), the status of total N of the soils in the study area was moderate under the CHL, NVL and CRF and low in the CUL. The OM showed strong association with total N (r = 0.92**) and mineral N contents (NO_3^- (r = 0.81**) and NH_4+ (r = 0.64**) (Table 4). Thus, the result revealed that land use and management practices that increased soil OM content, also increase the N contents of soils.

The concentration of available P with Bray II extraction method was ranged from 2.31 in the CHL to 18.91 mg kg-1 in the CUL (Table 3). The relatively high availability of P in the CHL could be associated with the added FYM on this cultivated land which reduce P fixation by masking the fixation sites on the soil colloids. On the other hand, the low availability of P in the natural vegetation land and other cultivated lands could be related to the inherent P deficiency of Vertisols as insoluble Ca and/or Mg phosphates complex through reactions with the relatively high clay contents. As a result, available P was positively and significantly associated with the OM (r = 0.80^{**}) and pH (r = 0.51^{*}) and negatively associated with the clay contents (r = -0.57^{**}) (Table 4).

In general, the result of OM, TN, mineral N' and Av. P under the CRF, CFL and CUL cultivated lands showed overall change towards the direction of loss of their quality compared to the soils attributes of the adjacent NVL and CHL. Furthermore, these chemical properties generally declined in CUL as compared to CFL. However, Continuous use of sole inorganic fertilizers lead to various harmful effects on the soil environment, and reducing the productivity of the soil by affecting soil health in terms of physical, chemical and biological properties (Surekha et al. 2013). Several research work in different parts of Ethiopia indicated a depletion risk in pH, OM, TN and Av.P contents under cultivated lands (Emiru and Gebrekidan (2013), Kiflu and Beyene (2013), Takele et al (2015), Mucheet al(2015), Adugnaand Abegaz (2016), Tesfahunegn (2016)). This might be due to continuous intensive cultivation with frequent tillage, application of acid forming fertilizers practice, overgrazing, erosion and removal of crops and crop residues with poor soil management practices.

Exchangeable cations (Ca, Mg, K, Na) were affected by land use and management practices in the study area. The highest exchangeable Ca, Mg and K values were observed in the CHL followed by in the NVL, whereas the lowest exchangeable values were observed in the CRF. The CEC values of the soils in the study area were also highest (49.44 cmol (+) kg^{-1}) in the homestead land followed by 43.78 cmol kg^{-1} in the NVL and lowest (27.13 cmol (+) kg^{-1}) in the CRF (Table 5). The depletion of CEC from the CRF, CFL and CUL were 38.03, 19.27 and 23.78%, respectively, as compared to the CEC in the NVL. The highest Exchangeable cations and CEC values obtained in the CHL could be related to high OM from continuously applied FYM and stable soil structure that decrease loss of cations by soil erosion. On the other hand, the lowest values in the CRF could be due to continuous use of the inorganic fertilizer that enhanced loss of base cations through leaching, erosion and crop harvest. Based on the ratings of FAO (2006), exchangeable Ca and Mg of soils in the NVL and CHL were very high and that of the CFL, CUL and CRF were high in the study area. However, the status of exchangeable K of the soils in the study area was high (0.94 cmol(+) kg^{-1}) and very high (1.46 cmol(+) kg^{-1}) in

Table 4. Pearson's correlation matrix for various soil physical and chemical parameters.

Matrix	pH	OM	N	AvP	EA	Ca	Mg	K	Na	CEC	Cu	Fe	Mn	Zn	FC	PWP	AWC	BD	CLAY	SILT	SAND	MWD
H	1																					
OM	0.43*	1																				
N	0.44*	0.93**	1																			
AvP	0.60**	0.78**	0.73**	1																		
EA	-0.45**	0.03	0.07	-0.18	1																	
Ca	0.83**	0.29	0.25	0.42*	-0.24	1																
Mg	0.71**	0.19	0.18	0.46**	-0.46**	0.63**	1															
K	0.68**	0.70**	0.68**	0.87**	-0.28	0.48**	0.51**	1														
Na	0.51**	-0.01	0.02	0.21	-0.22	0.41*	0.23	0.36*	1													
CEC	0.80**	0.41*	0.40*	0.65**	-0.28	0.78**	0.83**	0.68**	0.33	1												
Cu	0.01	0.37*	0.29	0.40*	-0.06	-0.11	0.21	0.22	-0.34	0.11	1											
Fe	0.08	0.14	0.03	-0.15	-0.13	0.01	-0.03	-0.04	0.1	-0.08	-0.01	1										
Mn	0.52**	0.74**	0.67**	0.66**	0.06	0.3	0.31	0.64**	0.07	0.52**	0.23	0.13	1									
Zn	0.55**	0.72**	0.67**	0.93**	-0.25	0.34	0.45*	0.83**	0.2	0.62**	0.26	-0.1	0.64	1								
Fc	0.75**	0.27	0.22	0.51**	-0.32	0.76**	0.88**	0.62**	0.35	0.80**	0.09	-0.06	0.37	0.46	1							
PWP	0.56**	0.08	0.04	0.27	-0.22	0.60**	0.79**	0.40*	0.25	0.61**	0.37*	-0.08	0.19	0.28	0.93**	1						
AWC	0.77**	0.51**	0.47**	0.72**	-0.36*	0.70**	0.65**	0.77**	0.36*	0.81**	0.78**	0	0.53**	0.60**	0.68**	0.35	1					
BD	-0.36*	-0.92**	-0.88**	-0.61**	0.01	-0.21	-0.15	-0.59**	0.09	-0.35	-0.60**	-0.21	-0.71**	-0.58**	-0.19	-0.01	-0.46**	1				
Clay	-0.17	-0.16	-0.19	-0.19	0.04	-0.12	-0.06	-0.08	0.42	-0.2	-0.05	-0.06	-0.27	-0.26	0.02	0.12	-0.17	0.29	1			
Silt	-0.07	0.08	0.09	-0.06	0.12	-0.05	0.09	0.06	-0.31	-0.05	-0.06	-0.19	0.06	0.02	0	0.05	-0.1	-0.1	-0.08	1		
Sand	0.69**	0.05	0.09	0.18	-0.42*	0.69**	0.66**	0.29	0.33	0.61**	0.35	0.19	0.08	0.22	0.65**	0.55**	0.55**	-0.06	-0.21	-0.21	1	
MWD	0.2	0.67**	0.54**	0.46**	-0.36*	0.67**	0.70**	0.43*	0.36	0.77**	0.54**	-0.15	0.18	0.4	0.68**	0.52**	0.66**	-0.12	-0.04	-0.07	0.55**	1

*,** Significant at 5 and 1% levels, respectively.

the CHL and the remaining lands had medium exchangeable K. Based on the ratings of Hazelton and Murphy (2007), the values of CEC under all land uses in the Vertisols are categorized as high level. With regards to soil depth, the higher values of exchangeable cations and CEC generally were recorded at the surface (0-15 cm) soil than subsurface (15-30 cm) soil. This decreased in CEC value in the subsurface layer, with the parallel declined in OM content is to be expected. The possible reason for the higher concentrations of exchangeable cations and CEC with higher OM could be related the decomposition of organic material (plant residue and FYM) to release K, Ca and Mg into the soil and makes soil less susceptible to erosion (Fageria, 2009).

The value of PBS was highest(80.04%) in the CHL while it was lowest (68.28%) in the CFL. This could be related to its higher OM content as compared to the other cultivated lands which leads to a greater in CEC than the increase in exchangeable bases regulating in the reduction of PBS. On the other hand, the CFL, CUL and CRF had lowered OM as compared with CHL which led in to decrease the CEC but increased PBS. It is because naturally the exchangeable bases in the Vertisols clay are high. The PBS in the Vertisols is greater than 50 and often close to 100% with Ca and Mg occupying more than 90% of the exchange sites (FAO, 2001).

The contents of available micronutrients (Fe, Mn, Zn and Cu) were significantly ($p \leq 0.05$) affected by land use and its corresponding management practices. The highest contents of Cu (6.18 mg kg^{-1}), Zn (1.87 mg kg^{-1}) and Mn (26.05 mg kg^{-1}) were recorded in the CHL and Fe (36.40 mg kg^{-1}) was recorded in the CUL. However, the lowest values of Cu (3.70 mg kg^{-1}) and Zn (0.44 mg kg^{-1}) were recorded under the

Table 5. Main effects of land use and soil management on exchangeable cations, CEC and micronutrients of Vertisols in the study area

Land use	Basic exchangeable cations (cmol(+) kg^{-1})				CEC (cmol(+) kg^{-1})	PBS (%)	Available micronutrients (mg kg^{-1})			
	Ca	Mg	K	Na			Cu	Fe	Mn	Zn
NVL	23.40^{a}	7.22^{ab}	0.51^{b}	0.30	43.78^{b}	71.79^{b}	3.96^{b}	34.07^{a}	14.65^{bc}	0.75^{b}
CHL	24.06^{a}	8.49^{a}	0.94^{a}	0.27	49.44^{a}	68.28^{b}	6.18^{a}	29.44^{ab}	26.05^{a}	1.87^{a}
CFL	21.15^{b}	6.75^{b}	0.45^{bc}	0.23	34.34^{c}	80.44^{a}	3.94^{b}	23.26^{b}	8.94^{c}	0.55^{b}
CRF	15.67^{c}	4.25^{c}	0.35^{bc}	0.14	27.13^{d}	75.23^{ab}	4.43^{b}	35.63^{a}	14.33^{bc}	0.44^{b}
CUL	20.10^{b}	5.70^{bc}	0.32^{c}	0.24	33.37^{c}	78.99^{a}	3.70^{b}	36.40^{a}	18.89^{ab}	0.54^{b}
LSD (0.05)	2.66	1.69	0.19	NS	3.58	10.02	1.44	10.30	8.27	0.71
Depth (cm)*										
0-15	21.78	6.55	0.57	0.25	39.29^{a}	73.31	4.75	32.20	18.99	1.03^{a}
15-30	20.37	6.41	0.46	0.22	36.33^{b}	76.94	4.14	31.32	14.15	0.63^{b}
LSD (0.05)	NS	NS	NS	NS	2.26	NS	NS	NS	NS	0.33

*Means within a column of the same factor followed by same letter are not significantly different at P > 0.05. NS = Not significant; LSD = Least of significant difference.

CUL and CRF, respectively. Similarly, the lowest values of Mn (8.94 mg kg^{-1}) and Fe (23.26 mg kg^{-1}) were recorded in the CFL (Table 5). With regards to soil depth, all values of micronutrients were numerically higher in the surface soil (0-15 cm) than in the subsurface (15-30 cm) soil layer (Table 5).

The availability of micronutrient is influenced by accumulation of OM and soil pH. The higher OM in surface soil can form soluble organic complex with most of micronutrients which are mobile and can be lost by leaching. However, the influence of pH on availability of Cu and Zn is less than that of Fe and Mn (Fageria, 2009). Therefore, the higher concentrations of Fe and Mn in the research farm are probably due to its lower pH as compared to the other land uses types. The contents of Fe and Mn in this study decreased with the increase of pH (r = -0.57** and r = -0.48*, respectively) (Table 4). Hence, these results indicated that soil pH is an important chemical property in determining availability of such micronutrients in the soils. In general, all of micronutrients (Fe, Mn, Cu and Zn) in study area are between the toxicity and sufficiency levels as per the rating by Lindsay and Norvell (1978). Therefore, there is no soil quality problem related to these micronutrients.

Conclusions

The results of this study are evidences of the significant changes in the quality attributes of the soils in the study area following the removal or destruction of vegetative cover, low organic input and frequent tillage that led to soil erosion and decline in soil quality. The result revealed good soil quality in terms of water availability, soil aggregate size distribution, bulk densities, OM, total and mineral N, available P, CEC, exchangeable base and micronutrient in continuous manure amended cultivated land as compared to the natural vegetation. However, these physical and chemical indicators in the research farm, fertilized and unfertilized cultivated lands showed overall change towards the direction of loss of their quality compared to the soils attributes of the adjacent native vegetation and homestead land. Therefore, there is a vital need to adopt appropriate soil and plant management practices that reduce soil degradation or maintain soil quality at a desirable level in the study area.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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REFERENCES

Abegaz A, Winowiecki A, Vagen A, Langan S, Smith J (2016). Spatial and temporal dynamics of soil organic carbon in landscapes of the upper Blue Nile Basin of the Ethiopian Highlands, Agr. Ecosyst. Environ. 218:190-208.

Ayele T, Beyene S, Esayas A (2015). Changes in land use on soil physicochemical properties: the case of smallholders Fruit-based land use systems in Arbaminch, southern Ethiopia International J. Curr. Res. 5(10):3203-3210.

Bahrami A, Emadodin I, Maryam R, Atashi MR, Bork HR (2010). Land-use change and soil degradation: A case study, North of Iran. Agric. Biol. J. N. Am. 1(4):600-605.

Bezabih B, Aticho A, Mossisa T Dume B (2016). The effect of land management practices on soil physical and chemical properties in Gojeb Sub-river Basin of Dedo District, Southwest Ethiopia. Journal of Soil Science and Environmental Management 7(10):154-165.

Bidisha M, Joerg R, Yakov K (2010). Effects of aggregation processes on distribution of aggregate size fractions and organic C content of a long-term fertilized soil European Journal of Soil Biol. 46:365-370

Bray RH, Kurtz LT (1945). Determination of total, organic and available forms of phosphorus in soils. Soil Sci. 9:39-45.

Bremner JM, Keeney DR (1965). Steam distillation methods for determination of ammonium, nitrate, and nitrite. J. Anal. Chem. 32:215-163.

Chapman HD (1965). Cation exchange capacityIn: Black CA., Evans DD, White JL, Ensminger LE, Clark FE (eds.) Methods of Soil Analysis. American Society of Agronomy, No. 9. Madison, Wisconsin, USA pp. 891-901.

Emiru N, Gebrekidan H (2013). Effect of land use changes and soil depth on soil organic matter, total nitrogen and available phosphorus contents of soils in Senbat watershed, western Ethiopia, J. Agric. Biol. Sci., 8(3):206-212

Fageria NK (2009). The Use of Nutrients in Crop Plants. Taylor & Francis Group, CRC Press, New York, USA pp. 31-123.

FAO (Food and Agriculture Organization) (2001). Major soils of the world .World reference base for soil resource reports 94. Rome.

FAO (Food and Agriculture Organization) (2006). Plant nutrition for food security: A Guide for integrated nutrient management. FAO, Fertilizer and Plant Nutrition Bulletin 16, Rome, Italy

Hazelton P, Murphy B (2007). Interoperating soil test results: what do all the numbers mean? 2nd Edition, CSIRO Publishing 152 p.

IFPRI (International Food Policy Research Institute) (2010). Fertilizer and Soil Fertility Potentials in Ethiopia.Working Paper, Addis Ababa, Ethiopia 42 p.

Imaz MJ, Virto I, Bescansa P, Enirique A, Ferandez-Ugalde O, Karlen DL (2010). Soil quality indicator response to tillage and residue management on semi-arid Mediterranean cropland. Soil Till. Res. 107(1):17-25.

Jaiswal PC (2003). Soil, Plant and Water Analysis. Kalyani, New Delhi, India.

Jamil N, Sajjad N, Ashraf H, Masood Z , Bazai ZA, Khan R, Anjum N, Akmal F, Arbab N, Tareen P, Khan R (2016). Physical and Chemical Properties of Soil Quality Indicating Forests Productivity: A Review Am-Euras. J. Toxicol. Sci. 8(2):60-68.

Kiflu A, Beyene S (2013). Effects of different land use systems on selected soil properties in South Ethiopia. J. Soil Sci. Environ. Manage. 4(5):100-107

Klute A (1965). Water holding capacity.. In: C.A. Black (eds.), Methods of Soil Analysis. American Society of Agronomy No. 9, Wisconsin, USA pp. 273-278

Lindsay WL, Norvell WA (1978). Development of a DTPA soil test for zinc, iron, manganese and copper. Soil Sci. Society Am. J. 42:421-428.

Mengesha T, Tadiwos C, Workineh H (1996). Explanation of the geological map of Ethiopia 2nd ed. Institute of Geology Surveys, Adddis Ababa,Ethiopia

Muche M, Kokeb A, Molla E (2015). Assessing the Physicochemical Properties of Soil under Different Land Use Types. J. Environ. Toxicol. 5: 309

Nigussie A, Thomas W, Kuyper B, Andreas de Neergaard (2015). Agricultural waste utilisation strategies and demand for urban waste compost: Evidence from smallholder farmers in Ethiopia Waste Manage. 44:82-93

Nortcliff S (2002). Standardization of soil quality attributes. Agriculture, Ecosystem and Environment, 88:161–168.

Peach M (1965). Hydrogen ion activity. pp. 374-390, In: C.A. Black, D.D. Evans, J.L. White, L.E. Ensminger and F.E. Clark (eds) Methods of Soil Analysis. American Society of Agronomy. Monograph No. 9. Madison, Wi. USA.

Shirani H, Hajabbasi M, Afyuni M, Hemmat A (2002). Effects of farm yard manure and tillage systems on soil physical properties and corn yield in central Iran. Soil and Tillage Research, 68:101-108.

Surekha K, Rao KV, Shobha Rani N, Latha PC, Kumar RM (2013) Evaluation of Organic and Conventional Rice Production Systems for their Productivity, Profitability, Grain Quality and Soil Health. Agrotechnol S11: 006.

Takele L, Chimdi A, Abebaw A (2015). Dynamics of soil fertility as influenced by different land use systems and soil depth in West Showa Zone, Gindeberet district, Ethiopia, Agriculture, Forestry and Fisheries. 3(6):489-494

Tekalign T (1991). Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa

Tesfahunegn GB (2016). Soil quality indicators response to land use and soil management systems in Northern Ethiopia's catchment, Land Degrad. Dev. 27:438-448.

Viezzoli C (1992). Scenarios of economic development in the Beles Valley. pp. 161-180. In: Paolo, D., and C. Viezzoli (eds) Resettlement and Rural development in Ethiopia, Social and Economic Research, Training and Technical Assistance in the Beles Valley. Milano, Italy.

Wakene N, Heluf G (2003). Forms of phosphorus and status of available micronutrients under different land-use systems of Alfisols in Bako area of Ethiopia. Ethiopian J. Nat. Resour. 5(1):17-37

Wasihun M, Muktar M, Teshome Y (2015). Evaluation of the effect of land use types on selected soil physico-chemical properties in Itang-Kir area of Gambella, region, Ethiopia, J. Biol. Agric. Healthcare 5:11.

Yuksek T, Kurdoglu O, Yuksek F (2010). The effects of land use changes and management types on suCRFace soil properties in kafkasor protected area in Artvin, Turkey. Land Degradation Dev. 21:582–59.

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Irrigation technology and crop choices in Ethiopia: Spate vis-a-vis rainwater-harvesting irrigation technologies

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Moisture-stress weakens the use of modern inputs such as fertilizer, which could undermine yields. In a growing population, low yields cause food shortage. Investing in irrigation mitigates moisture-stress but expensive for smallholder farmers. Spate irrigation, a sudden flood run-off diverting, is cheaper to invest in than other irrigation technologies such as ponds and shallow-wells. This study investigated factors deriving the choice of spate irrigation in Ethiopia, and compared crop-choices and yields among irrigation technologies. To investigate the technology choice, logit model was estimated using data collected from Ethiopia in 2005. Secondary data was analyzed to examine crop-choice and yields. The findings show that: (1) farmers with higher irrigation capital, family-labour, lower operation and maintenance (O&M) costs and living in more arid and rainfall-shortage areas choose spate irrigation; (2) market access does not affect the choice; (3) spate users often grow cereals and pulses than other irrigation users, and this enhances food security; (4) spate irrigation increases grain supplies by increasing yields. These findings suggest that encouraging irrigation-capital creation, low-cost O&M, meteorological services, and considering regional diversities increased the probability of modernizing spate irrigation. The findings also inform the decision on crop choice in disadvantaged and remote areas to improve livelihood.

Key words: Irrigation technology, spate irrigation, rainwater harvesting, crop-choice, Ethiopia.

INTRODUCTION

Moisture stress constrains crop production in drought prone Ethiopia. It decreases the use of modern inputs such as fertilizer and improved seeds. The use of low modern input in turn limits yields. Consequently, food shortage happens. One way out is to invest in irrigation (Tilman et al., 2002). But, the question is which type of

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irrigation, large or small-scale? The efficiency of the large-scale irrigation is often low in Africa (Inocencio et al., 2005). Consequently, large-scale schemes in 1970s and 1980s in many African countries such as Ethiopia (e.g., Alwero and Gode dams) failed for low efficiency, high O&M costs and management limitations. During late 1990s, small-scale irrigations such as rainwater harvesting technologies (WHTs), in their broad definition ponds, shallow-wells and stream/flood diversions, were advocated as options mainly due to the relatively cheaper investment finance required to starting and maintaining them (Wakeyo, 2012: 1; World Bank, 1994).

Previous studies underlined that harvested rainwater reduces the negative effect of weather risk in crop production (Ngigi, 2016; Lasage and Verburg, 2015; Kato et al., 2011; Fox et al., 2005). These studies concluded that WHTs increase yields and sustain income by reducing production risk (Barron and Okwach, 2005). Because of this advantage, governments increasingly allocate public budgets (Lasage and Verburg, 2015) and start to stimulate smallholder farmers to invest in them (Wakeyo, 2012: 1-5). When rainwater harvesting program was stimulated in Ethiopia during early 2000s, the objective was to reduce the risk of rainfall shortage especially during the ripening phase of cereals (Gezahegn et al., 2006). However, because the quantity of water in ponds and shallow-wells is too small to water large parcels, farmers were using the water for high-value crops including fruits and vegetables on small plots (Wakeyo, 2012: 41), unlike in other countries such as Kenya for maize production (Barron and Okwach, 2005). This means that the risk reducing likelihood of harvested rainwater for production of cereal and pulses, which are the staple food crops in Ethiopia, could be low. However, to fill moisture stress gap in cereal and pulses production, spate irrigation could be better than ponds and shallow-wells.

Spate irrigation, 'sudden flood' in macro or micro catchment, and river run-offs (Ako et al., 2010), is interesting to study and understand its effectiveness in reducing moisture stress relative to WHTs. In spate irrigation, farmers wait until flood is drained and do not keep the water for future use unlike WHTs, though floods can also fill ponds (Pachpute et al., 2009). Often, spate irrigation is a traditional and incomparable to that of modern schemes (Al-Jayyousi, 1999). In Ethiopia, both spate irrigation and WHTs were promoted during early 2000s to supplement rain-fed and achieve food security. However, why farmers choose WHTs (ponds and shallow-wells) instead of spate irrigation is not well studied.

Studies also indicate that spate irrigation is used mainly for cereals, pulses, oilseeds (Mehari et al., 2008). The question is how it affects crop-choice. Often irrigation conditions rise in yields, but where irrigation is not available yields are almost stagnant in Ethiopia. For example, the FAOSTAT (2014) website indicates that wheat and maize yields in Ethiopia, are respectively 2.21 and 3.0 tonne per hectare in 2012, mainly due to risky rain-fed production. These yields are only one-fourth and one-eighth of the global highest yields respectively. Under risky weather condition, subsistent farmers do not easily change cropping patterns. They tend to grow traditional crops for food as a mechanism of avoiding risk (Wakeyo, 2012: 1; Rosenzweig and Binswanger, 1993). Under this relationship, one can ask research questions such as for which crops is spate-irrigation suitable and what their yield could look like.

This study contributes to understand spate irrigation better. Systematic studies on spate irrigation are lacking (IFAD, 2009; FAO, 2010) because spate irrigation has been carried out by subsistence-farmers often in remote, forgotten and disadvantaged areas that miss attention from researchers. The objective of this study is thus to: (1) identify factors that determine the choice of spate irrigation than other small-scale irrigation; and (2) compare the crop choice in spate irrigation with that of WHT; and study yields. The study could inform policy-makers about irrigation technology choice in disadvantaged areas.

To the best of our knowledge, no study used primary household data to look into spate irrigation. Most empirical studies focus on storage based WHTs instead of spate irrigation (He et al., 2007; Oweis and Hachum, 2006; Rockstrom et al., 2002). In addition, previous studies use qualitative analysis to investigate why farmers go for spate irrigation in a few Asian and North African countries (Mehari et al., 2007, 2008). Similar studies carried out in Ethiopia on spate irrigation are also qualitative and used qualitative methodologies (Kato et al., 2011; Van Steenbergen et al., 2011). Our study contributes to the knowledge of spate irrigation by using household survey data and econometric analysis.

STYLIZED FACTS ABOUT SPATE IRRIGATION

Investment and operating requirements

Investment finance requirement

Spate irrigation is easy to start than other types of irrigation because of several reasons. Mainly, it requires relatively low finance to invest (FAO, 2010). The traditional structures are less expensive because they use labour input and local material for diversion. In Ethiopia, on average it costs $170 to 220 per ha for non-permanent spate irrigation scheme and $450 for permanent scheme (Alemayehu, 2008). For instance, in Koloba spate irrigation, the estimated cost is $330 to 450 per ha for permanent scheme. These costs are not so high compared to the average cost of permanent WH schemes which is about $800 to 1000 per ha. This indicates the cost advantage of spate irrigation in areas where technologies such as WH are too expensive to invest in.

Skill requirement

In spate irrigation, the structures of the schemes are not sophisticated to demand advanced expert skills. Farmers can construct them from local materials using simple hand-tools. Just furrow can also be used and other conveyance equipment may not be critically important. In WHTs such as ponds, imported materials such as plastic geo-membrane and water lifting equipment are necessary. In addition, from their experience, farmers realized that plastic-sheet ponds do better than cement-ponds (Wakeyo and Gardebroek, 2015). The shortage of plastic sheets, however, forced farmers to disadopt the plastic ponds (Wakeyo and Gardebroek, 2015). This implies that constraints such as plastic sheet shortage for pond construction do not affect spate irrigation.

Labour

Labour seems to be relatively less constraining in spate irrigation than others because floods are occasional. However, during flood-diversion, labour demand is high and labour shortage could undermine the success in flood trapping for spate irrigation (Lawrence and Steenbergen, 2005). Labour shortage could also invite failures when demand overlaps with seasonal and high-paying activities.

Crop choice

Literatures indicate an integrated approach is used to study how farmers decide their crop choice (Benin et al., 2004; Evers et al., 1998). The investment decisions on reservoir or water source, method of irrigation and crop-choice are more integrated than separate. Therefore, crop-choice considers the length of growing-period, quantity of water, socio-economic condition and culture, including labour, market, and consumption pattern.

The crop-choice could affect the success in spate irrigation. Successful cash-crops that performed well in Yemen, Pakistan and Eritrea include pulses and oilseeds (van Steenburgen et al., 2011). In Ethiopia, successes are observed in cereals and pulses e.g., maize and chickpeas, and perennials. For example in central areas, farmers harvest chickpeas in February after the major growing season, using the spate moisture collected in October and November, at the end of the major rainy season.

Other socio-economic aspects

Income and uncertainties

The majority of farmers using spate irrigation in Pakistan, Yemen and Eritrea are resource poor, with per capita income of less than a USD a day (FAO, 2010). The weather uncertainties, lack of access to modern markets limit farmers to a subsistence level. In areas where spate irrigations are used, credit and information are missing; transport and communication are scant. In addition, education, potable water, and health facilities are inadequate. Malaria and water-borne diseases are prevalent. Also, locations in the command area affects income, that is, upstream farmers are richer than downstream spate-irrigation users, as usual in conventional irrigation (Lipton, 2007). Also, because of weather uncertainties, users of spate irrigation could often face low returns and crop failures. To escape those income uncertainties, farmers diversify their income (van den Ham, 2008) by keeping livestock, working off-farm and saving resources. In addition, to avoid risk, irrigators cultivate low-yield and drought-resistant traditional and relatively low water intensive crops such as sorghum, barley and wheat.

Land and tenure systems

The average farm-size in spate irrigation is generally small in many countries. It is less than 2.5 ha in Eritrea, Morocco and Tunisia; but it goes large in Balochistan (Pakistan) and selected areas in Yemen, with an average of 5.4 to 7.8 and 2.5 to 5.0 ha (FAO, 2010), receptively. The average irrigated landholding in Ethiopia is unknown, but estimated to be two hectares in Dodota-Sire spate irrigation (Aman, 2006).

In addition to farm-size, in several countries tenure-uncertainties are common. Often the tenure system varies from full ownership by landlords to several degree of ownership by tenants. In Sudan (FAO, 2010), where land is rotating between farmers annually, the tenure system allows the use of rotating spate irrigation among farmers on a fixed land, but prohibits permanent schemes including WHTs.

In Ethiopia, from land ownership perspective, farm land is public with land use right is certified. The land certification may encourage investment in private WHTs. The land certification is also complemented with share-cropping and contracting and this may allow farmers to access 'spate land'. Spate-irrigation could also be communal under a regulation that allows cooperation. Therefore, in the empirical analysis, to test the influence of farm-size on irrigation technology choice is appropriate instead of the influence of land tenure.

Water management, water share and equity

The water management in spate irrigation varies between countries and communities. In some countries (e.g., Eritrea) communal irrigation rights and rules are available. Flood water sharing is based on water volume where distribution is proportional and rotational because estimating the flood volume is possible. Based on the measured volume in meter-cube per second a sharing rule is set in Eritrea[1]. The problem is that under rotational distribution, flood is not sufficient even for upstream farmers e.g., Tahima in Yemen (Mehari et al., 2007). In other countries, however, flood management depends on the construction around fields. For instance, in Pakistan, substantial structures of bund are constructed in farmer-managed schemes to guide and divert flood. In the *tokar* system in Sudan, diversion and guide bunds are supported by embankments to restrict outflows to the sea and retain flood flows (FAO, 2010). In Ethiopia, farmers whose plots are close to run-off areas are beneficiary, unless they contract it out for share-cropping.

Equity of access to run-off is often a challenge in spate irrigation. FAO (2010) remarked that in Pakistan and Eritrea, the mechanism of solving access to flood is by dispersing land-owners plot in several parts of a command area than in a single one (common in Pakistan and Tunisia) and ownership rotation of the irrigable land (e.g. Sudan and Eritrea). In the case of Ethiopia, land ownership is relatively fixed by land certification. This means that the certified land-use right seems to dictate the flood use right. However, because ownership is relatively fixed, flexibility is lacking unlike the case of Pakistan and Eritrea, and individual farmers could choose the fixed water storages such as ponds, shallow-wells instead of flood diversions. Nevertheless, to increase access to flood share cropping, renting in, contracting or exchanging land are common (Oka et al., 2013), as in Dodota-Sire spate-irrigation scheme.

Limiting factors

Climate uncertainty and sedimentation

Documents indicate that climate variability limits the use of spate irrigation (FAO, 2010). This is because flood availability depends on the rainfall, and its shortage hinders the use. The uncertainties are exacerbated by climate change, risk of damage and collapse of canals due to the flood that causes high cost of maintenance. These problems are also common in ponds, but not often in shallow-wells because of is reliable water source (Playan and Mateos, 2006). Sedimentation is also another difficulty common in spate irrigation. Water logging and erosion have a disastrous effect if flood-breaks are not constructed. Birhanu and Mengiste (2007) indicated that in Arsi-Dodta spate irrigation scheme in Ethiopia, the effect of water-logging is so serious that continuous irrigation water flow stunts the growth of cereals. In addition, technical faults could also exacerbate sedimentation. Faults cause course-change and flood loses, creates gullies, reduces soil moisture and increases maintenance burden (van Steenbergen et al., 2011). The success thus depends on technical effectiveness, flood management, maintenance capacity, soil type and geo-physical conditions similar to that of WHTs.

Conflicts

Diversion of run-off is carried out within a watershed where farmers' interests could overlap in collecting and diverting the water run-offs. Often unequal sharing of flood between upstream and the downstream users is the cause of conflict. Defining the water-right, water distribution and its enforcement, and paying proper attention to the traditional rules (Meinzen-Dick and Nkonya, 2007; Ostrom and Gardner, 1993) could be solutions to decrease conflicts. In individual storage facilities such as WHT, conflicts are relatively low because of individual scheme ownership in limited space.

Studies indicate that a defined water right is necessary to address the conflicts in spate irrigation. Coulter et al. (2010) studied low lands of Ethiopian Somale Region and the finding supports this claim. Mehari et al. (2007) also remarked that in Eritrea local rules or agreements for spate irrigation are more important than national or regional water use laws, and sometimes both local and national laws work complementarily.

EMPIRICAL METHOD AND HYPOTHESIS

Empirical method

Econometric analysis is used to test the determinants of technology choice between spate irrigation and WHTs, which is a binary choice. With the aim of identifying factors deriving the choice of two categories of irrigation, binary choice models such as probit and logit can be estimated (Verbeek, 2008). The question is how to choose between logit and probit models. The basic principle to choose between the two is the distribution of the error term in the latent variable equation. In case of probit model the distribution is normal with mean zero and constant variance, whereas in logit model the distribution is logistic (Cameron and Trivedi, 2009: 476-479). In addition to the distribution, empirical fit of the data is also essential for the choice. For example, econometric studies suggest looking at the sample size (Cakmakyapan and Goktas, 2013) as criteria to choose between them, suggesting that in large sample the estimation of logit fits to the data better than probit. Moreover, checking the correct classification of the estimate is also leading to choose between the two models. Finally, ease of interpretation of the coefficients is also another criterion for choosing. Studies indicate that logit model is preferred for interpretation. Therefore, because of its many advantage over probit, we chose the logit model for estimation. The cumulative distribution function of the logit model is:

$$\Pr(\mathrm{Y}=1|\mathrm{X})\mathrm{e}^{-X'\beta}]^{-1} \quad (1)$$

where Y is the dichotomous dependent variable that represents

[1]Flood volume (*fv)* is categorized as *fv< 25, 25 <fv< 50* and *fv>50-100* m^3/s. When *fv is* low, i.e. < 25 m^3/s, rotational distribution is not feasible (Mehari et al. 2007).

whether spate irrigation is chosen or not; $\Pr(Y=1|X)$ is the probability of choosing spate irrigation given the vector of explanatory variables X; and β is vector of coefficient of explanatory variables; and e is the base of natural logarithm.

Equation 1 can be rewritten in several ways. The most simplified form (Walsh, 1987) leads to the estimation of the probability of choosing spate irrigation of an individual variable keeping the influence of all other variables constant:

$$\Pr(Y=1|X) = \frac{e^{\beta_o+\sum_i^k \beta_i X_i}}{1+e^{\beta_o+\sum_i^k \beta_i X_i}} \quad (2)$$

for k explanatory variables included in the estimation. For convenience in estimation, Equation 2 is equivalent to estimating the marginal effect of each exogenous variable (Cameron and Trivedi, 2009: 479).

The dependent variable of the econometric model is a dummy variable indicating whether the farmer chose spate or other small-scale irrigation. We assigned 1 to users of spate irrigation and 0 to non-users.[2]

Variables included in the estimation of the logit model

Based on the stylized facts, previous empirical studies and (van Steenbergen et al., 2011; FAO, 2010) theoretical literature in technology adoption, variables potentially affecting the choice of spate vis-à-vis other irrigation are identified and coefficient sign is hypothesized. For the sake of space, only the hypothesized sign of coefficients of estimation are indicated.

The variables responsible for technology choice in irrigation are household head's age (+), gender (±), education (±), livestock size (±), farm-size (+), market access (±) (Sadoulet and de Janvry, 2006), specialization in crop production (+), ease of selling output (+), rainfall-shortage months (±) (Wakeyo and Gardebroek, 2013), household size(±), family labour availability (+) (Moser and Barrett, 2006), training (±), irrigation capital (proxy: irrigation equipment-cost) (±), O&M cost (±), aridity (±), slope (+) (Bracken and Croke, 2007), agro-ecology (±), low, medium, and high altitude (Pachpute et al., 2009) (±), and regions (±).

STUDY AREA AND DATA

Ethiopia has 12.7 million farmer households and total land of 112.3 million ha. Of this total land, 16.4 million (15%) is suitable for crop production. In the country, smallholder farmers produce 95% of the agricultural output. About 90% of the 80 million lives in the highlands that covers 60% of the land area. High altitude, slope and dominance of plateau characterize the topography. The high altitude and slope cause fast flood to divert and use it for spate irrigation or trap it into ponds. About 200,000 ha is under spate irrigation and the amount of land under WHTs is unknown.

The study areas of the spate irrigation include 30 sample sub-districts selected from the four major regions of Ethiopia. A primary data was collected in 2005 from the four major regions and used for econometric analysis of cross-sectional data. To investigate the other objectives, secondary data are used in supplement of the available data. The study makes comparison of the yield effect of spate irrigation with rain-fed.

In 2005, a survey was conducted in the four regions and categorized farmers into ponds, shallow-wells and spate irrigation users. The selected households were stratified by their regional and sub-district distribution and the type of WHTs. Most sample farmers use ponds, followed by shallow-well and spate-irrigation users (9%). In terms of agro-ecology, nearly 80% of the sample farmers are from high- and midlands, and 15% are from lowlands. Among the spate irrigation users, 25% are from the lowlands and 75% are from the high and midlands.

RESULTS

Descriptive statistics

Among the explanatory variable, the average farm-size is 1.65 ha, which varies by district. In low-land districts, it is larger than that of the mid- and highlands because the later are densely populated and farm-land is fragmented (1.67 compared to 1.48 ha for other WHTs users). On average, larger farms could lead lowlanders to choose spate irrigation on their relatively larger farms compared to that of highlanders. The problem in the lowlands could be labour shortage, for example. The computed data (not depicted here) also indicates that farmers facing labour shortage in spate irrigation are higher (36%) than in other irrigation (27%).

Agro-ecologies condition farming systems. Accordingly, mid- and highlands of Ethiopia engage in mixed farming whereas lowlanders engage in livestock rearing. In the low lands, farmers access water from collected rainwater or rivers. The midlands also face water scarcity and they use spate irrigation to supplement their rain-fed cultivation.

The average number of rainfall shortage months is 3.5, about 3.7 for spate users, but 3.4 for other technology users. The data shows March, April, May, June, September and October are from the highest to lowest frequency. Farmers use spate for supplementary irrigation mainly during the minor growing season from March to May.

The data also shows that spate irrigation users are disadvantaged in marketing opportunities. The mean walking distance to market in hours is longer for users (1.5 h travel on foot), but shorter (1.4 h) for non-users. Similarly, the ease of selling output is lower for users than for non-users. The statistics is summarized in Figure 1. Higher mean age could show that more often older farmers tend to use spate irrigation than younger, unlike (Feder et al., 1985). It could mean that spate irrigation depends on experience.

Choosing between spate and other irrigation: Estimated econometric results

A logit model is estimated for spate irrigation choice (dummy) on data collected from 1705 Ethiopian farmers with robust variance estimation. Next marginal values are computed and indicated in Table 1. The marginal effect

[2] For the sake of space, the descriptive statistics is not depicted here. It can be provided on request.

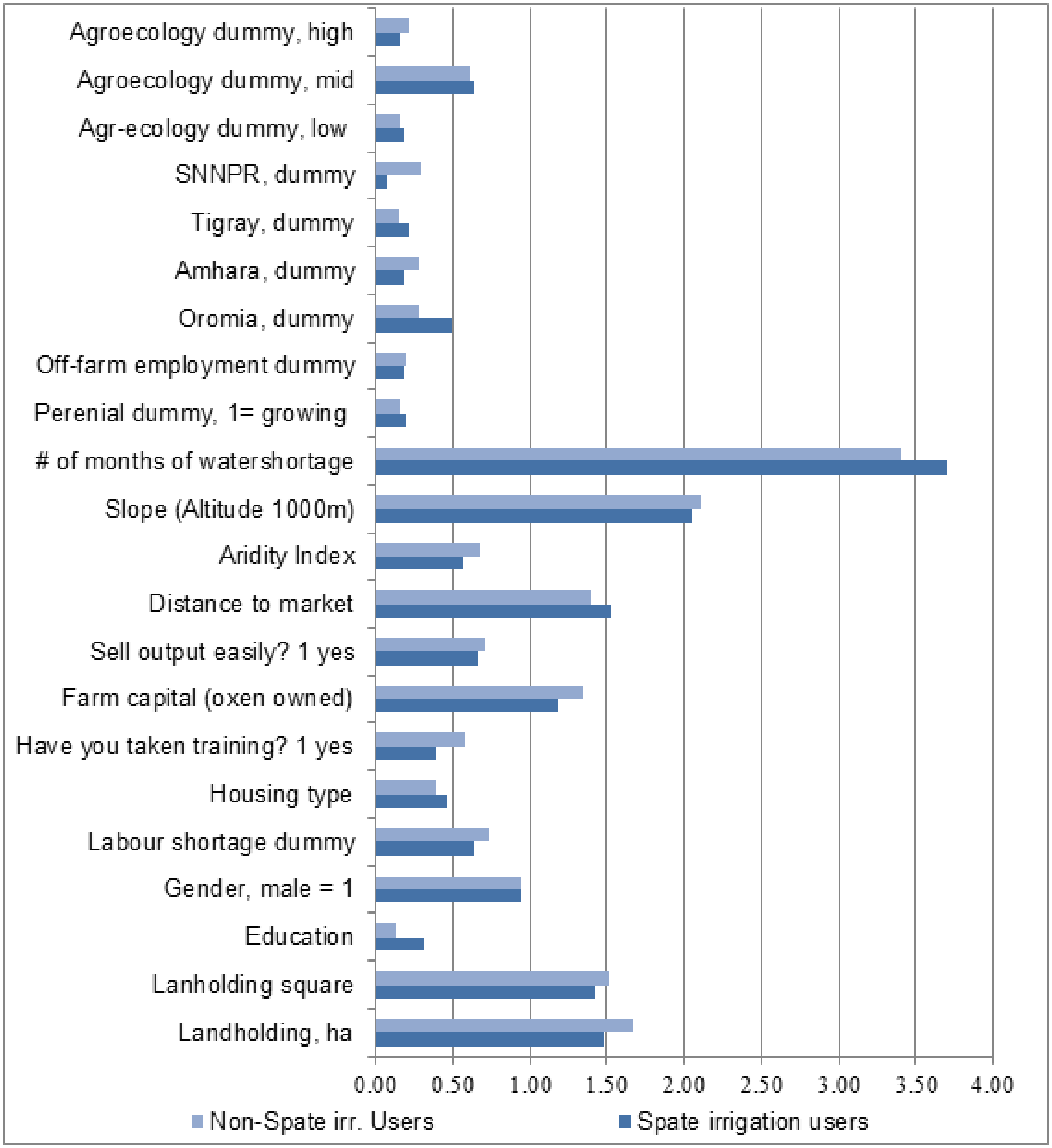

Figure 1. Statistical Summary of variables used in the estimation of technology choice.

indicated in Table 1 is used for interpretation (the parametric estimate can be provided on request)[3].

The estimated result indicates that farm-size, relatively lower age, lower aridity, O&M costs, training, being in Southern Nations and Nationalities and People's Region (SNNPR) and Amhara region decrease the probability to use spate irrigation, whereas owning more irrigation capital, family labour, literacy, relatively older age, living in lowlands and mid-highlands, the number rainfall-shortage months, slope and being in Oromia increase the probability of choosing spate irrigation than other WHTs. Many of the findings are in line with the stylized facts, e.g. spate irrigation is common in the lowlands (van Steenbergen et al., 2011; FAO, 2010; Pachpute et al.,

[3]The test results of the estimation that leads to the computation of marginal effect show robust estimate of logit model. Accordingly, the Wald test rejects the null hypothesis that all coefficients are zero at 1% level of significance. Moreover, the computed classification of the predicted values indicates that 91.85% of them are correctly classified, showing robustness and correct specification of the model.

Table 1. Estimated marginal values.

Variable	dy/dx[a]	Delta method (Standard errors)
Education (1 is literate, 0 otherwise)	0.042***	0.014
Age	-0.008***	0.003
Age square	0.092***	0.026
Gender, male=1	-0.010	0.027
Number of livestock	-0.001	0.001
Farm-size	-0.029*	0.016
Squared farm-size	0.001	0.003
Distance to market, '000km	0.0001	0.0001
Labour availability (no shortage = 1)	0.044***	0.014
Specialization, dummy (1= one crop)	0.017	0.017
Did you take training on irrigation? (Yes = 1)	-0.059***	0.013
Irrigation capital (in '000 ETB[b])	0.010*	0.007
Annual cost (in '000 ETB)	-0.098	0.069
Aridity index	-0.039*	0.024
Number of rainfall-shortage months	0.012**	0.005
Slope (proxy: altitude)	0.032**	0.015
Agro-ecology, low	0.043*	0.025
Agro-ecology, mid	0.031*	0.019
SNNPR, dummy	-0.107***	0.029
Amhara, dummy	-0.039*	0.025
Oromia, dummy	0.051**	0.023

***, ** and * respectively indicate 1, 5 and 10% significance levels([a]). [b]ETB is the Ethiopian Currency Birr. One ETB was 0.0741 US$ in June 2010.

2009); certain slope eases run-off diversion; more aridity increases the probability of using spate irrigation than WHTs. Low altitude areas have rainfall shortage and farmers use the opportunity of occasional run-off for irrigation. In Ethiopia, areas listed as users of spate irrigation are either in the relatively low-lands or mid altitudes. The mid-highlands have substantial share of crop production but, often weather shocks undermine yields. In fact the samples are from highlands and within the highlands the relatively low landers choose spate irrigation, in line with our expectation. Unlike low and midlands, in the highlands, population density, relatively small farm-size and precipitation invite WHTs than spate irrigation.

The estimated marginal effect indicates that a unit change in irrigation capital, proxied by the value of irrigation equipment, increases the probability to choose spate irrigation by 0.01, indicating that spate irrigation is more capital intensive compared to ponds and shallow-wells. Higher irrigation capital means that less expensive and simple hand-tool irrigation equipment such as water cans and buckets do not help much in spate irrigation, as they are in ponds and shallow-wells. Therefore, farmers with higher irrigation capital could trap sudden and powerful water run-off, manage and use it. This finding is in line with the descriptive statistics. Contrarily, higher annual-cost of O&M tends to discourage the probability to choose spate irrigation, indicating that farmers spend relatively less on O&M of ponds and shallow-wells than in spate irrigation which is likely, because after construction, the WH schemes are usually not susceptible to flooding.

The estimated marginal value also indicates a unit rise in aridity index decreases the probability of choosing spate irrigation by 0.044. In less arid areas, relatively better rainfall could discourage spate irrigation and farmers choose to use WHTs. The significance of aridity thus indicates that with the increasing drought effect of climate change, spate irrigation becomes more important. In the estimation, also the positive and significant coefficient of number of months of water shortage is consistent to our expectation, that is, when the number of water shortage months listed by farmers increases the probability to choose spate irrigation increases due to the problem of rainfall shortage for long time. FAO (2010) suggests that spate irrigation is common in long and dry-season areas of occasional rainfall. In WHTs irrigation, this variable is found to increase the likelihood of abandoning WHTs (Wakeyo and Gardebroek, 2015) because the precondition for collecting harvested water is the availability of run-off and the probability that run-off fills ponds declines with increasing number of dry months.

The estimates also show relatively small farm-size decreases the probability of using spate irrigation but very large farms (positive but insignificant coefficient) increase the probability of using it. The reason for choosing spate irrigation with small farm size could be that: (1) farmers with large landholding may have options to diversify crops to decrease risk than to use spate irrigation, this is a finding contrary to that of Marenya and Barrett (2007) with the adoption of improved natural resource management practices in Kenya; (2) small farm size may limit the space to trap flood; (3) but for small landholders it could be easy to construct ponds and shallow-wells.

The estimated result also showed that labour shortage decreases the probability to choose spate irrigation. Because irrigation activities are labour intensive (Wakeyo and Gardebroek, 2013; Moser and Barrett, 2006), farmers who face family labour shortage do not start spate irrigation. The estimated marginal value also indicates when a household escapes labour shortage, the probability to start spate irrigation increases by 0.044. On the other hand, relatively lower age carries a negative and significant coefficient whereas relatively older age carries a positive and significant coefficient. The former's negative sign indicates that younger farmers are more interested in ponds and shallow-wells whereas older farmers are interested in spate irrigation. The older farmers have accumulated experiences in using spate irrigation which is a traditional irrigation practice.

Education is found to positively affect the choice of spate irrigation, unlike the one suggested by the stylized facts. A move from illiterate to literate increases the probability of choosing spate irrigation by 0.043. A strange result is that training decreases the probability of using spate irrigation. This happens because farmers took training prior to choosing technologies and they may tend to choose WHTs afterwards instead of spate irrigation.

Similarly, being in Oromia regions is associated with increasing the probability of spate irrigation whereas being in SNNPR is associated with decreasing it. In Oromia, the regional government supports spate irrigation more than the case in other regions, in line with the finding of Alemayehu (2008).

In this study, there is no evidence that livestock asset, very large farm-size, household size, level of specialization in crop production, ease of selling output, distance to market, and gender affect the choice of spate irrigation. The fact that market variables are less important in spate irrigation could indicate that farmers are not using them to produce high-value crops, rather subsistence food crops (Moore and Fisher, 2012). Creating market access could lift spate-irrigation users in subsistence agriculture.

The estimated econometric model fulfils the necessary test criteria, that is, Wald test indicates that not all the coefficients are equal to zero.

Comparing crop choice in spate and other irrigation methods

In dealing with the crop choice, we hypothesized that spate irrigation tends to favour crops that grow on a relatively larger plot such as cereals, pulses and oil-seeds than smaller plots unlike WHTs (Wakeyo, 2012: 2-5). Those crops are important to increase food-crop supply for food security because of the cereal-biased consumption culture in Ethiopia. Ponds and shallow-wells favour vegetable and fruits, that is, cash-crops on small plots, because of the limited quantity of water.

The 2005 irrigation technology type and crop choice data is summarized in Table 2. The table indicates that the number of households that use irrigation for a category of crops, e.g., cereals and vegetables. Both ponds and shallow-well users favour vegetable and fruit growing, garlic, onion, cabbage, tomato, potato, papaya, avocado, etc., whereas spate irrigation grow cereals and pulses, such as maize, wheat, *teff (eragrostistef)* and sorghum.

Using the water from ponds, only in 2.5% of full irrigation users and 12.7% of supplementary irrigation users produce cereals and pulses, respectively. Similarly, using shallow-wells only 2.5 and 3.4% of the users produce cereals and pulses by using supplementary irrigation and full irrigation, respectively. On the other hand, households using spate irrigation tend to favour cereals and pulses. Table 2 indicates that 3 and 24.6% of the households use supplementary spate irrigation, respectively, to produce cereals and pulses than vegetables, fruits and other tree crops.

Cereals, pulses and oilseeds production increase food supply. In spate irrigation, crops including *teff*, barely, wheat, maize, sorghum, chickpeas, field peas and vetch are produced (Figure 2), and most farmers use spate irrigation to produce maize, *teff* and barely.

Yield differences

Spate irrigation not only favours the production of cereals, pulses and oilseeds, but also increases their productivity (Van den Ham, 2008). Figure 3 indicates the change in yield (increasing yield) after starting to use spate irrigation in Dodota plains of Arsi in Ethiopia. The finding is similar to the one discussed by Postel (1999: 225) for Nabataea, Israel.

DISCUSSION

The study investigated the factors behind the choice of small-scale irrigation technologies by individual farmers and compares their crop choices and yield effects. The finding mainly shows labour-shortage and illiteracy could undermine the use of spate irrigation. Different from what it seems, spate irrigation is a labour intensive activity. Unlike other irrigation technologies, the use of treadle and motor pumps, which could ease labour shortage, is uncommon in spate irrigation in Ethiopia. Because of this, it requires to learn the use of the equipment from the experiences of other countries that predominantly use

Table 2. Irrigation technologies and crop choices in Ethiopia (2005).

Technology/Irrigation		Crop choice					
		Cereal (a)	Pulses and oilseed (b)	Vegetables and fruits (c)	Others (d)	Total (e)	Percent [(a+b)/e×100] (f)
Pond	Full	34	12	1302	39	1387	2.5
	Supplementary	206	53	1730	303	2145	12.7
Shallow-well	Full	3	-	120	3	126	2.5
	Supplementary	5	5	266	16	292	3.4
Spate irrigation	Full	4	-	128	3		3.0
	Supplementary	42	-	111	15	167	24.6

Computed from EDRI's data. Note that the table is adopted from Fujimoto et al. (2012).

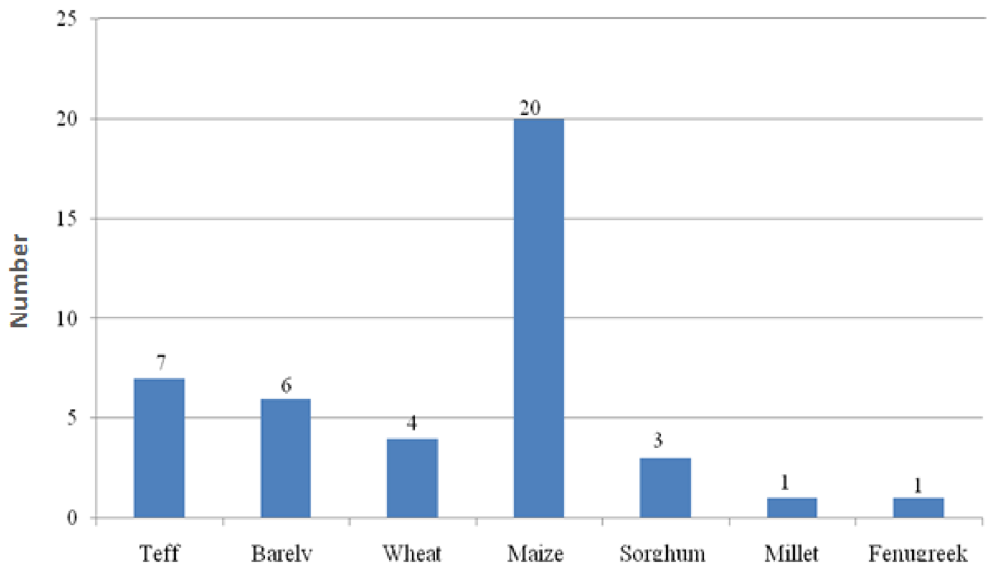

Figure 2. Sample households growing crops by supplementary irrigation in 2005.

spate irrigation (e.g., Pakistan). Examining the experience of other countries helps to avoid the risk of under-capacity uses of pumps for occasional flood.

The number of months of water shortage, and geographical factors influence technology choice. Information from meteorological service could decrease uncertainty and enables farmers to avoid risk in their crop choice and input uses. Moreover, irrigation capital also plays a positive role in spate irrigation. The need for farm equipment, flood breaks, maintenance of schemes damaged by flood, requires access to financial resource.

Literate farmers use spate irrigation more often than illiterate farmers indicating the importance of education in the seemingly low-skill irrigation compared to what is discussed in the stylized facts. On the other hand, it should not be surprising that training decreases the probability of using spate irrigation because the trained farmers could choose other irrigation methods.

Farm-size significantly decreases the probability of choosing spate irrigation. However, size is a relative variable and if the sample was also taken from the lowlands in the peripheral regions, the outcome could be different because the average farm-size in the lowlands of the four regions is often less than that of the lowlands in the peripheral regions. Therefore, rather than concluding about the role of farm-size, re-examining the finding in a further study could be essential.

Geographical location, agro-ecology, aridity and length of months of water shortage determine the use of spate irrigation. This shows that not all locations are suitable for spate irrigation. In line with this conclusion spate irrigation is a choice in the mid-highlands and the low-lands

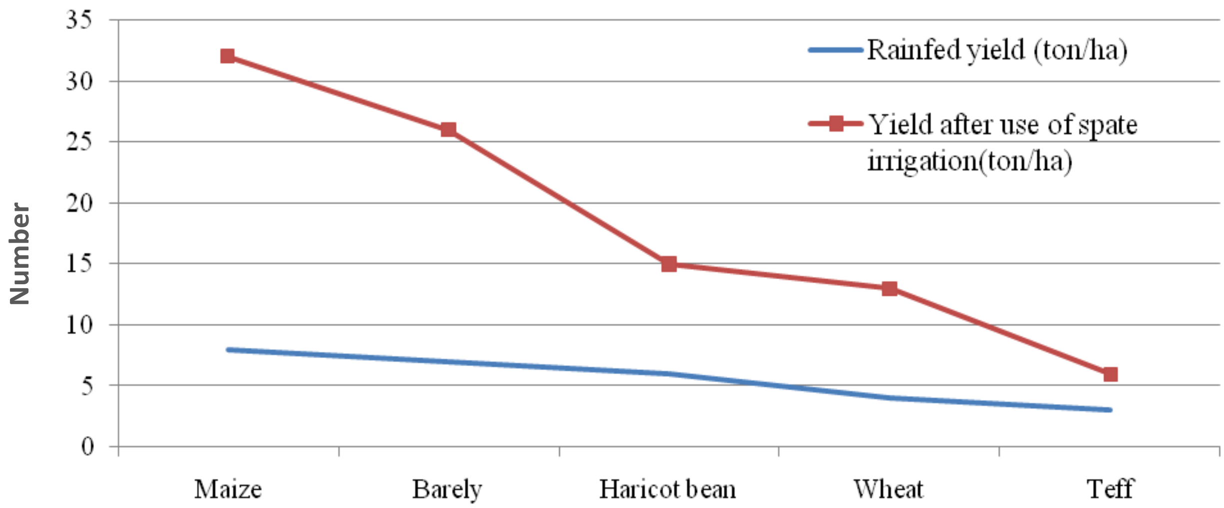

Figure 3. Change in yields after the use of spate irrigation in Dodota, Arsi 2007 (van den Ham, 2008).

compared to the highlands. The mid-highlands are the sources of a substantial share of crop production in Ethiopia, but yield is undermined by weather shocks. The use of spate irrigation in the mid-highlands means that crop production can be protected from such risks. So, to encourage spate irrigation in the midlands could enhance the source of food supply.

Diversity among administrative regions in institutional support makes difference in irrigation technology choice. Regional support to spate irrigation users through providing extension services, stimulating financial resource, orienting farmers, providing information to farmers have positive effects on the returns. These measures could decrease the number of subsistent poor households, who lose their asset and fall into poverty probability due to drought shocks (Nega et al., 2010; Barrett and Ikegami, 2008) lifts out of poverty in the disadvantaged low lands. If spate irrigation is used instead of the sophisticated and expensive irrigation schemes, Ethiopian farmers could increase food supply at low cost by decreasing the rainfall risk and by increasing yields.

Overall, three advantages of spate irrigation can be listed: (1) very large farm-size is positive but insignificant, which could indicate that spate irrigation is advantageous compared to other WHTs to develop larger farms than the case of WHTs (Wakeyo and Gardebroek, 2015); (2) because spate irrigation is a sudden flood overflowing wide areas where evaporation is high storage is costly, growing cereals and pulses more than high-value crops attracts farmers to address their staple food demand (food security); (3) spate irrigation is advantageous to grow crops of short growing period such pulses. This could open a specialization opportunity for relatively large farm-holder subsistence farmers in low lands, given that they are connected to markets by road infrastructure.

Spate irrigation increases food-supply at a relatively low cost by decreasing weather risk and increasing yields. It increases the yields and improves food-security because these crops are often staple-food crops. In fact the analysis is a simple comparison and does not try to measure precisely the crop choice and yield effects. In other words, several other factors could play role in choosing spate irrigation and the issue requires further studies. In addition, in the data used for the study the lowlands outside the four regions are not included in the survey. Had they been included, interesting insights would have been possible.

Conclusions

Some smallholder farmers in Ethiopia choose spate irrigation, that is, diverting a sudden flood-water which could otherwise be useless, instead of storing it into ponds, for several choice driving factors identified in this study. Spate irrigation enhances the production of cereals and pulses, which are often sources of staple food in Ethiopia. Evidences also show its significant impact on cereal yields. This implies that spate irrigation could improve food security in low-yield and drought prone country. Its lower investment cost compared to other irrigation methods makes it attractive in areas where other types of irrigation such as ponds and shallow-wells are not economically feasible, especially in remote and disadvantaged areas.

The findings lead to suggest scenarios under which spate irrigation is practiced. Smallholder farmers in arid and semi-arid areas, which are getting short period of rain and flood opportunity use to irrigate their relatively large farms for cereals, pulses and oilseeds. In arid and semi-arid areas, storage of flood water into WHTs is limited by high evaporation and insufficient water to irrigate large farms. This means that with the expanding aridity due to climate change and expected flooding, the importance of spate irrigation could grow. However, irrigation capital to divert and protect damaging flood is required. In addition, not all places are feasible for spate irrigation. Mid-and low agro-ecologies of the four major regions in Ethiopia are suitable. Moreover, like other irrigation methods spate irrigation is labor intensive. Therefore midlands and lowlands in relatively remote areas of intensive short period rainfall traditionally use spate irrigation. To modernize them, encouraging infrastructure to divert and protect irrigation schemes from damaging floods, investment in road to create market access, and promoting labor-saving technologies to ease labor scarcity are essential.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Ako AA, Eyong GT, Nken GE (2010). Water resources management and integratedwater resources management in Cameroon. Water Resour. Manage. 24:871-888.

Al-Jayyousi OR (1999).Rehabilitation of irrigation distribution systems: The case of Jericho City. Technical Communication. Water Resour. Manage.13:117-132.

Alemayehu M (2008). Country pastures resource profile Ethiopia.FAO.http://www.fao. org/ag/AGP/AGPC/doc/counprof/ethiopia/ethiopia.htm Accessed: June 26, 2012.

Aman H (2006). A draft design document on Koloba Bika (Boru Dodota) spate irrigation project, Oromia Water Resource Bureau, Adama, Ethiopia

Barrett CB, Carter MR, Ikegami M (2008). Poverty traps and social protection. Available at SSRN 1141881.

Barron J, Okwach G (2005). Run-off water harvesting for dry spell mitigation in maize (*Zea mays* L.): results from on-farm research in semi-arid Kenya. Agric. water manage. 74(1):1-21.

Benin S, Smale M, Pender J, Gebremedhin B, Ehui S (2004). The Economic Determinants of Cereal Crop Diversity on Farms in the Ethiopian Highlands. Agric. Econ. 31:197-208.

Birhanu K, Mengistu B (2007). On-farm assessment of Boru Spate Irrigation Systems, Oromia Irrigation Development Authority, January 2007, Finfine, Ethiopia. http://www.spate-irrigation.org/wordpress/wp-content/uploads/2011/06/OnFarmAssessmentDoddota.doc.Accessed : January 12, 2017.

Bracken LJ, Croke J (2007).The concept of hydrological connectivity and its contributionto understanding runoff-dominated geomorphic systems. Hydrol. Process. 21:1749-1763.

Cakmakyapan S, Goktas A (2013). A comparison of binary logit and probit models with a simulation study. J. Soc. Econ. Stat. 2(1): 1-17

Cameron AC, Trivedi PK (2009). Micreconometrics Using Stata. Revised Edition. A Stata Press Publication, Texas, United States

Coulter L, Kebede S, Zeleke B (2010). Water economy baseline report: Water and livelihoods in a highland to lowland transect in eastern Ethiopia. Research-inspired Policy and Practice Learning in Ethiopia and the Nile Region. http://www.rippleethiopia.org/documents/stream/20101001-working-paper-16.

Evers AJM, Elliott RL, Stevens EW (1998). Integrated decision making for reservoir, irrigation and crop management. Agric. Syst. 58(4):529-554.

FAOSTAT (2014). www.fao.org/faostat/en Accessed: February 12, 2014.

Feder G, Just RE, Zilberman D (1985). Adoption of agricultural innovations in developing countries: a survey. Econ. Dev. Cult. Change 33:255-297.

Food and Agricultural Organization/FAO (2010). Guideline on spate Irrigation. Irrig. Drain. Paper65, Rome.

Fox P, Rockström J, Barron J (2005). Risk analysis and economic viability of water harvesting for supplemental irrigation in semi-arid Burkina Faso and Kenya. Agric. Syst. 83(3):231-250.

Fujimoto N, Teklu E, Wakeyo MB (2012).Importance and challenges of spate irrigation in Ethiopia (in Japanese). Water Land Environ. Eng. 80(8):655-658

Gezahegn A, Gemechu A, Kiflu G, Mekonnen B, Tilahun H, Kidane G (2006). Water Harvesting Practices and its Impacts on Livelihood Outcomes in Ethiopia. Research Report No.6. Ethiopian Development Research Institute, Addis Ababa, Ethiopia.

He XF, Cao H, Li FM (2007). Econometric analysis of the determinants of adoption of rainwater harvesting and supplementary irrigation technology (RHSIT) in the Semi-arid Loess Plateau of China. Agric. Water Manage. 89(3):243-250.

Inocencio A, Kikuchi M, Tonosaki A, Maruyama A, Sally H (2005). Costs of irrigation projects: A comparison of Sub-Saharan Africa and other developing regions and finding options to reduce costs. IWMI, 117, Pretoria.

IFAD (International Funds for Agricultural Development) (2009). Country Program Evaluation, Ethiopia. www.ifad.org/evaluation/public.html/eksyst/doc/country/pf/ethiopia/ethiopia.pdf: Accessed: June 8, 2010.

Kato E, Ringler C, Yesuf M, Bryan E (2011). Soil and water conservation technologies : a buffer against production risk in the face of climate change? Insights from the Nile basin in Ethiopia. Agric. Econ. 42(5):593-604.

Lasage R, Verburg PH (2015). Evaluation of small scale water harvesting techniques for semi-arid environments. J. Arid. Environ. 118:48-57.

Lawrence P, Van Steenbergen F (2005). Improving community spate irrigation. Report 154, Wallingford, United Kingdom.

Lipton M (2007).Farm water and rural poverty reduction in developing Asia. Irrig. Drain. 56:127-146.

Marenya PP, Barrett CB (2007). Household-level determinants of adoption of improved natural resources management practices among smallholder farmers in western Kenya. Food Policy 32:515-536.

Mehari A, Schultz B, Depeweg H, De Laat PJM (2008). Modeling soil moisture and assessing its impact on water sharing and crop yield for the Wadilaba spate irrigation system, Eritrea. Irrig. Drain. 57(1):1-16.

Mehari A, Van Steenbergen F, Schultz B (2007).Water rights and rules and management in spate irrigation systems in Eritrea, Yemen and Pakistan, in: Van Koppen B, Giordano M, Butterworth J (edt.) Series 5, CABI, UK.

Meinzen-Dick RS, Nkonya L (2007). Understanding legal pluralism in water and landrights: Lessons from Africa and Asia, pp12-27 in:Van Koppen, B., Giordano, M.andButterworth, J.(eds.),CABI, London

Moore S, Fisher JB (2012). Challenges and opportunities in GRACE-based groundwater storage assessment and management: an example from Yemen. Water Resour. Manage. 26(6):1425-1453.

Moser CM, Barrett CB (2006). The complex dynamics of smallholder technology adoption: The case of SRI in Madagascar. Agric. Econ. 35(3):373-388.

Nega F, Mathijs E, Deckers J, Haile M, Nyssen J, Tollens E (2010). Rural Poverty dynamics impact of intervention programs upon chronic and transitory poverty in Northern Ethiopia. Afr. Dev. Rev.

22(1):92-114.
Ngigi SN (2016). Climate change adaptation strategies: water resources management options for smallholder farming systems in sub-Saharan Africa. New York, NY: The Earth Institute at Columbia University.
Oka N, Koide J, Mostafa H, Sakata S, Wakeyo MB, Fujimoto N (2013). Relationship between agricultural land systems and water use during the application of participatory irrigation management. Scientific Paper Series. Manage. Econ. Eng. Agric. Rural Dev. 13(3):179-86
Ostrom E, Gardner R (1993). Coping with asymmetries in the commons: self-governing irrigation systems can work. J. Econ. Perspect. 7(4):93-112.
Oweis T, Hachum A (2006). Water harvesting and supplemental irrigation for improved water productivity of dry farming systems in West Asia and North Africa. Agric. Water Manage. 80(1):57-73.
Pachpute JS, Tumbo SD, Sally H, Mul ML (2009). Sustainability of rainwater harvesting systems in rural catchment of sub-Saharan Africa. Water Resour. Manage. 23:2815-39.
Playan E, Mateos L (2006). Modernization and optimization of irrigation systems to increase water productivity. Agric. Water Manage. 80(1-3):100-116.
Postel S (1999). Pillar of sand: Can the irrigation miracle last? W.W. Norton and Company, World Watch Institute, United States.
Rockstrom J, Barron J, Fox P (2002). Rainwater management for increased productivity among smallholder farmers in drought prone environments. Phys. Chem. Earth 27:949-959.
Rosenzweig MR, Binswanger HP (1993).Wealth, weather risk and the composition and profitability of agricultural investment. Econ. J. 103:56-78.
Sadoulet E, De Janvry A (2006). Progress in the modeling of rural households' behavior under market failures. In Poverty, inequality and development. 155-181 Springer US.
Tilman D, Cassman KG, Matson PA, Naylor R, Polasky S (2002). Agricultural sustainability and intensive production practices. Nature 418:671-677.
Van den Ham J (2008). Dodota spate irrigation system Ethiopia:a case study of spate irrigation management and livelihood options. M.Sc.Thesis, Wageningen University. The Netherlands.
Van Steenbergen F, Mehari AH, Alemeyehu T, Alamirew T, Geleta Y (2011). Status and potential of spate irrigation in Ethiopia. Water Resour. Manage. 25(7):1899-1913.
Verbeek M (2008). A Guide to Modern Econometrics.Third edition. John Wiley & Sons.
Wakeyo MB (2012). Economic Analysis of Water Harvesting Technologies in Ethiopia. PhD Dissertation. Wageningen University
Wakeyo MB, Gardebroek C (2013). Does water harvesting induce fertilizer use? Evidence from smallholders in Ethiopia, Agric. Syst. 104(1):54-63.
Wakeyo MB, Gardebroek C (2015). Empty ponds, Empty pockets? Disadoption of water harvesting technologies in Ethiopia. J. Arid Environ. 120(2):78-86.
Walsh A (1987). Teaching Understanding and Interpretation of Logit Regression. Teaching Sociol. Teaching Res. Methods Stat. 5(2):178-183
World Bank (1994). Water Resource Management, policy paper, Washington D.C.

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Full Length Research Paper

Using morphometric traits for live body weight estimation and multivariate analysis in Central Highland and Woyto-Guji Goat Breeds, Ethiopia

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The study was conducted to differentiate the Woyto-Guji and Central Highland goat breeds of Ethiopia and derive the most accurate linear regression equation for live body weight prediction. Morphological measurements were taken on randomly selected 531 adult female goats (263 from Woyto-Guji and 268 from Central Highland). Positive and highly significant (P<0.001) correlations were observed between body weight and most independent body measurement variables in both breeds. The highest relationship between chest girth and body weight were illustrated in both breeds (r=0.85 for Woyto-Guji and r=0.82 for Central Highland). The multiple regressions found five parameters to be significant (P<0.05) for Woyto-Guji (chest girth, body length, pelvic width, chest width and ramp length) and Central Highland (chest girth, body length, ramp length, horn and ear length) with R^2 values of 84% and 79%, respectively. Body weight, body length, height at wither, chest width, ramp length, pelvic width, horn length and ear length had a significant (P<0.15) discriminating power on the breeds. Nearest neighbor discriminating function analysis shows that 93.23% of Woyto-Guji and 92.96% of Central Highland breeds were classified into their source population. The morphological variations obtained in this study should be consolidated with more evidence drawn from genetic analysis.

Key words: Central Highland, goat, multivariate, morphometric traits, Woyto-Guji.

INTRODUCTION

The ultimate goal of the livestock and meat industry is to have an accurate and objective measurement method for assessing the economically important traits of animals and to determine the value and merit of the carcass while the animal is still alive (Boggs and Merkel, 1993). The use of morphometric traits to predict live body weight (LBW) can be important to make a selection and cull decisions for the local farmers as it can be a relatively low cost, high accuracy and consistency (Musa et al., 2012). Morphometric traits in some cases can be more reliable than modern weighing machines as the latter can give biased measurements caused by gut fullness (Obike et

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al., 2010). Body measurements that are used to predict LBW may affect its determination directly and indirectly (Yakubu and Mohammod, 2012).

Understanding the diversity, distribution, basic characteristics, comparative performance and the current status of each country's animal genetic resources are essential for their efficient and sustainable use, development and conservation. Complete national inventories, supported by periodic monitoring of trends and associated risks, are a basic requirement for the effective management of animal genetic resources. Without such information, some breed populations and unique characteristics they contain may decline significantly, or be lost, before their value is recognized and measures taken to conserve them (FAO, 2007).

Different univariate models and multivariate approaches have been used to determine relationships among body weight and several body measurements. Other studies have utilized correlations to express the relationship between body measurement variables, body weight and carcass traits. Regression equations have been established to estimate body weight from body dimensions (Singh and Mishra, 2004; Gorgulu et al., 2005; Oke and Ogbonnaya, 2011). Therefore, the purpose of this paper is to find out and study the morphometric traits of Woyto-Guji and Central Highland goats in order to differentiate the breeds and derive the most accurate linear regression equation for LBW prediction.

MATERIALS AND METHODS

Environmental setting of the study locations and goat populations

Sampling of Central Highland and Woyto-Guji goat breeds was from Meta-Robi and Konso districts, respectively. Data were conducted from April to May 2013 in Meta-Robi and March to April 2013 in Konso district. Meta-Robi is located at 100 km north-west from the capital Addis Ababa. The district lies in a hilly land scope at elevations from 1,200 to 2,900 m.a.s.l and located at 9°20' N latitude and 38°10' E longitude. The mean annual temperature and rainfall ranges from 23 to 31°C and 750 to 1100 mm, respectively. Over 95% of the population, practices mixed crop-livestock production system (Emmenegger, 2012). Konso is located at 595 km away from Addis Ababa in the southwest of Ethiopia; it is located at 5° 17' 36'' N latitude and 37° 29' 05'' E longitude and lies between 600 and 2100 m.a.s.l (Konso District Agricultural Office, 2008, unpublished data). The average total annual rainfall is 550 mm; the temperature ranges between 12 and 33°C (Tesfaye, 2003). The annual rainfall variation is between 400 and 1000 mm (Cheung et al., 2008). The production system is integrated crop-livestock system (Forch, 2003).

Morphological variables measured

Morphological measurements were taken on randomly selected 531 adult (= 4PPI) female goats (263 from Woyto-Guji and 268 from Central Highland goat breeds). The nine morphometric traits measured were body weight (BW), body length (BL), height at wither (HW), chest girth (CG), chest width (CW), ramp length (RL), pelvic width (PW), ear length (EL) and horn length (HL). Linear body measurements were taken using graduated measuring tape, but wither height measurement (cm) was done using calibrated metal caliper. Body weight was measured using suspended spring balance in kg. Measurements were done in the morning before the animals were released for grazing. All measurements were carried out by the same person, in order to avoid inter-individual variations.

Data analysis

Statistical analysis was carried out using the Statistical Analysis System (SAS Version 9.2, 2008). Discriminant analysis was used to classify the sampled populations into homogenous groups on the basis of the measured variables. Stepwise discriminant analysis procedure (PROC STEPDISC) was employed to identify the relative importance of variables in discriminating identified goat breeds. The CANDISC procedure was used to generate the univariate test of the selected traits, canonical functions and the plots of breed membership. The PROC DISCRIM was employed to obtain the Mahalanobis distances and linear discriminant functions.

Correlation (Pearson's correlation coefficient) between body weight and the linear body measurements were computed for the goat breeds. The stepwise REG procedure of SAS (2005) was used to determine the relative importance of live-animal body measurements in a model designed to predict body weight. Variables that best fitted the model were selected using C(*p*) statistic, Alkaike's Information Criteria (AIC), Schwarz Bayesian Criteria (SBC), R^2 (R-square) and MSE (Mean square of error).

Multiple linear regression model

The multiple linear regression model is as follow:

$$Yj = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \beta 5X5 + \beta 6X6 + \beta 7X7 + \beta 8X8 + ej$$

where Yj = the dependent variable body weight; β0 = the intercept; X1, X2, X3, X4, X5, X6, X7 and X8 are the independent variables as body length, chest girth, height at wither, chest width, pelvic width, rump length, horn length and ear length, respectively; β1, β2, β3, β4, β5, β6, β7 and β8 are the regression coefficient of the variables X1, X2, X3, X4, X5, X6, X7 and X8, respectively; ej= residual error.

RESULTS

Correlation between body weight and linear body measurements

Positive and highly significant (P<0.001) correlations were observed between body weight and the majority of independent variables of the breeds (Table 1). The highest relationship between chest girth with body weight were illustrated in both breeds (r=0.85 for Woyto-Guji and r=0.82 for Central Highland).

Body length, height at wither, chest girth, chest width, ramp length, pelvic width, horn length and ear length had a small to high positive correlations with one another, but there was a negative correlation between horn and ear length in Woyto-Guji goats. In Central Highland goats,

Table 1. Coefficient of correlation between body weight and linear body measurements (above diagonal for Central Highland and below for Woyto-Guji goats).

Correlation	BW	BL	HW	CG	CW	RL	PW	HL	EL
BW		0.62***	0.20***	0.82***	0.39***	0.56***	0.52***	0.30***	0.05*
BL	0.84***		0.25***	0.55***	0.14*	0.56***	0.45***	0.28***	0.08^{NS}
HW	0.66***	0.68***		0.22***	0.13*	0.26***	0.21***	0.10^{NS}	0.10^{NS}
CG	0.85***	0.73***	0.63***		0.52***	0.56***	0.54***	0.40***	0.001^{NS}
CW	0.45***	0.32***	0.21***	0.45***		0.28***	0.25***	0.27***	-0.04
RL	0.62***	0.57***	0.54***	0.56***	0.24***		0.48***	0.23***	0.15*
PW	0.68***	0.63***	0.51***	0.59***	0.29***	0.53***		0.28***	-0.03
HL	0.33***	0.35***	0.24***	0.30***	0.15*	0.26***	0.25***		0.04
EL	0.24***	0.24***	0.31***	0.19**	0.14*	0.19**	0.25***	-0.07	

BW=Body Weight; BL=Body Length; HW=Height at Wither; CG=Chest Girth; CW=Chest Width; RL=Ramp Length; PW=Pelvic Width; HL=Horn Length; EL=Ear Length; NS=non-significant; *P<0.05;**P<0.01; ***P<0.001

Table 2. Multiple regression analysis of live body weight on different body measurements of Woyto-Guji and Central Highland goats.

Breed	Equations	β0	β1	β2	β3	β4	β5	R2	C (p)	AIC	RMSE	SBC
	CG	-36.88	0.9					0.72	201.4	395.56	2.13	402.68
	CG+BL	-38.31	0.52	0.48				0.82	35.53	278.54	1.7	289.23
Woyto-Guji	CG+BL+PW	-38.12	0.48	0.42	0.47			0.83	18.18	262.54	1.64	276.81
	CG+BL+PW+CW	-38.77	0.44	0.42	0.45	0.28		0.84	10.37	254.93	1.61	272.76
	CG+BL+PW+CW+RL	-39.95	0.42	0.4	0.39	0.29	0.28	0.84	4.47	248.92	1.59	270.3
	CG	-46.35	1.04					0.73	77.86	450.68	2.33	457.84
	CG+BL	-60.48	0.85	0.45				0.79	5.95	387.47	2.07	398.21
CHL	CG+BL+RL	-61.63	0.81	0.41	0.3			0.79	4.11	385.61	2.05	399.93
	CG+BL+RL+HL	-62.48	0.84	0.42	0.3	-0.08		0.79	3.69	385.14	2.05	403.03
	CG+BL+RL+HL+EL	-64.59	0.84	0.42	0.26	-0.09	0.17	0.79	3.54	384.93	2.04	406.41

BL=Body Length CG=Chest Girth; CW=Chest Width; RL=Ramp Length; PW=Pelvic Width; HL=Horn Length; EL=Ear Length; CHL= Central Highland.

body length, height at wither, chest girth, chest width, ramp length, pelvic width, horn length and ear length had a small to high positive correlation with one another, but the ear length had a negative correlation with chest width, pelvic width and horn length.

Prediction of body weight from linear body measurements

In the prediction of body weight, the multiple regressions found five parameters to be significant (P<0.05) for Woyto-Guji (chest girth, body length, pelvic width, chest width and ramp length) and Central Highland goats (chest girth, body length, ramp length, horn and ear length) with R^2 values of 84 and 79%, respectively (Table 2).

Discriminant analysis

The discriminant analysis was carried out using nine quantitative variables (body weight, body length, height at withered, chest girth, chest width, ramp length, pelvic width, horn length and ear length) to identify as best discriminating variables on stepwise selection summery (Table 3). Based on the significance (P<0.15), all but chest girth did not have significant discriminating powers on the two goat breeds and was removed.

Discriminant function analysis

Table 4 represents the percent classification rate (hit rate) of female sample populations into each district. Most (93.23%) of Woyto-Guji and 92.96% of Central Highland goats were classified into their source population.

Canonical discriminant analysis

The pairwise squared Mahalanobis' distance among the district's population for females were highly significant

Table 3. Significant traits that discriminated the two goat breeds.

Step	Variables	Partial R^2	F-value	P-value	Wilk's Lambda	ASCC
1	Ramp length	0.5263	593.35	<0.0001	0.4737	0.5263
2	Pelvic width	0.1291	79.04	<0.0001	0.4125	0.5875
3	Horn length	0.1379	85.07	<0.0001	0.3556	0.6444
4	Ear length	0.1044	61.87	<0.0001	0.3185	0.6815
5	Height at withers	0.0505	28.19	<0.0001	0.3024	0.6976
6	Chest width	0.0177	9.53	0.0021	0.2971	0.7029
7	Body length	0.0050	2.66	0.1036	0.2956	0.7044
8	Body weight	0.0101	5.35	0.0211	0.2926	0.7074

The P-values for both Wilks' Lambda and ASCC were highly significant (P<0.0001)

Table 4. Percent classified into each district (hit rate) of female populations.

From District	Konso	Meta-Robi	Total
Konso	248 (93.23)	18 (6.77)	266 (100)
Meta-Robi	19 (7.04)	251 (92.96)	270 (100)
Total	267 (49.81)	269 (50.19)	536 (100)
Priors	0.4963	0.5037	
Rate	0.0677	0.0704	0.069

Numbers before the parenthesis indicates the number of observations

Table 5. Square Mahalanobis distance between sites for the female sample populations.

District	Konso	Meta-Robi
Konso	0	10.26787
Meta-Robi	***	0

***P<0.0001

Table 6. Multivariate statistics.

Statistics	Value	F value	Num DF	Den DF	Pr>F
Wilks' lambda	0.2926	159.24	8	527	<0.0001
Pillai's trace	0.7074	159.24	8	527	<0.0001
Hotelling-Lawley trace	2.4173	159.24	8	527	<0.0001
Roy's greatest root	2.4173	159.24	8	527	<0.0001

(P<0.0001). This shows the existence of measurable group differences between sampled populations from each site (Table 6). Larger differentiation (10.27) was observed between the two districts sampled goat populations (Table 5). All multivariate statistics for the differences between the districts was also significant (P<0.0001) in all of the four multivariate tests (Wilks' lambda, Pillai's trace, Hotelling-Lawley trace and Roy's greatest root; Table 6).

Univariate analysis of variance (ANOVA) revealed highly significant (P<0.0001) difference in all the morphometric measurements except pelvic width (Table 7). By comparing the F-value and highest amount of significant discriminating potential, chest width has the least amount to discriminate the two breeds.

The standardized canonical coefficients indicate the partial contribution of each variable to the discriminant function, controlling for other attributes entered in the equation. Accordingly, the total standardized canonical coefficients given in the Table 8 indicate that the explanatory variables, ramp length, horn length, ear length, height at wither and body length significantly

Table 7. Univariate Test statistics.

S/N	Variable	Pooled STD	Between STD	F Value	P-Value
1	Body weight	0.8796	0.6743	157.53	***
2	Body length	0.8165	0.8173	268.56	***
3	Height at withers	0.7958	0.857	310.82	***
4	Chest width	0.8938	0.6359	135.67	***
5	Ramp length	0.6889	1.025	593.35	***
6	Pelvic width	0.9992	0.0842	1.9	Ns
7	Horn length	0.7938	0.8606	314.98	***
8	Ear length	0.8329	0.7835	237.16	***

***P<0.0001; Ns= non-significant.

Table 8. Total-sample standardized canonical coefficient.

Variable	CAN1
Body weight	-0.2221
Body length	0.2519
Height at wither	0.3352
Chest width	0.2292
Ramp length	0.9817
Pelvic width	-0.606
Horn length	0.5078
Ear length	0.3999

Table 9. Total-Sample standardized class means.

District	Variable							
	BW	BL	HW	CW	RL	PW	HL	EL
Konso	-0.4804	-0.5823	-0.6105	-0.453	-0.7302	-0.06	-0.6131	-0.5582
Meta-Robi	0.4733	0.5736	0.6015	0.4463	0.7194	0.0591	0.604	0.5499

BW=Body Weight; BL=Body Length; HW=Height at Wither; CG=Chest Girth; CW=Chest Width; RL=Ramp Length; PW=Pelvic Width; HL=Horn Length; EL=Ear Length.

contributed to the first canonical variable (*CAN1*). The correlation between *CAN1* and the goat populations sampled from the two districts was high (0.84).

The standardized class means values of the eight quantitative variables are presented in Table 9. The morphometric variables of Central Highland goat population were relatively higher than the Woyto-Guji counterparts.

DISCUSSION

The correlation is one of the most common and most useful statistical tools that describe the degree of relationship between two variables. The current result on the coefficients of correlation between body weight and the majority of independent variables were positive, strong and significant. However, this study has disclosed the highest relationship between chest girth with body weight in both breeds. Similarly, the highest correlation of chest girth with body weight than other body measurements was reported by several authors (Dereje, 2012, unpublished data; Biruh, 2013, unpublished data; Feki, 2013, unpublished data). Thus, the association may also be useful as a selection criterion, since positive correlations of traits suggest that the traits may be under the same genetic influences (Jimmy et al., 2010). The strong relationship existing between body weight and body measurements in the present study in both breeds suggests that either or the combination of these morphological traits could be used to estimate live weight in goats fairly well in the situation where weighbridges or scales are not available. The possibility of using simple body measurements that can be carried out in the field to predict important economic traits have been demonstrated by (Vargas et al., 2007; Ozkaya and Bozkurt, 2009).

Genetic variation is vital for the populations to adapt to varying environments and to respond to artificial selection; therefore, any conservation and development scheme should start from assessing the state of variation in the population (Toro et al., 2011). The discriminant analysis based on significant F-values indicated body weight, body length, height at withered, chest width, ramp length, pelvic width, horn length and ear length as the linear measures permitting discrimination between the Woyto-Guji and Central Highland goats. Some of these discriminating variables are similar to those reported by other researchers in sheep (Carneiro et al., 2010; Yakubu and Ibrahim, 2011) and goats (Yakubu et al., 2011). The higher the overall percent classification rate (hit rate) is also an indication of the fact that, the two breeds belong to different breeds. The high correct assignment to source genetic groups. Similarly, Yakubu et al. (2010) was able to correctly allocate more than 99% into their different groups. Additionally, Wilks' Lambda, the ratio of within-group variability to total variability on the discriminating variables, is an inverse measure of the importance of the discriminant functions (Brown and Tinsley, 1983; Betz, 1987; Huberty, 1994). In this case, the value of Wilks' Lambda was 0.29. This shows that most (70.7%) of the variability in the discriminating variables were because the difference was between rather than within the breeds.

Conclusion

The study revealed that the coefficients of correlation between body weight and the majority of independent variables were positive, strong and significant. Moreover, the high correlations between chest girth and body weight would imply that the live weight could be predicted fairly accurately from chest girth rather than other variables. Body weight, body length, height at withered, chest width, ramp length, pelvic width, horn length and ear length were found as the most discriminating variables to separate Woyto-Guji and Central Highland goats. Most of the animals were correctly assigned into their breeds of origin. The morphological variations obtained in this study should be consolidated with more evidence drawn from genetic analysis.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Betz NE (1987). Use of discriminant analysis in counseling psychology research. J. Couns. Psychol. 21:393-403.

Boggs DL, Merkel RA (1993). Beef carcass evaluation, grading, and pricing. In: DL. Boggs and RA. Merkel, (eds), Live Animal Carcass Evaluation and Selection Manual. Kendall Hunt Publishing Co., Dubuque, IA. P 105.

Brown MT, Tinsley HEA (1983). Discriminant analysis. J. Leisure Res. 11: 290-310.

Carneiro H, Louvandini H, Paiva SR, Macedo F, Mernies B, McManus C (2010). Morphological characterization of sheep breeds in Brazil, Uruguay and Colombia. Small Rumin. Res. 94:58-65.

Cheung WH, Senay GB, Singh A (2008). Trends and Spatial Distribution of Annual and Seasonal Rainfall in Ethiopia.

Emmenegger R (2012). The Roads of Decentralisation: The History of Rural Road Construction in Ethiopia. NCCR North-South Dialogue 39. Bern and Zurich, Switzerland: NCCR North-South.

FAO (2007). The state of the world's animal genetic resources for food and agriculture, edited by B. Rischkowsky & D. Pilling. Rome 523p.

Forch W (2003). Case Study: The Agricultural System of the Konso in South Western Ethiopia FWU Water Resources Publications.1.

Gorgulu O, Sar A, Keskin M, Bicer O, Gul S (2005). Some prediction equations of live weight from different body measurements in Shami (Damascus) goats. J. Anim.Vet. Adv. 4:532-534.

Huberty CJ (1994). Applied Discriminant Analysis. New York: Wiley.

Musa AM, Idam NZ, Elamin KM (2012). Heart Girth Reflect Live Body Weight in Sudanese Shogur Sheep under Field Conditions. World Vet. J. 2(4):54-56.

Obike OM, Ibe SN, Oke UK (2010). Estimation of pre-and post-weaning bodyweight of rabbits in a humid tropical environment using linear body measurements. Am-Eurasian J. Agric. Environ. Sci. 9(4):440-444.

Oke UK, Ogbonnaya EO (2011). Application of physical body traits in the assessment of breed and performance of WAD sheep in a humid tropical environment. Livest. Res. Rural Dev. 23(24).

Ozkaya S, Bozkurt Y (2009). The accuracy of prediction of body weight from body measurements in beef cattle. Archiv Tierzucht. 52:371-377.

SAS (2008). SAS Institute Inc. Cary. North Carolina, USA.

Singh PN, Mishra AK (2004). Prediction of body weight using conformation traits in Barbari goats. Indian J. Small Rum. 10(2):173.

Tesfaye B (2003). Understanding Farmers: Explaining soil and water conservation in Konso, Wolaita and Wello, Ethiopia. Doctoral thesis Wageningen University, the Netherlands.

Toro MA, Meuwissen THE, Fernández J, Shaat I, Mäki-Tanila A (2011). Assessing the genetic diversity in small farm animal populations. Animal 5:1-15.

Vargas S, Larbi A, Sanchez M (2007). Analysis of size and conformation of native Creole goat breeds and crossbreds used in smallholder agrosilvopastoral systems in Puebla, Mexico. Trop. Anim. Health Prod. 39:279-286.

Yakubu A, Salako AE, Imumorin IG, Ige AO, Akinyemi MO (2010). Discriminant analysis of morphometric differentiation in the West African Dwarf and Red Sokoto goats. South Afr. J. Anim. Sci. P 40.

Yakubu A, Ibrahim IA (2011). Multivariate analysis of morphostructural characteristics in Nigerian indigenous sheep, Italian J. Anim. Sci. 10:83-86.

Yakubu A, Salako AE, Imumorin IG (2011). Comparative multivariate analysis of biometric traits of West African Dwarf and Red Sokoto goats, Tro. Anim. Health Prod. 43:561-566.

Yakubu A, Mohammed GL (2012). Application of path analysis methodology in assessing the relationship between body weight and biometric traits of Red Sokoto goats in Northern Nigeria. Biotechnol. Anim. Husb. 28 (1):107-117.

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Full Length Research Paper

Amelioration of cacao seedlings with bio – degraded coffee husk for enhanced nursery performance

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Cacao is a major economic crop in West Africa and some other parts of the world and is grown through nursery prior to field establishment. The husk of *Coffea* species forms over 40% of the matured seeds and is regarded as a waste despite its nutrient composition status. Husks of *Coffea arabica* and *Coffea canephora* were degraded using *Trichoderma harzianum*, *Streptomyces* spp. and the combination of these microbes for 1, 15, and 30 days. Each of bio - degraded *C. arabica* and *C. canephora* husks was added to a 2 - week old F_3 amazon cacao variety in a nursery experiment laid out in a completely randomized design (CRD). The effect of ameliorated cacao seedling gave positive enhancement of growth performance of cacao in terms of plant height, number of leaves, stem girth and leaf area. The effect of *T. harzianum* and *Streptomyces* degraded *C. arabica* was more evident on cacao growth at 4 weeks after application but *T. harzianum* and *Streptomyces* degraded *C. canephora* significantly enhanced cacao growth performance at termination of the study. The 30-day *T. harzianum* combined with *Streptomyces* degraded *C. canephora* husk showed the best plant height (37.47 mm), number of leaves (27.33), fresh root weight (10.87g) and root thickness (1.57 µm). The highest fresh shoot weight (18.53 mm) was recorded in 30-day *T. harzianum* combined with *Streptomyces* degraded *C. arabica* husk and a day *T. harzianum* degraded *C. canephora* husk was the best in fresh plant weight (20.50 g) at the end of the nursery experiment. There were reduced acidity of the soil and an addition of macro nutrients and organic matter contents by the bio-degraded *C. arabica* and *C. canephora* husk in the soil. The cacao seedlings were however free of any disease or insect-pest infestation.

Key words: Cacao, amelioration, nursery, soil fertility, coffee husk, bio-degradation.

INTRODUCTION

Theobroma cacao L. is one of the important perennial crops worldwide due to its economic relevance for chocolate and cosmetics industries (Almeida and Valle, 2007). However, good nursery establishment determines growth of cocoa economy and 80% of seedlings are polythene however, bags - grown which have greater chances of establishment and survival after transplanting (Opeke, 2006). Rhodes (1995) opined that hybrid cocoa

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seedlings raised in nursery are deficient in phosphorous, potassium, calcium, magnesium and effective cation exchange capacity (ECEC) in the soil used for production.

Coffee (*Coffea* species) is another important commodity in Nigeria because of the economic value of its berry, the husk forms over 40% of the matured seeds and it is a major bye-product from the coffee processing industry and regarded as a waste. Coffee husk compost contains plant nutrients of 2.07% N, 0.55% P_2O_5 and 2.87% K_2O and it influences crop yields (Dzung et al., 2013). The husk is however being utilized as fertilizer in cashew nursery (Nduka et al., 2015); it is also rich in lignocelluloses materials, which make it ideal substrate for microbial processes. Divakaran and Elango (2009) however reported that coffee husk contains appreciable amount of pectin, tannin which favors rapid growth of microorganisms.

Trichoderma spp. are bio-control agent (Howell, 2003; Adeniyi et al., 2013), that help plants to withstand abiotic stresses and also improved the water holding capacity of soil (Mastouri et al., 2010), decomposed organic materials, suitable organization of soil fertility (Guimarães et al., 2013), and promoting the growth of plants in greenhouse and field (Kaewchai et al., 2009). These Microbial inoculants improved Nitrogen (N) fixation or indirectly improved the nutrient availability in the soil to facilitate plants growth (Mc Near, 2013). *Trichoderma* spp. have been reported for lots of crops (Hermosa, 2012; Hoyos-Carvajal et al*.,* 2009; Kaewchai et al*.,* 2009). Bae et al. (2009) reported that *T. hamatum* induce tolerance in cocoa against water deficit through increasing root growth.

Bio-fertilizers have been successfully used not only to control plant diseases but also to promote the growth and development of plants in nursery greenhouse and field production. This study thus evaluates *T. harzianum* and *Streptomyces* spp - degraded coffee husk to enhance nursery performance of cacao seedling.

MATERIALS AND METHODS

Sources of materials

Coffee husk samples of *C. arabica* and *C. canephora* were collected from Crop Processing Unit and pure cultures of *Trichoderma harzianum* and *Streptomyces* spp. were sourced from Plant Pathology laboratory both of Cocoa Research Institute of Nigeria, Ibadan, Nigeria.

Preparation and bio - degradation of coffee husk

Fifty grams (50 g) of dried coffee husk samples were weighed separately into 100 ml of sterile distilled water in 500 ml beakers, agitated vigorously and stirred continuously for 10 to 15 minutes. Each beaker was covered with aluminium foil, autoclaved at 121°C for 15 min and allowed to cool on a laboratory bench. A 10 mm inoculum disc pure culture of *T. harzianum* and *Streptomyces* spp. was inoculated first separately and combined into different sterilized weighed coffee husks in 500 ml beakers. The degradation of the husks was allowed over 1, 15 and 30 days and sterilized coffee husk without either *T. harzianum* or *Streptomyces* spp. served as control. The husks with the inocula were incubated at ambient temperature (28° ± 2°C) on a shaker to allow homogenized degradation for the specified periods. The mixtures in beakers were maintained under sterile conditions and covered with sterile foil. At specified period of degradation, each coffee husk mixture was oven dried and maintained for further studies.

Assay of degraded coffee husk in nursery

The 2 - week old F_3 amazon cocoa were raised in polythene bags containing 5kg of soil, incorporated with 6.25 g of 1, 15 and 30-day each of bio-degraded coffee husk arranged in a completely randomized design (CRD) for each of *C. arabica* and *C. canephora*. The applications and control were replicated in triplicates and data on vegetative growth parameters such as plant height, stem girth, leaf area, and number of leaves, started 4 weeks after application and subsequently recorded 12 and 24 weeks after application. The nursery experiment was terminated at 26 weeks after planting. The cocoa seedlings were harvested, sub-divided into parts: roots, stems and leaves and fresh weight recorded and plant parts were separately oven-dried and weighed. The plant samples were analyzed according to the standard methods of Association of Official Analytical Chemists (AOAC) (1990).

Data analysis

All data obtained were subjected to statistical analysis using the analysis of variance and differences between treatments means were separated by Duncan Multiple Range Test (DMRT) at 5% probability level.

RESULTS AND DISCUSSION

The performance of cacao seedlings ameliorated with coffee husk degraded at varying periods using *T. harzianum* showed significant variations in growth parameters. At 4 weeks after applications, cacao seedlings treated with a day *Streptomyces* degraded *C. arabica* husk gave the best plant height (2.40 mm) and was not significantly different from seedlings ameliorated with 1 day and 15 days *Streptomyces* degraded *C. canephora.* The other treatments were not significantly different from the control except the 30 days *T. harzianum* degraded *C. arabica* husk. The highest number of leaves was recorded in varied periods of degradations of *C. arabica* husk with *T. harzianum, Streptomyces* or both and *C. canephora* degraded with *T. harzianum* or *Streptomyces* were not significantly different (Table 1). The essence of biological degradation of the coffee husk was to increase the fertility of the soil and make available the nutrients from the added sources to the cocoa seedling and the solubility action of organic acids produced during the decomposition of organic matter (coffee husk) applied resulting in more release of native and as well applied nutrients which corroborate the findings of Bellakki et al. (1998).

Table 1. Effect of treatment types on growth of cacao seedling (4 weeks after application).

Treatments	Day of degradation	Plant Height (cm)	Number of leaves	Stem Girth (cm^2)	Leaf area (cm^2)
C. arabica + *Trichoderma*	30	12.20^{c}	3.67^{b}	0.19^{abcd}	0.37^{c}
	15	15,13^{abc}	5.33^{ab}	0.28^{abc}	0.87^{bc}
	1	17.77^{abc}	7.33^{a}	0.20^{abcd}	0.9^{bc}
C. arabica + *Streptomyces*	30	18.67^{abc}	7.00^{a}	0.30^{ab}	0.72^{bc}
	15	17.13^{abc}	5.33^{ab}	0.21^{abcd}	0.79^{bc}
	1	20.40^{a}	7.67^{a}	0.29^{ab}	0.70^{bc}
C. arabica + *Trichoderma* + *Streptomyces*	30	16.70^{abc}	6.00^{ab}	0.34^{a}	1.23^{b}
	15	15.30^{abc}	6.00^{ab}	0.19^{abcd}	0.19^{b}
	1	18.30^{abc}	7.67^{a}	0.24^{abcd}	1.19^{b}
C. canephora + *Trichoderma*	30	18.17^{abc}	6.67^{ab}	0.20^{abcd}	0.79^{bc}
	15	15.63^{abc}	5.67^{ab}	0.22^{abcd}	0.72^{bc}
	1	17.80^{abc}	7.07^{a}	0.21^{abcd}	2.0^{a}
C. canephora + *Streptomyces*	30	18.83^{ab}	6.67^{ab}	0.24^{abcd}	0.99^{bc}
	15	19.70^{a}	6.33^{ab}	0.23^{abcd}	0.75^{bc}
	1	20.40^{a}	7.00^{a}	0.21^{abcd}	1.12^{bc}
C. canephora + *Trichoderma* + *Streptomyces*	30	16.77^{abc}	6.67^{ab}	0.20^{abcd}	1.30^{b}
	15	15.60^{abc}	5.33^{ab}	0.12^{cd}	0.74^{bc}
	1	17.10^{abc}	5.00^{ab}	0.19^{abcd}	0.97^{bc}
	Control	15.40^{abc}	6.00^{ab}	0.09^{d}	0.58^{bc}

*Means followed by the same letter in each column are not statistically different according to DMRT (P = 0.05)

The result obtained also showed that 30-day *T. harzianum* combined with *Streptomyces* degraded *C. arabica* husk gave the thickest (0.34 cm^2) stem in term of girth and the highest leaf area recorded in cacao seedlings ameliorated with a day *T. harzianum* degraded *C. canephora* and was significantly higher than other applications and the control (Table 1). Table 2 shows the growth pattern of cacao seedlings at 12 weeks after application, which followed a similar trend of performance as plant height was the least (14.83 cm) in 30-day *T. harzianum* degraded *C. arabica* husk and highest recorded in 30-day *Streptomyces* degraded *C. canephora* husk and some other applications were significantly comparable. The 30-day *T. harzianum* combined with *Streptomyces* degraded *C. canephora* husk recorded the highest number of leaves in cacao. One day *Streptomyces* degraded *C. arabica* husk and a day *T. harzianum* degraded *C. canephora* husk recorded 0.63 and 12.99 cm^2 as the best stem girth value and leaf area, respectively (Table 2).

According to Mora et al. (1999) coffee husk is a material that has low moisture holding capacity with a very short lifespan, as its decays in a short time and its environmentally alternative material in agriculture (Leifa et al., 2001). Cocoa being a perennial plant, the effectiveness of its growth rate ability can be monitored in the seedling period and as a result when transferred to the field, its performance and yield will be better. Earlier workers have reported the advantage of using high quality organic manure for better crop growth and biomass accumulation (Preetu, 2004 and Vijaya, 2007). It was reported that chemical fertilizer was easy for uptake, but using the compost needed long time to degrade and mineralize and express effectiveness.

The cocoa seedlings plant height and number of leaves at 24 weeks after planting were significantly enhanced when a combination of *T. harzianum* and *Streptomyces* was used to degrade *C. canephora* husk for 30days. But the trend was different with stem girth and leaf area as it significantly improved cocoa seedling performance with a day of degradation of *C. canephora* husk using *T. harzinum* and *Streptomyces* treatments, respectively. However, the control treatment was significantly lower compared to other applications and significant similarities were also recorded in growth parameters ameliorated with different applications (Figure 1a).

The stem girth was significantly higher (1.56 cm^2) in *C. canephora* degraded for a day by *Streptomyces* and significant similarity were recorded in stem girth treated with C. Arabica degraded with Trichoderma for a day and

Table 2. Effect of treatment types on growth of cacao seedling (12 weeks after application).

Treatments	Day of degradation	Plant Height (cm)	Number of leaves	Stem Girth (cm^2)	Leaf area (cm^2)
C. arabica + *Trichoderma*	30	14.83^{c}	5.67^{f}	0.37^{ef}	2.33^{c}
	15	21.73^{abc}	6.67^{ef}	0.52^{abcde}	5.45^{bc}
	1	19.47^{abc}	10.00^{bcde}	0.38^{ef}	5.64^{bc}
C. arabica + *Streptomyces*	30	26.30^{ab}	9.33^{bcde}	0.58^{ab}	4.53^{bc}
	15	21.23^{abc}	7.67^{def}	0.49^{abcde}	9.33^{ab}
	1	24.87^{ab}	11.67^{b}	0.63^{a}	4.40^{bc}
C. Arabica + *Trichoderma* + *Streptomyces*	30	22.63^{abc}	10.67^{bcd}	0.46^{bcde}	5.63^{bc}
	15	20.63^{abc}	8.00^{cdef}	0.36^{ef}	5.29^{bc}
	1	22.4^{abc}	11.33^{bc}	0.49^{abcde}	7.45^{bc}
C. canephora + *Trichoderma*	30	24.63^{ab}	10.33^{bcd}	0.45^{bcde}	4.96^{bc}
	15	19.20^{bc}	9.33^{bcd}	0.39^{def}	4.54^{bc}
	1	24.17^{abc}	11.33^{bc}	0.45^{bcde}	12.99^{a}
C. canephora + *Streptomyces*	30	29.03^{a}	10.33^{bcd}	0.48^{abcde}	6.24^{bc}
	15	27.33^{ab}	8.33^{bcdef}	0.55^{abc}	4.66^{bc}
	1	25.90^{ab}	10.33^{bcd}	0.49^{abcde}	7.00^{bc}
C. canephora + *Trichoderma* + *Streptomyces*	30	22.77^{abc}	16.00^{a}	0.49^{abcde}	8.11^{ab}
	15	22.77^{abc}	10.33^{bcd}	0.47^{abcde}	4.61^{bc}
	1	21.67^{abc}	9.00^{bcde}	0.55^{abcd}	6.09^{bc}
	Control	20.43^{abc}	9.33^{bcde}	0.39^{cdef}	3.66^{bc}

*Means followed by the same letter in each column are not statistically different according to DMRT (P = 0.05)

15 days, *Streptomyces* degraded *C. arabica* for 15 days, *C. canephora* degraded with *Trichoderma* for 30 days and combinations of a day degraded *C. canephora*, *Trichoderma* and *Streptomyces.* The stem girth of untreated control was significantly thinner than all treatment (Figure 1b).

The *T. harzianum* and *Streptomyces* degraded coffee husk showed significant variations in fresh and dry plant weights. The dry weight was significantly high in *C. arabica* and *C. canephora* husks at 1 day degradation and differed significantly from control either *T. harzianum* or *Streptomyces* was used to degrade the coffee husk (Figure 2). The shoot fresh weight was similarly comparable in all treatments whereas the dry weight shows significant difference only when the husk was degraded for 1 day using *Streptomyces*. In the root, a 30-day *T. harzianum* and *Streptomyces* degraded *C. canephora* husk increased the root thickness by 1.57 mm when compare to other applications (Figure 2).

Figure 3 showed the effect of treatment types on the fresh and dry root weight and its thickness. The fresh root weight of a 30-day *T. harzianum* degraded *C. canephora* treated cacao seedling was significantly higher than other treatments; it was also the same for the fresh root of cacao treated with 15-day *Streptomyces* degraded *C. arabica* husk while other applications had significant similarities in their fresh root weight.

However, a day *T. harzianum* degraded *C. arabica* husk had the highest dry root weight but not significantly different from 1 and 15-day combined *T. harzianum* and *Streptomyces* degraded *C. canephora* husk; but the control gave the least dry root weight. Distinct cacao root thickness enhancement was recorded in 30-day *T. harzianum* degraded *C. canephora* husk which was significantly different from other applications and control while other treatment were similar. A combination of *T. harzianum* and *Streptomyces* degraded *C. canephora* husk will enhance good vigour of cacao seedling. There was no significant variation in fresh root weight of bio-degraded *C. arabica* but *C. canephora* degraded coffee husk showed variations in fresh root weight. The reverse is however the case for dry root weight between bio-degraded *C. Arabica* and *C. canephora.*

Table 3 showed *C. arabica* decomposed with Trichoderma spp was significantly higher in soil pH, other treatments also reduced acidity of the soil and both

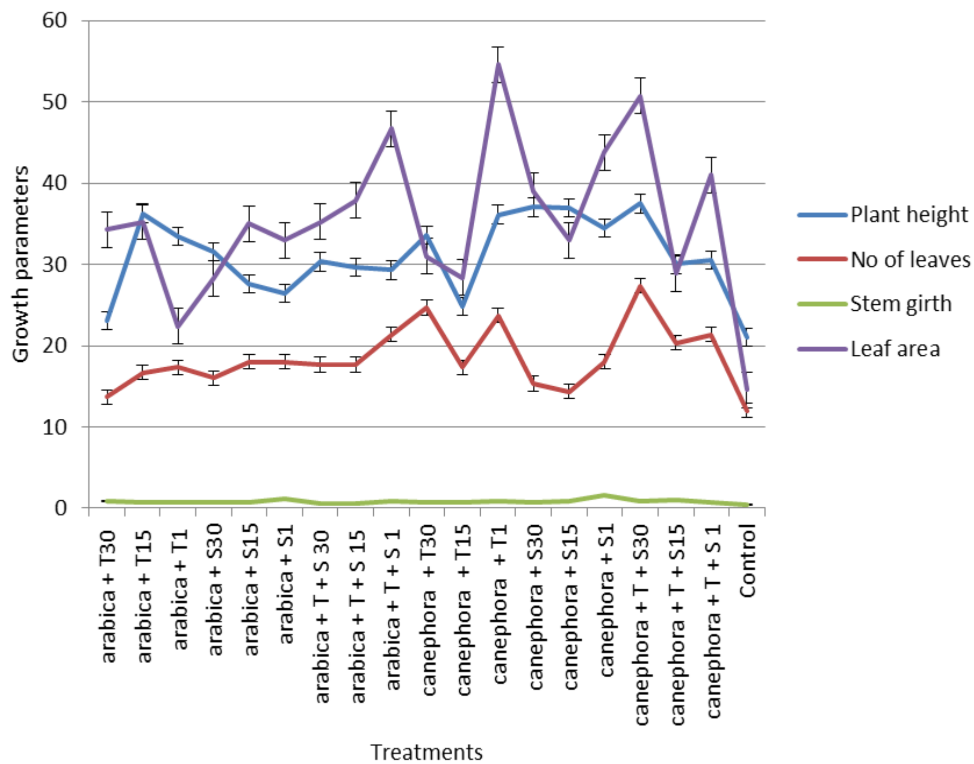

Figure 1a. Influence of treatment types on growth of cacao after 26 weeks in nursery.

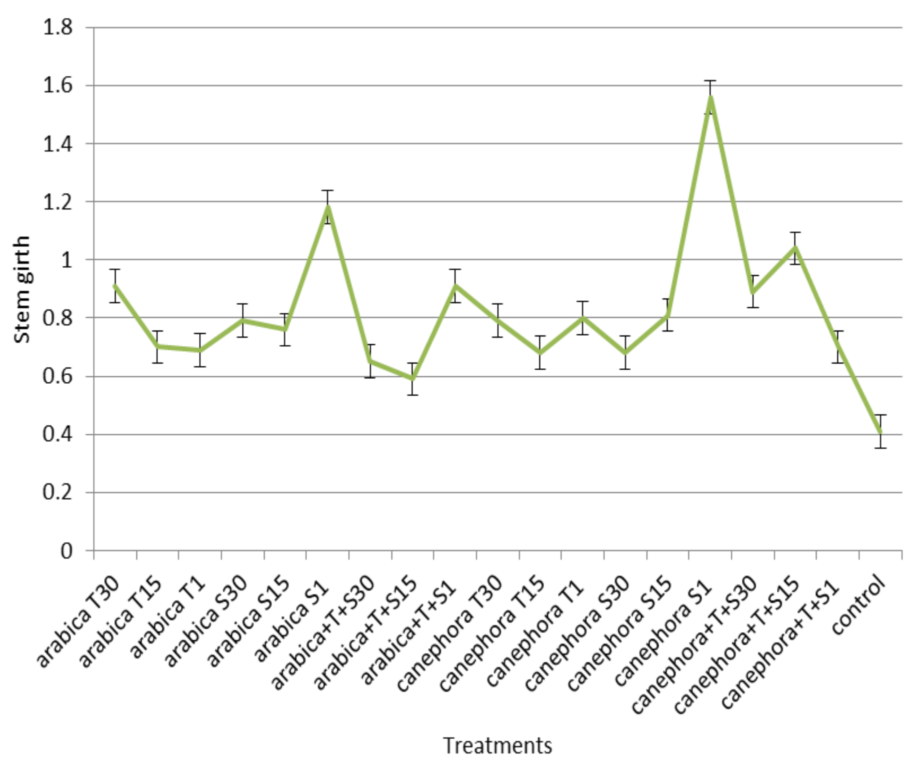

Figure 1b. Influence of treatment types on stem girth of cacao after 26 weeks in nursery

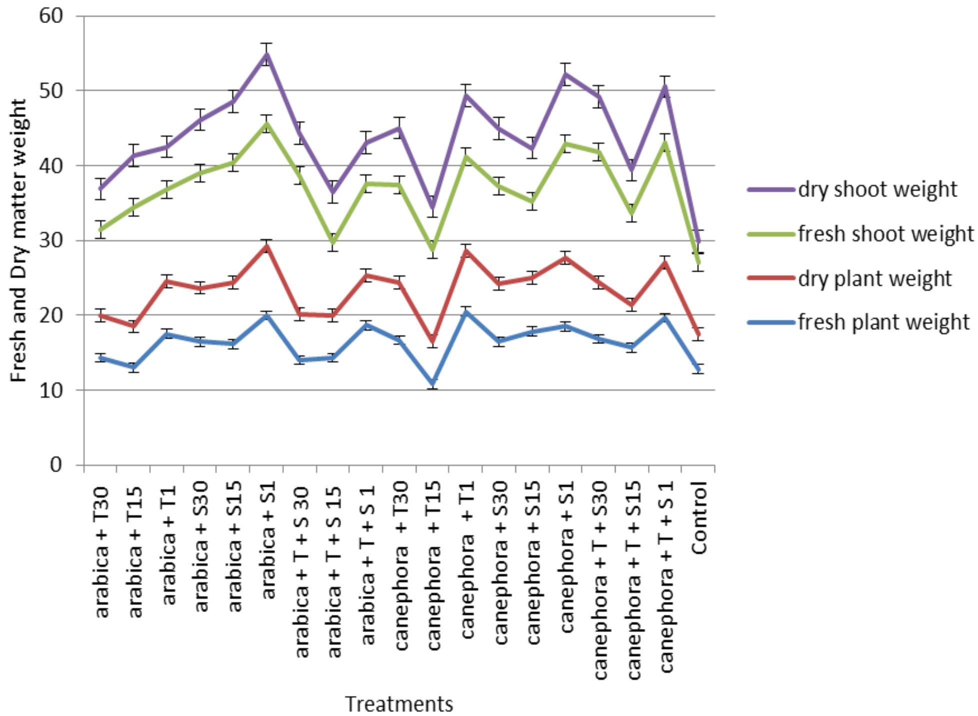

Figure 2. Effect of applications on plant and shoot weight of cacao after nursery.

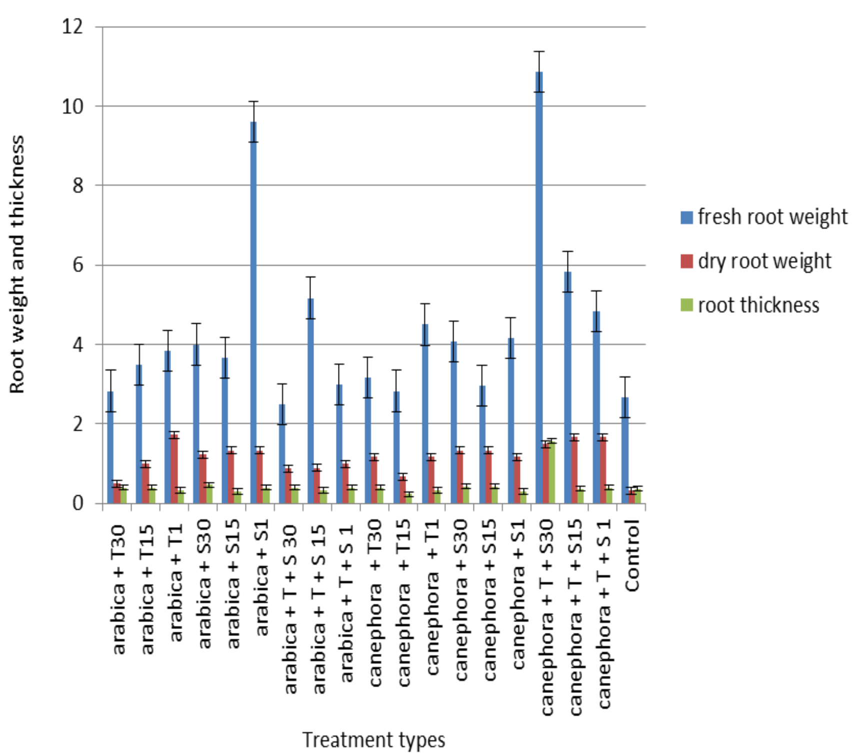

Figure 3. Effect of applications on root weight and thickness of cacao stem after nursery.

Table 3. Post treatment analysis of cacao soil ameliorated with degraded coffee husk.

Soil treatment	pH	OC (%)	OM (%)	N (%)	P (%)	K (%)	Na (Cmol/kg)	Ca (Cmol/kg)	Mg (Cmol/kg)
C. arabica + Trichoderma	7.13[a]	1.32[c]	3.09[c]	0.38[a]	4.96[b]	0.45[a]	0.44[c]	2.23[ab]	0.83[a]
C. arabica + Streptomyces	6.77[b]	2.09[ab]	3.23[b]	0.43[a]	4.45[b]	0.48[a]	0.42[c]	2.30[ab]	1.03[a]
C. Arabica + Trichoderma +Streptomyces	6.58[bc]	2.48[a]	4.07[a]	0.46[a]	7.34[b]	0.46[a]	0.47[b]	2.80[a]	1.03[a]
C. canephora+ Trichoderma	6.75[b]	2.01[ab]	3.35[b]	0.44[a]	3.72[b]	0.57[a]	0.47[b]	1.80[b]	1.10[a]
C.canephora+ Streptomyces	6.37[c]	1.84[bc]	3.40[c]	0.42[a]	4.46[b]	0.56[a]	0.40[d]	1.93[b]	0.93[a]
C. canephora+ Trichoderma+Streptomyces	6.99[d]	1.55[bc]	2.63[d]	0.46[a]	11.84[a]	0.48[a]	0.52[a]	1.47[b]	1.10[a]
Initial soil sample	5.70	1.51	2.77	0.12	3.80	0.32	0.10	1.30	0.60

Trichoderma and *Streptomyces* decomposed *C. arabica* enhances the organic carbon content in soil. The combined *Trichoderma* and *Streptomyces* decomposed *C. canephora* used as soil amendment increases the macro nutrients and organic matters of the soil. The content of mineral nutrients and organic matters was increased in the soil in this study and was translated to uptake of such by cacao seedlings. Westerman and Bicudo (2005) reported that increase in using organic fertilizer contributed to improve the physical, chemical and biological characteristics of soil and sustainable agricultural cultivation. The high level of phosphorus both in the soil residue and leaf was reported by Young (1994); he also reported that the level of phosphorus is important in determining the quality of the compost as phosphorus is an essential nutrient in plant growth. In addition, the activity of effective microorganisms in the compost such as *Trichoderma*, and *Streptomyces* also plays important roles in increasing the uptake of mineral nutrients and fertility of soil for cacao.

However, no significant difference was recorded in the nitrogen (N), Magnesium (Mg) and Potassium (P) contents of bio-degraded *C. arabica* and *C. canephora* soil except in *Trichoderma* and *Streptomyces* degraded *C. canephora* husk but the N, P, K were higher than in the initial soil. This implies addition of the macro elements and organic matter contents by the bio-degraded *C. arabica* and *C. canephora* husk to the soil. However significant differences were recorded in the quantity of the macro elements and organic matter content of the soil among the treatments. The only variation was recorded in *Trichoderma* degraded *C. arabica* husk which reduced the organic content of the soil. The post treatment evaluation of the cacao seedlings for disease and insect-pest status showed they are healthy and free of infestation.

The high organic carbon reported in this study is also similar to the earlier work of Young (1994) which implies that high organic carbon provides preliminary energy source to provide good quality compost. The reduce pH recorded in soil samples after treatment application was similar to the finding of Jahromi et al., (2011) which reported that biological treatment reduces the pH. The change in pH value may be associated with the increase in amino nitrogen content and the presence of metabolic waste products within the substrates. The increase in soil pH in this study also corroborate the earlier findings of Izolda, (2001) which reported pH < 4 was potentially toxic organic acid and if increased in soil solution above 5.5, nitrogen (in the form of nitrate) is made available to plants. Phosphorus made available to plants when soil with pH 6.0 to 7.0 and pH of 6.99 in this study had 11.84% available phosphorus for cocoa plant development when the *C. canephora* husk was decomposed with a combination of *Trichoderma* and *Streptomyces spp* for a period of 30 days.

The findings in this study are also comparable to the work of Rudresh et al. (2005) and Shaban and El-Bramawy (2011) that described the improvement in growth parameters under glasshouse and field experiments due to the combined inoculation of *Trichoderma spp*. with other fungus. Therefore, *Trichoderma* with *Streptomyces spp* can be used for bio-decomposition of coffee husk and added as a good substitute for producing positive growth of cocoa seedlings by improving the soil fertility.

This also corroborate the findings of Harman (2006) which reported that *Trichoderma* - plant association, instead of producing deleterious effect, are of benefits to the host plant in health, growth, and productivity. It was reported that *Streptomyces* spp. enhanced growth and performance of the crop plants Brown (1974), while *Trichoderma sp* are also reported as growth promoting fungi by enhancing the availability of nutrients and minerals (N and P) for plants, producing plant growth hormones and decomposing organic material (Kaewchai et al., 2009), and inducing tolerance in cocoa plants against water deficit through increasing root growth (Bae et al., 2009).

Conclusion

The amelioration of cacao seedling using *T. harzianum* and *Streptomyces* degraded coffee husks positively enhanced nursery performance of cacao. The effect of *T. harzianum* and *Streptomyces* degraded *C. arabica* was more evident on growth during initial stages, however *T. harzianum* and *Streptomyces* degraded *C. canephora* gave a lasting effect on cacao growth by end of nursery experiment. A combination of 30-day *T. harzianum* and *Streptomyces* degraded *C. canephora* husk gave the best plant height, number of leaves, fresh root weight and best vigour of root thickness, but 30-day *T. harzianum* combined with *Streptomyces* degraded *C. arabica* husk gave best fresh shoot weight and a day *T. harzianum* degraded *C. canephora* was best in fresh plant weight by the end of nursery experiment. There was increase in the macro elements and organic matter contents by the bio-degraded *C. arabica* and *C. canephora* husk in the soil. These treatments could be further tried on field establishment to determine their effect on field performance and yield of cacao.

CONFLICT OF INTEREST

The authors have not declared any conflict of interest

REFERENCES

Adeniyi DO, Adedeji AR, Oduwaye OF, Kolawole OO (2013). Evaluation of Biocontrolagents against *Lasiodiplodia theobromae* causing Inflorescence blight of Cashew in Nigeria. IOSR J. Agric. Vet. Sci. 5(3):46-48.

Almeida AAF, Valle RR (2007).Ecophysiology of the cacao tree. Braz. J. Plant Physiol.19:425-448.

AOAC (1990). Official Methods for Analysis of the Association of Official Analytical Chemists 15th Edition. Helrich K (ed), Arlington Virginia. Washington D.C.

Bae H, Sicher RC, Kim MS, Kim SH, Strem MD (2009). The beneficial endophyte *Trichoderma hamatum* isolate DIS 219b promotes growth and delays the onset of the drought response in *Theobroma cacao*. J. Expt. Bot. 60(11):3279- 3295.

Bellakki MA, Badnur VP, Shetty RA(1998). Effect of long term integrated nutrient management on some important properties of vertisols. J. Ind. Soc. Soil Sci. 46:176-180.

Brown ME (1974). Seed and root bacterization. Ann.Rev. Phytopathol. 12:181-197.

Divakaran J, Elango R (2009). Microbial consortium for effective composting of coffee pulpwaste by enzymatic activities. Global J. Environ. Res. (3):92-95.

Dzung T, Dzung T,Khanh VTP (2013). Evaluation of coffee husk compost for improving soil fertility and sustainable coffee production in rural central highland of Vietnam. Res. Environ. 3(4):77-82.

Guimarães DV, Silva-Gonzaga MI, Silva TO, Silva TL, Silva DN, Silva-Matias MI (2013).Soil organic matter pools and carbon fractions in soil under different land uses. Soil and Tillage Res. 126:177-182.

Harman G (2006). Overview of mechanisms and uses of *Trichoderma spp*. Phytopathology 96:190-194.

Hermosa R, Viterbo A, Chet I, Monte E (2012). Plant beneficial effects of *Trichoderma* and of its genes 158(P61):17-25.

Howell CR (2003). Mechanisms employed by *Trichoderma* species in the biological control of plant disease; the history and evolution of current concepts. Plant Dis. 87:4-10.

Hoyos-Carvajal L, Orduz S, Bissett J (2009). Growth stimulation in bean (*Phaseolus vulgaris* L.) by *Trichoderma.* Biol. Control 51(3):409-416.

Izolda T (2001). Image of pH scale, information derived from: "Nutrient Manager: Focus on pH and Lime", published by the University of Maryland's Cooperative Extension Service and Department of Agronomy; The Handbook of Soils and Climate in Agriculture; theTop soil on Tour Mini Curriculum and Hands on Test Kit by the LaMotte Company, and the Miami Museum of Science web site. http://soil.gsfc.nasa.gov/soil_pH/plant_pH.htm

Jahromi MF, Liang JB, Rosfarizan M, Goh YM, Shokryazdan P, Ho YW (2011). In: Efficiency of rice straw lignocelluloses degradability by *Aspergillus terreus* ATCC 74135in solid state fermentation. Afr. J. Biotechnol. 10(21):4428-4435.

Kaewchai S, Soytong K, Hyde KD (2009). Mycofungicides and fungal biofertilizers. Fungal diversity. 38:25-50.

Leifa F, Pandey A, Soccol CR (2001). Production of flammulina velutipes on coffee husk and coffee spent-ground, "Braz. Arch. Biol. Technol. 44(2):205-212.

Mastouri F, Bjorkman T, Harman GE (2010). Seed treatment with *Trichoderma harzianum* alleviates biotic, abiotic and physiological stresses in germinating seeds and seedlings. Phytopathology 100:1213-1221.

Mc Near Jr DH (2013). The Rhizosphere - Roots, Soil and Everything In Between. Nat. Educ. Knowl. 4(3):1.

Mora A, Russell DW, Dungy CI, Losch M, Dusdieker L (1999). The Iowa Infant Feeding Attitude Scale: Analysis of Reliability and Validity. J. Appl. Social Psychol. 29(11):2362-2380.

Nduka BA, Adewale DB, Akanbi OSO, Adejobi KB (2015). Nursery Soil Amendments for Cashew Seedling Production: A Comparative Analysis of Coffee Husk and NPK. J. Agric. Sci. 7(3):111.

Opeke LK (2006). Tropical Tree Crops. Spectrum Books Ltd. Pub. Ilorin: Woye and SonsNigeria Ltd.

Preetu (2004). Evaluation of quality, maturity indices and agronomic efficiency of compost prepared using coffee husk and pulp. M.Sc. (Agri.) Thesis, Univ. Agric. Sci. Bangalore (India).

Rhodes ER (1995). Nutrient depletion by food crops in Ghana and soil organic nitrogen management. Agric. Syst. 48(1):101-118.

Rudresh DL, Shivaprakash MK, Prasad RD (2005). Effect of combined application of Rhizobium, phosphate solubilizing bacterium and *Trichoderma* spp. on growth, nutrient uptake and yield of chickpea (*Cicer aritenium* L.). Appl. Soil Ecol.28:139-146.

Shaban WI, El-Bramawy MA (2011). Impact of dual inoculation with *Rhizobium* and*Trichoderma* on damping off, root rot diseases and plant growth parameters of some legumes field crop under greenhouse conditions. Int. Res. J. Agric. Sci. Soil Sci. 1(3):098-108.

Vijaya KN (2007). Effect of coffee pulp effluent on growth and yield of

SRI paddy. M. Sc.(Agri.) Thesis, Univ. Agric. Sci., Bangalore (India).
Westerman PW, Bicudo JR (2005). Management considerations for organic wastes use in agriculture. Bioresour. Technol. 96:215-221.
Young CC (1994). Selection and application of biofertilizers in Taiwan Agriculture. In: International Seminar on the Use of Micro Organic Fertilizers for Agricultural Production. Rural Development Administration of Korea and Food and Fertilizer Technology Center, Suwon pp. 147-165.

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Biological nitrogen fixation by pigeon pea and cowpea in the “doubled-up” and other cropping systems on the Luvisols of Central Malawi

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Legumes form a very important component in Malawi’s cropping systems because of their roles in food security, income generation and soil fertility improvement through biological nitrogen fixation (BNF). They are commonly grown in various cropping systems including sole cropping, cereal-legume intercrops and legume-legume intercrops (also commonly referred to as “doubled-up”). However, information on BNF by the pigeon pea and cowpea under doubled-up system is scanty. Therefore, a study was conducted at two sites of Lilongwe and Dowa in the 2013/14 growing season, to quantify and compare the amounts of biologically fixed nitrogen in the three legume cropping systems. The experiments were laid out in a randomized complete block design and BNF was estimated using the modified nitrogen difference method. Results showed that there were significant differences ($P < 0.05$) in nodule numbers, nodule dry weights, and quantities of N_2 fixed per unit area due to cropping systems’ effects at both sites. Sole cropped pigeon pea produced the highest N_2 fixed (92.9 kg N ha^{-1}) which was significantly higher by 86, 30 and 36% than the amounts fixed in the cowpea-maize intercrop (13.1 kg N ha^{-1}), sole cowpea (62.5 kg N ha^{-1}) and pigeon pea-maize intercrop (59.9 kg N ha^{-1}), respectively, at the Dowa site. On the other hand, the total sum of the amounts of N_2 fixed (82.9 kg N ha^{-1}) by the component crops in the pigeon pea-cowpea “doubled-up” was comparable to that by sole cropped pigeon pea at the Dowa site. However, for Lilongwe site the doubled-up cropping system total amount of biologically fixed nitrogen (57.4 kg N ha^{-1}) was significantly lower than that by the sole cropped pigeon pea (85.7 kg N ha^{-1}) by 33%. From this study it can be noted that all three legume cropping systems can lead to substantial amounts of biologically fixed nitrogen, but their implementation should consider both combinations and environmental factors for specific sites.

Key words: Biological nitrogen fixation, cowpea; cropping systems, cereal-legume intercrop; legume-legume intercrop, pigeon pea.

INTRODUCTION

The quest for high agricultural productivity in many parts of the world is hampered by many factors including climate variability, growing human populations that put more pressure on land resources and reduced productivity of the soils (AGRA, 2014; Reynolds et al., 2015). In Sub-Saharan Africa, the challenge of declining soil productivity is enormous, which is also exacerbated by low economic status of most smallholder farmers who cannot afford enough quantities of inorganic fertilizers to effectively replenish nutrients in their farms (Druille and Barreto-Hurle, 2012; AGRA, 2014). In Malawi, declining soil fertility, with reference to nitrogen as the major limiting nutrient for crop growth, has been the biggest challenge in sustainably achieving optimum yields of maize, the main staple crop of the country (Kumwenda et al., 1997; Makumba, 2003). Although various technologies of soil management have been developed by researchers and some practised by smallholder farmers, they face numerous challenges in many parts of Sub-Saharan Africa, including Malawi, in terms of adoption by smallholder farmers due to various reasons. These include transportation costs and low level of ownership of livestock that could produce manure (Ajayi et al., 2007) and low nutrient content of many organic soil amendments (Palm et al., 1997).

However, legumes that are known to participate in symbiotic N_2 fixation are commonly grown in many parts of Sub-Saharan Africa. In Malawi, commonly grown legumes include common beans (*Phaseolus vulgaris*), cowpea (*Vigna ungiculata*), soybean (*Glycine max*), groundnut (*Arachis hypogaea*) and pigeon pea (*Cajanus cajan*) (Mhango et al., 2012; Ngwira et al., 2012). Snapp et al. (2014) reported that 35 to 50% of maize plots surveyed in Malawi integrated some legumes. Legumes offer many advantages to farmers, including increased income, protein source and soil fertility improvement through biological nitrogen fixation (BNF). Biological nitrogen fixation is achieved through the involvement of legumes in a mutualistic relationship with bacteria, mainly rhizobia. Rhizobia is a generalized name but is a group that includes various genera such as *Allorrhizobium*, *Bradyrhizobium*, *Rhizobium*, *Sinorhizobium* and *Mesorhizobium* (Giller, 2001; Syvia et al., 2005; Berrada and Fikri-Benbrahim, 2014).

In Malawi, farmers grow legumes in various cropping systems, including sole cropping, cereal-legume intercrops and legume-legume intercropping which is popularly known as “doubled-up” legume technology (ICRISAT/MAI, 2000; Mhango et al., 2012). A doubled-up legume technology is where a legume is intercropped with another legume and this is commonly done by involving a tall legume such as pigeon pea and other relatively short legumes such as groundnuts, soybean or cowpea (ICRISAT/MAI, 2000). Farmers ranked doubled-up legumes as being highly beneficial, citing reasons such as increased food security, labour saving and soil fertility improvement (Phiri et al., 2012). However, most information on the quantities of biologically fixed N is based on sole crops. Mhango (2011) and Njira et al. (2012) reported on biological nitrogen fixation for doubled-ups of pigeon pea-groundnuts (42 to 82.8 kg N ha^{-1}) and pigeon pea-soybean (53.6 kg N ha^{-1}) whereas Phiri et al. (2014) reported soil fertility improvement due to pigeon pea-groundnut intercrop. However, not much has been done to evaluate quantities of biologically fixed N under doubled-ups involving most of the recent legume varieties and information on pigeon pea-cowpea doubled-up BNF is scanty. Therefore, the objective of this study was to assess nodulation and quantify the amount of nitrogen that is biologically fixed per unit area by each of pigeon pea and cowpea in a doubled-up cropping system, their combined amount of N and in comparison with N_2 fixed when grown as sole crops or in cereal-legume intercrops. In this paper, the terms N_2 fixed and biologically fixed nitrogen (N) are used interchangeably.

MATERIALS AND METHODS

Site identification and characterization of soils of the study sites

Two sites, Lilongwe and Dowa, both in the Central region of Malawi were identified for the study. The two sites were considered to increase the scope of identifying consistence and repeatability of treatment effects as recommended by Nielsen (2010). In Lilongwe district, the experiment was conducted at the Lilongwe University of Agriculture and Natural Resources research farm within the Mkwinda Extension Planning Area (EPA), whereas in Dowa district the experiment was conducted at Nachisaka EPA. Rain gauges were installed at both sites for rainfall monitoring. Soils of the two sites have been classified as Chromic Luvisols in the World Reference Base System (Typic Hapludalfs in the USDA Soil Taxonomy) (Chilimba et al., 2011; Mutegi et al., 2015).

Soil samples were collected using an auger from depths of 0 - 20 and 20 - 40 cm, based on the simple random sampling plan, before planting and after harvesting according to Anderson and Ingram (1993). The sampling during pre-planting involved sampling from six points in Lilongwe and nine points in Dowa and for each of these sites soils were pooled into depth-wise composite samples. The nine points in the Dowa site were considered because the slope was slightly higher than that of the Lilongwe site which was

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generally flat. These were air dried and analysed for various parameters namely: Soil texture by the hydrometer method (Bouyoucos, 1962), pH in water by the potentiometric method (Thomas, 1996), total nitrogen (N%) by micro-Kjedahl method (Bremner and Mulvaney 1982), soil extractable phosphorus (P) by Mehlich-3 method (Mehlich, 1984) and boron using the hot water soluble method as outlined by Anderson and Ingram (1989). Organic carbon (C) was determined using the wet oxidation method by dichromate (Nelson and Sommers, 1982), exchangeable bases, iron (Fe), manganese (Mn) and zinc (Zn) by Mehlich-3 method (Mehlich, 1984). Post-harvest sampling involved sampling soils from each plot for analysis of mineral N, extracted using 2 M KCl, followed by colorimetric determination according to Anderson and Ingram (1989) that was used in the modified nitrogen difference method for determination of biologically fixed N according to Peoples et al. (1989), described in detail in the section for BNF determination.

Experimental design and treatment description

The experiment was laid out in the randomized complete block design (RCBD) with three replicates at both sites. Treatments included sole cropped cowpea, sole cropped pigeon pea, pigeon pea-cowpea intercrop, cowpea-maize intercrop, pigeon pea-maize intercrop and sole cropped maize. Varieties planted were the *Alectra vogelii*-resistant cowpea known as *Mkanakaufiti* (IT99K-494-6), the medium duration pigeon pea known as *Mwayiwathu alimi* (ICEAP 00557), and the *Mkangala* (DKC 8053) variety of maize. The treatments were replicated three times. The plot of sole cropped maize (without fertilizer) was included to serve the purpose of reference crop in the determination of BNF by the modified nitrogen difference method (Peoples et al., 1989). All the maize in the intercrops was not fertilized to avoid confounding effects on BNF through N transfer that might occur. Furthermore, the nitrogen difference method is more reliable in low N than in higher soil N conditions (Danso et al., 1992).

The size of each treatment plot was 15 m by 7 m and included 20 ridges of 7 m long at the spacing of 75 cm. Three pigeon pea seeds were planted per planting station at 90 cm between planting stations within the row/ridge at the ridge spacing of 75 cm in both sole and intercrop according to MoAFS (2012). In-row intercropping was done by planting either cowpea or maize between pigeon pea planting stations within the ridge/row according to MoAFS (2012). In sole cowpea, two seeds were planted per planting station at a spacing of 20 cm between planting stations along the ridge and at a distance of 75 cm between ridges, whereas the intercropped cowpea was planted at the same distance of 20 cm, which made three planting stations per every space between two pigeon pea planting stations. Similar to pigeon pea, three maize seeds were planted per planting station at 90 cm between planting stations within the row/ridge at a ridge spacing of 75 cm in both sole and intercrop. This made the planting pattern of intercropped maize and pigeon pea involving the planting station of pigeon pea being systematically in the middle of the space between maize planting stations. No rhizobial inoculation was done on both cowpea and pigeon pea. Therefore, nodulation and BNF in this study was dependent on indigenous rhizobia from soil.

Nodulation assessment, plant sampling and analysis

Nodulation assessment was conducted both in cowpea and pigeon pea at 50% flowering of each crop. These activities were conducted at different times as these crops grow and reach specific growth stages at different periods. Nodulation assessment included careful uprooting of plants, counting number of nodules, recording fresh and dry weights of nodules and determining the effectiveness of the nodules by slicing them and checking their internal colours. Effective nodules are identified by pink, red or brown colours while other colours such as green, white and yellow mean non-effectiveness (Peoples et al., 1989; Sylvia et al., 2005). Ten plants were randomly sampled from each plot of cowpea and nodules numbers from each of these plants were recorded. The procedure of sampling for pigeon pea plants was similar to that of sampling cowpea.

However, eight plants were sampled for pigeon pea since its plant population was lower than that of cowpea. Furthermore, 10 nodules were randomly sampled, each nodule cut into halves to check the internal colour for determination of effectiveness. Number of effective nodules was expressed as the percentage of effectiveness. Fresh and dry weights were also taken from the total number of nodules per plant. Plant samples were collected from the fields at 50% flowering from each of the legumes and at tasseling stage for maize for analysis of % N.

Determination of biological nitrogen fixation and percentage of nitrogen derived from the atmosphere (%N_{dfa})

The total N percentage determined in the plant samples was multiplied by total dry matter yields of each crop. Biological nitrogen fixation was determined using the modified Nitrogen-Difference method (Peoples et al., 1989). Therefore, the formula used was as shown in the following equation after Peoples et al. (1989):

$$Q = [\text{N yield (legume)} - \text{N yield (control)}] + [\text{N soil (legume)} - \text{N soil (control)}]$$

Where: Q (kg ha^{-1}) = Quantity of the biologically fixed nitrogen; N yield [legume] (kg ha^{-1}) = Nitrogen yield of a legume; N yield [control] (kg ha^{-1}) = Nitrogen yield of a non-fixing plant; N soil (kg ha^{-1}) = Post-harvest soil nitrogen in legume or control plot; Control/reference crop = Unfertilized maize.

The percentage of nitrogen derived from the atmosphere (%N_{dfa}) was determined as follows:

$$\%N_{dfa} = \frac{N_2 \text{ fixed}}{\text{N yield}} \times 100$$

Where: N_2 fixed is the biologically fixed nitrogen; N yield is the total N uptake.

Determination of total dry matter yields

The total dry matter yields (total biomass yields) were needed for the quantification of BNF and were determined for all the crops, which are cowpea, pigeon pea and maize. A net plot of 13.5 m by 4.3 m was demarcated and all the plants for a specific crop were cut at ground level for the total above ground biomass. These were weighed for fresh weights and samples taken to the laboratory for oven drying and determination of dry matter yields according to Mloza-Banda (1994).

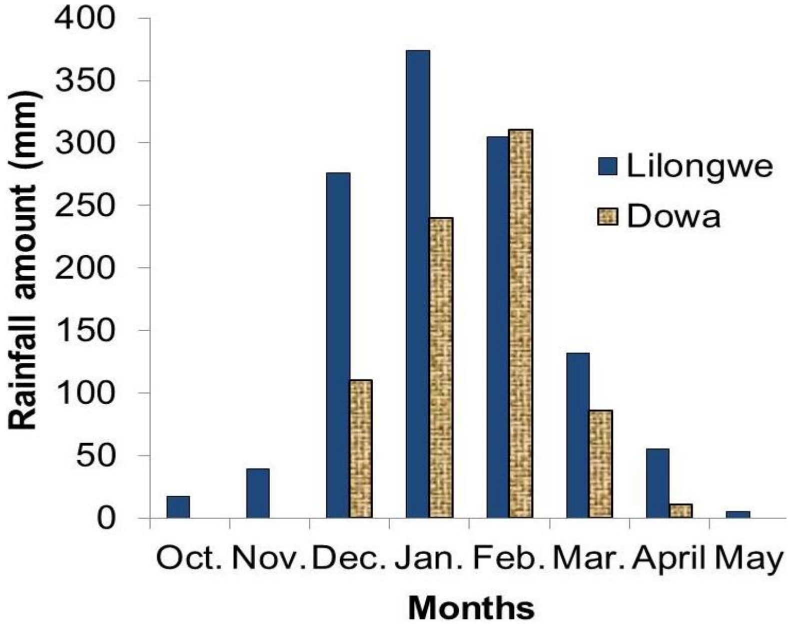

Figure 1. Rainfall amounts for Lilongwe and Dowa sites in the 2013/14 cropping season.

Statistical and data analysis

All the obtained data were subjected to analysis of variance (ANOVA) using Genstat 15th edition statistical package. Consideration of plant population of cowpea was made, as it was planted with different populations in the sole and intercropped systems. This was achieved by determination of parameters that needed cowpea plant population on per plant basis and where needed covariate analyses were applied according to Gomez and Gomez (1984). Means were separated using the least significant difference test (LSD) at 5% level of significance.

RESULTS

Rainfall amounts at the two study sites in the 2013/14 cropping season

Figure 1 shows the amount of rainfall at the two study sites. Results show the highest monthly rainfall in the months of January and February for Lilongwe and Dowa, respectively. Lilongwe site received higher total amount of rainfall (1205 mm) than the Dowa site (758 mm). However, the total amounts of rainfall at both sites are within the required rainfall amount ranges for the crops that were planted in this study, based on MoAFS (2012). Rainfall distribution was favourable at both sites especially for cowpea and maize as it was moderately high in the month of February when these two crops were podding and tasseling, respectively.

Soil properties of the Lilongwe and Dowa study sites

Results for the determination of soil properties for the two study sites are shown in Table 1. The topsoil mean values indicated moderately acid for Lilongwe and slightly acid for Dowa site whereas the subsoils of both sites were slightly acid with the same mean value (Table 1). Dowa soil had high organic matter for both top and subsoil whereas Lilongwe showed low organic matter for both depth ranges (Table 1). Further details for various soil properties and their ratings according to Landon (1991) and Chilimba (2007) are presented in Table 1.

Nodulation of pigeon pea as affected by cropping system at the two study sites

Table 2 shows that there were significant differences ($P < 0.05$) in pigeon pea nodule dry weights as influenced by cropping system at both sites. Nodule dry weights were significantly higher ($P < 0.05$) in sole cropped pigeon pea by 25 and 48% than that of pigeon pea in the pigeon pea-cowpea and pigeon pea-maize intercrops, respectively, at the Lilongwe site. Similarly, at the Dowa site, sole pigeon pea showed significantly higher ($P < 0.05$) nodule dry weights by 28 and 46% than that of pigeon pea in pigeon pea-cowpea and pigeon pea-maize intercrops, respectively. Furthermore, at the Dowa site, nodule

Table 1. Soil properties of the Lilongwe and Dowa study sites in Malawi.

Soil property	Lilongwe		Dowa		Lilongwe		Dowa	
	0 - 20 cm	Rating	0 - 20 cm	Rating	20 - 40 cm	Rating	20 - 40 cm	Rating
pH_{water} 1:2.5	6.00	Moderately acid	6.20	Slightly acid	6.2	Slightly acid	6.2	Slightly acid
Organic C (%)	1.10	Low	2.8	Medium	0.9	Low	2.5	Medium
SOM (%)	1.80	Low	4.7	High	1.6	Low	4.4	High
Total N (%)	0.05	Very low	0.14	Medium	0.05	Very low	0.10	Low
Mehlich-3 P (mg/kg)	57	High	41	High	28	Adequate	21	Low
Mg ($cmol_+$/kg)	1.24	High	0.99	High	1.18	High	1.12	High
Ca ($cmol_+$/kg)	4.24	High	4.78	High	5.2	High	5.3	High
K ($cmol_+$/kg)	0.35	High	0.23	Adequate	0.22	Adequate	0.23	Adequate
Fe (mg/kg)	19.11	Adequate	19.2	Adequate	15.6	Adequate	19.0	Adequate
Zn (mg/kg)	2.56	Adequate	12.2	High	4.0	Adequate	17.4	High
Mn (mg/kg)	10.3	High	17.1	High	11.49	High	15.4	High
B (mg/kg)	0.58	Adequate	0.15	Adequate	0.08	Low	0.16	Adequate
Bulk density (g/cm^3)	1.53	-	1.45	-	1.54	-	1.52	-
Particle size distribution								
Sand	46.4		46.7		47.6		45	-
Silt	22.7		23.3		29.1		24.4	-
Clay	30.9		30.0		23.3		30.6	-
Textural class	Sand clay loam		Sandy clay loam		Loam		Clay loam	-

Ratings are based on Landon (1991) and Chilimba (2007).

numbers were significantly higher (P < 0.05) in the sole cropped pigeon pea than those of pigeon pea in the pigeon pea-maize intercrops by 31% and slightly higher than those in the pigeon pea-cowpea intercrop. However, at the Lilongwe site, nodule numbers were only slightly higher in the sole cropped pigeon pea than that of pigeon pea in the pigeon pea-cowpea and pigeon pea-maize intercrops. Furthermore, no significant differences were observed in nodule effectiveness at both study sites.

Nodulation of cowpea as affected by cropping system at the two study sites

The effect of cropping system on the extent of nodulation was as presented in Table 3. Results show that sole cropped cowpea produced significantly (P < 0.05) higher nodule numbers than those of cowpea in the cowpea-maize intercrop by 38%, at the Dowa site. However, sole cropped cowpea nodule numbers were only slightly higher in the Lilongwe site. On the other hand, significant differences were observed in cowpea nodule dry weights in both Lilongwe and Dowa sites. Sole cowpea produced significantly higher (P < 0.05) nodule dry weights by 38 and 36% than those of cowpea in the cowpea-pigeon pea and cowpea-maize intercrops, respectively.

Table 2. Pigeon pea nodule numbers, dry weights and effectiveness as affected by cropping system at the two study sites.

Parameter	Cropping system	Site	
		Lilongwe	Dowa
Nodule numbers/plant	PP	12	13
	PP+CP	10	12
	PP+MZ	9	9
	LSD (0.05)	2.6	3.8
	F pr.	0.085	0.045
	CV %	11.2	15.0
Nodule dry weight (mg/plant)	PP	335.6[a]	353.6[a]
	PP+CP	251.5[b]	254.3[ab]
	PP+MZ	174.7[c]	191.9[b]
	LSD (0.05)	47.1	125.5
	F pr.	0.002	0.045
	CV %	8.2	20.8
Nodule effectiveness (%)	PP	66.7	66.7
	PP+CP	53.3	63.3
	PP+MZ	56.7	63.3
	LSD (0.05)	15.1[ns]	15.1[ns]
	F pr.	0.145	0.79
	CV %	11.3	10.3

Means with different letters in the same column are significantly different according to LSD at 5% significant level; ns = non-significant difference; CV = coefficient of variation; F pr. = F probability; PP = pigeon pea; CP = cowpea and MZ = maize; PP+CP = PP intercropped with CP; PP+MZ = PP intercropped with MZ; PP+CP and CP+PP have been used interchangeably in this paper.

No significant differences were observed in cowpea nodule effectiveness in both sites of the study.

Quantities of N_2 fixed and $\%N_{dfa}$ by pigeon pea at Lilongwe and Dowa sites

The amounts of biologically fixed N by pigeon pea and cowpea on a per plant basis and the % Ndfa, as influenced by cropping system are as presented in Table 4. The per plant basis analysis was intended to see the performance of the crop as it grows in different cropping systems whereas per hectare basis (Figure 2A to B) was done specifically to show quantities for each crop per unit area, and consideration of plant population was done by covariate analysis on the cowpea data as it was sown in different plant populations in the different cropping systems. Results show that there were significant differences ($P < 0.05$) in biologically fixed N by the legumes as influenced by cropping system at both study sites (Figure 2A to B). In the Lilongwe site, sole cropped pigeon pea showed significantly higher ($P < 0.05$) N_2 fixed per plant (Table 4) than that by pigeon pea under both intercrops of pigeon pea-cowpea and pigeon pea-maize by 42 and 33%, respectively.

On the other hand, N_2 fixed per hectare by pigeon pea (Figure 2A to B) was also significantly higher ($P < 0.05$) in the sole pigeon pea than that by pigeon pea in the pigeon pea-cowpea or pigeon pea-maize intercrops by 47 and 36%, respectively. However, no significant differences were noted in the N_2 fixed by pigeon pea in the pigeon pea-cowpea and pigeon pea-maize intercrops. The $\%N_{dfa}$, in the Lilongwe site (Table 4) was significantly higher ($P < 0.05$) in the sole pigeon pea by 17 and 12%, respectively, than that by pigeon pea in the pigeon pea-cowpea and pigeon pea-maize intercrops. Comparison of results on pigeon pea $\%N_{dfa}$ in the pigeon pea-cowpea and pigeon pea-maize intercrops showed no significant differences.

Similar to the Lilongwe site, at the Dowa site, there were significant differences ($P < 0.05$) in the N_2 fixed for both per plant (Table 4) and per hectare basis (Figure 2A to B). Sole cropped pigeon pea N_2 fixed per plant was significantly higher ($P < 0.05$) than that by pigeon pea in the pigeon pea-cowpea and pigeon pea-maize intercrops by 27 and 28%, respectively. On the other hand, N_2 fixed

Table 3. Cowpea nodule numbers, dry weights and effectiveness as affected by cropping system at the two study sites.

Parameter	Cropping system	Site	
		Lilongwe	Dowa
Nodule numbers/plant	CP	11	16[a]
	CP+PP	8	12[ab]
	CP+MZ	8	10[b]
	LSD (0.05)	3.99[ns]	5.16
	F pr.	0.256	0.043
	CV %	19.9	18.3
Nodule dry weight (mg/plant)	CP	519.1[a]	711.4[a]
	CP+PP	323.7[b]	492.8[b]
	CP+MZ	330.7[b]	419.9[b]
	LSD (0.05)	73.1	205.8
	F pr.	0.003	0.037
	CV %	8.2	16.8
Nodule effectiveness (%)	CP	83.3	86.7
	CP+PP	76.7	86.7
	CP+MZ	80.0	80.0
	LSD (0.05)	18.5[ns]	17.7[ns]
	F pr.	0.64	0.54
	CV %	10.2	9.3

Means with different letters in the same column are significantly different according to LSD at 5% significant level; ns = non-significant difference; CV = coefficient of variation; F pr. = F probability; PP = pigeon pea; CP = cowpea and MZ = maize; PP+CP = PP intercropped with CP; PP+MZ = PP intercropped with MZ; PP+CP and CP+PP have been used interchangeably in this paper.

per hectare was also significantly higher ($P < 0.05$) in the sole cropped pigeon pea than those by pigeon pea in the pigeon pea-cowpea and pigeon pea-maize intercrops by 31 and 36%, respectively. No significant differences were observed in N_2 fixed by pigeon pea in the pigeon pea-cowpea and pigeon pea-maize intercrops. Furthermore, sole cropped pigeon pea showed significantly higher ($P < 0.05$) $\%N_{dfa}$ than that by pigeon pea in the pigeon pea-cowpea and pigeon pea-maize intercrop, by 10 and 12%, respectively. No significant differences were observed in $\%N_{dfa}$ by pigeon pea in the pigeon pea-cowpea and pigeon pea-maize intercrops.

Quantities of N2 fixed and $\%N_{dfa}$ by cowpea at Lilongwe and Dowa sites

Results of biological nitrogen fixation by cowpea indicate that there were significant differences ($P < 0.05$) in N_2 fixed and $\%N_{dfa}$ as influenced by cropping system. The N_2 content per plant in sole cropped cowpea (Table 4) was significantly higher ($P < 0.05$) than that by cowpea in the intercrops with pigeon pea and maize, by 70% over each of the intercropped cowpea. Furthermore, the $\%N_{dfa}$ by the sole cowpea was significantly higher ($P < 0.05$) than that by cowpea in an intercrop with pigeon pea and with maize by 58 and 61%, respectively. There were no significant differences in N_2 fixed per plant by cowpea in the cowpea-pigeon pea or cowpea-maize intercrops.

On the other hand, results of N_2 fixed by cowpea at the Dowa site show that there were significant differences ($P < 0.05$) as influenced by cropping system (Table 4). Sole cropped cowpea produced significantly higher ($P < 0.05$) plant N content by 48 and 66% than that of cowpea in an intercrop with pigeon pea or maize. Furthermore, the $\%N_{dfa}$ by sole cowpea was also significantly higher ($P < 0.05$) than that by cowpea in the cowpea-pigeon pea and cowpea-maize intercrops, by 46 and 57%, respectively (Table 4). Similar trends were observed on both per plant basis (Table 4) and per hectare basis (Figure 2C to D).

Total biologically fixed N for the different overall cropping systems

The cropping systems included sole crops, legume-

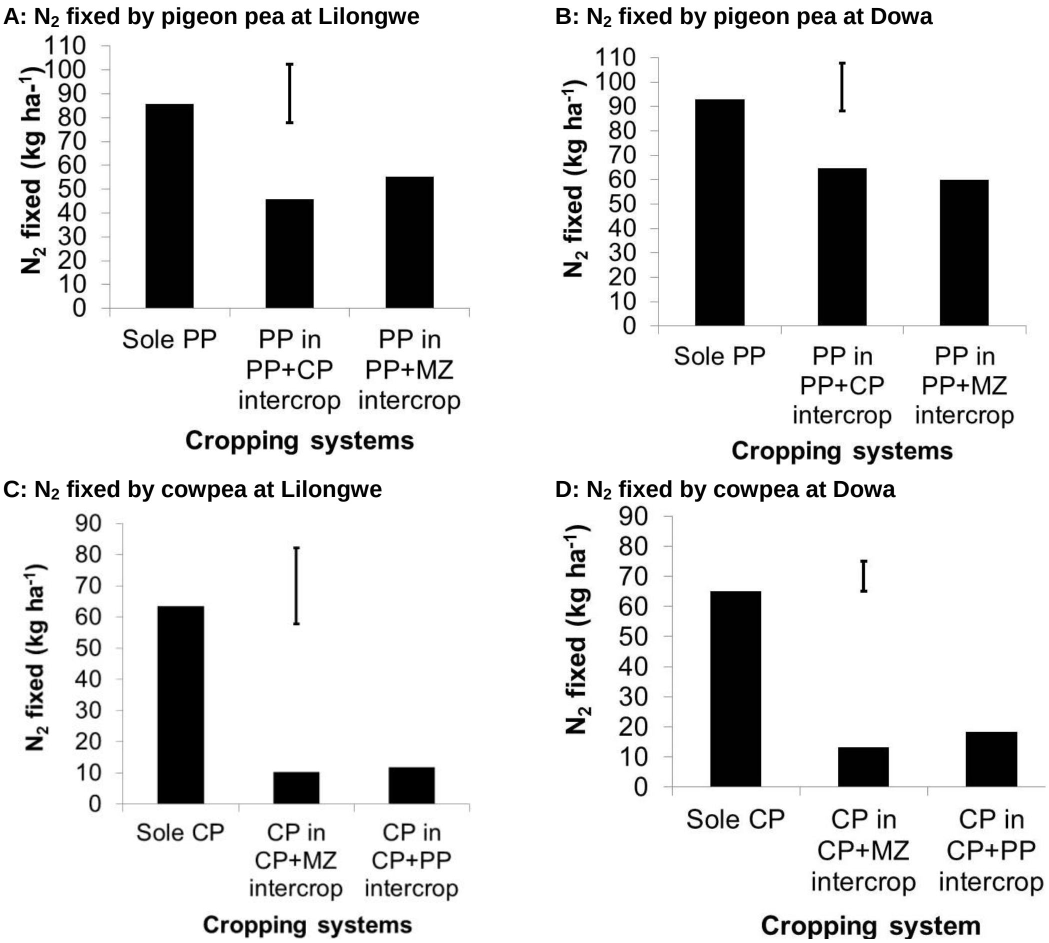

Figure 2. Quantities of N_2 biologically fixed by pigeon pea and cowpea grown in different cropping systems at Lilongwe and Dowa sites. PP = pigeon pea; CP = cowpea and Mz = maize; PP+CP = PP intercropped with CP; PP+MZ = PP intercropped with MZ; PP+CP and CP+PP have been used interchangeably in this paper; covariate analysis was done on the cowpea N_2 fixed; the inserted vertical bar within each graph represents the LSD.

legume and cereal-legume combinations. The legume-legume plot was the same size as others while it contained two plant species that were biologically contributing nitrogen to the system. Therefore, this section shows comparisons where the amount of nitrogen fixed by a doubled-up cropping system is the summation of the N_2 fixed from the component crops, that is pigeon pea and cowpea added together. Results show significant differences (P<0.05) as influenced by cropping system (Figure 3A to B).

Sole cropped pigeon pea had the highest amount of N_2 fixed at both study sites. At the Dowa site, sole cropped pigeon pea produced 30, 36 and 86% higher amounts of biologically fixed N than those by the sole cropped cowpea, pigeon pea-maize and cowpea-maize intercrops, respectively. Similarly, the sum of N_2 fixed by pigeon pea and cowpea in the "doubled-up" system was comparable to that of the sole cropped pigeon pea. The total sum of the amounts of N_2 fixed by pigeon pea-cowpea intercrop at the Dowa site was 21, 28 and 84% more than the biologically fixed N contributed by the sole cropped cowpea, pigeon pea-maize and cowpea-maize intercrops, respectively.

Similarly, at the Lilongwe site, sole cropped pigeon pea produced the highest amount of N_2 fixed. However, it was not significantly higher than that by sole cropped cowpea but was significantly higher than the total sum of the amounts of N_2 fixed by the pigeon pea-cowpea "doubled-up", by 33%. On the other hand the pigeon pea-cowpea "double-up" N_2 fixed was not significantly different from

Table 4. Pigeon pea and cowpea biological nitrogen fixation and Ndfa as affected by cropping system at the two study sites.

Crop	Cropping system	Lilongwe site		Dowa site	
		N_2 fixed/plant (g)	N_{dfa} (%)	N_2 fixed/plant (g)	N_{dfa} (%)
PP	PP	1.90[a]	75.7[a]	2.61[a]	76.0[a]
	PP+CP	1.11[b]	62.6[b]	1.91[b]	68.7[b]
	PP+MZ	1.27[b]	66.6[b]	1.89[b]	66.7[b]
	LSD (0.05)	0.59	7.34	0.59	6.49
	F pr.	0.042	0.018	0.044	0.036
	CV (%)	15.1	4.7	12.1	4.1
CP	CP	0.48[a]	69.4[a]	0.50[a]	68.8[a]
	CP+PP	0.14[b]	28.7[b]	0.27[b]	37.3[b]
	CP+MZ	0.14[b]	27.2[b]	0.17[b]	29.5[b]
	LSD	0.22	19.9	0.13	14.1
	F pr.	0.021	0.007	0.005	0.003
	CV (%)	38.7	21	17.9	13.8

Means with different letters in the same column are significantly different according to LSD at 5% significant level; ns = non-significant difference; F pr. = F probability; PP = pigeon pea; CP = cowpea and MZ = maize; PP+CP = PP intercropped with CP; PP+MZ = PP intercropped with MZ; PP+CP and CP+PP have been used interchangeably in this paper.

those in the sole cropped cowpea or pigeon-pea maize intercrop but was significantly higher ($P < 0.05$) than that of the cowpea-maize intercrop, by 82%.

DISCUSSION

Growth, nodulation and biological nitrogen fixation of legume plants are influenced by many factors including soil temperature, soil reaction, essential macro- and micro-nutrients, presence of effective microbial symbionts and cropping systems (Giller, 2001; Mohammadi et al., 2012). In this study, cropping system effects have been consistent in most of the parameters determined and statistical differences in nodulation and N_2 fixed of both cowpea and pigeon pea have to some extent been influenced by the conditions of the sites where these crops were grown. The significantly higher pigeon pea nodule numbers, nodule weights, N_2 fixed and $\%N_{dfa}$ in sole cropping than in the intercrops as observed in this study could be attributed to a number of factors such as inter-specific competition between the two plant species for nutrients, light or moisture. Pigeon pea that was intercropped with maize or cowpea faced competition for growth resources including nutrients. Ghosh et al. (2006) reported reduction in relative nitrogen yields in pigeon pea when intercropped with soybean, which was attributed to competition for N, whereas Katayama et al. (1995) in a similar study in a shallow Alfisol in India reported reduction in $\%N_{dfa}$ when pigeon pea was intercropped with various crops including cowpea. Pigeon pea reduction in growth and N_2 fixation as influenced by intercropping with various crops such as maize, soybean, groundnuts or sorghum has been reported in a number of similar studies (Egbe, 2007; Mhango, 2011; Njira et al., 2012: Egbe et al., 2015).

Long and medium duration pigeon pea varieties are known for their slow growth that gives the crop a good quality for intercropping as it allows the companion crop to grow and reach maturity before pigeon pea completes its life cycle. This characteristic makes it susceptible to inter-specific competition depending on planting pattern and the type of companion crop. In this study the companion crops, cowpea and maize, all have shorter and faster growth habits than pigeon pea, which can offer stiff competition to pigeon pea in the early growth stages. Mangla et al. (2011) noted that slow growers are out-competed when faced with inter-specific competition for nutrients such as N. Similarly, cowpea indicated significant reduction in number of nodules, N_2 fixed and $\%N_{dfa}$ in intercrops with pigeon pea or maize which can be attributed to competition for growth resources. Similar observations have been reported in a number of other studies. Van Kassel and Roskoski (1998) reported stiff competition in a cowpea-maize intercrop where the intercropped maize took twice as much N as the cowpea as compared to similar amounts that were taken up in sole crops. However, Katayama et al. (1995) observed no significant differences in $\%N_{dfa}$ by cowpea in sole cropping and in an intercrop with pigeon pea which was

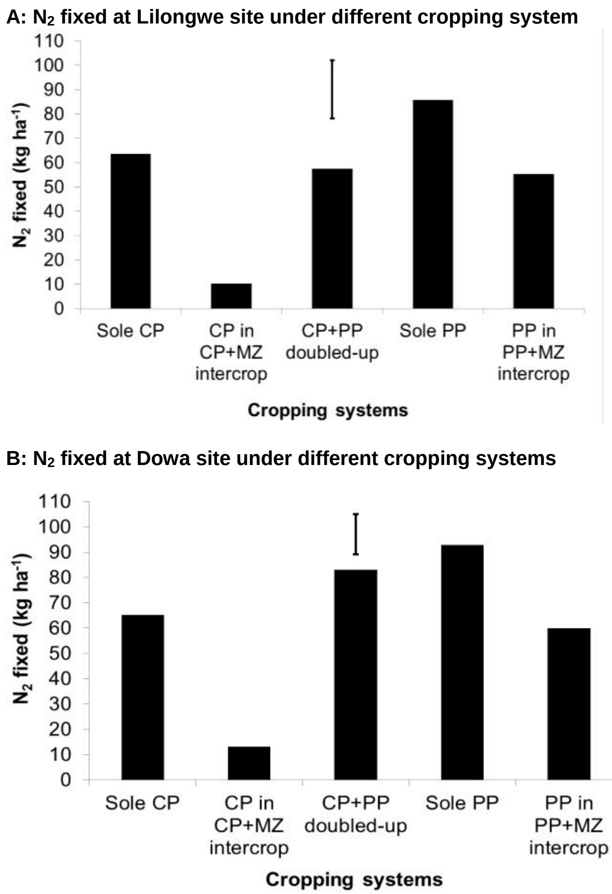

Figure 3. Total amounts of biologically fixed nitrogen (kg N ha^{-1}) contributed by the legume components. The amount of biologically fixed nitrogen in the CP+PP "doubled-up" is the sum of N_2 fixed by each of the PP and CP components. The inserted vertical bar within each graph represents the LSD; PP = pigeon pea; CP = cowpea and Mz = maize; PP+CP = PP intercropped with CP; PP+MZ = PP intercropped with MZ; PP+CP and CP+PP have been used interchangeably in this paper.

attributed to the indeterminate, spreading and climbing nature of the cowpea variety used in that experiment which gave it an advantage in exploiting resources. The present study has shown that the overall contribution of N per unit area by a cropping system with consideration of both component crops in the pigeon pea-cowpea intercrop (summing up their biologically fixed N) depended on both the system and to some extent the site effects. The Dowa site indicated comparably high amounts of N_2 fixed (kg N ha^{-1}) in the sole pigeon pea and pigeon pea-cowpea doubled-up, but in the Lilongwe site the doubled-up system showed significant reduction in the overall N_2 fixed in the doubled-up. This shows some dynamics in how cropping systems may impact the performance of the crops in different environments. As to the sites under this study, phosphorus, which is needed much in BNF, was above critical values in the 0 - 20 cm depth at both sites. However, N and soil organic matter levels for Lilongwe soils were low whereas Dowa site showed medium N level and high organic matter levels based on ratings by Landon (1991).

High amounts of N in the soil are reported to suppress BNF through reduction of nitrogenase activity, especially when nitrates are perpetually in high amounts (Havlin et al., 2005). However, small additional sources or starter amounts of N have been reported to enhance BNF in legumes where soils are low in N (Mulongoy, 1995; Adu-Gyamfi et al., 1997; Ahmed et al., 2014). In this study, additional N application was not considered because of the sensitivity of the N-difference method (Danso et al., 1992). On the other hand, in a number of studies, increase in soil organic matter has been associated with increased BNF. Increased nodulation and BNF due to increase in soil organic matter has been reported in soybean (Lawson et al., 1995; Coskan and Dogan, 2011; Hayat et al., 2012). Similarly, in this study, N level and the higher organic matter levels for Dowa could have contributed to the increase in nodulation and BNF of cowpea and pigeon pea. Mangla et al. (2011) reported reduction in the effects of inter-specific competition when N was increased to an intercropping system of two different plant species. On the other hand, soil organic matter has many functions in the soil including acting as a soil nutrient supply and reserve for metabolically active microbial community, increasing water holding capacity and enhancing chelation and bioavailability of micronutrients (Sylvia et al., 2005; Brady and Weil, 2008). All these factors are very important in the N_2 fixation process as they enhance the healthy growth of both the legume plant and the microbial symbionts.

Conclusions

From this study it can be concluded that both cropping systems and site of the study had an influence on nodulation, $\%N_{dfa}$ and the total amount of N_2 fixed by the two legume species in the different cropping systems. At the Dowa site, sole cropped pigeon pea produced the highest amount of biologically fixed N (92.9 kg ha^{-1}), which was significantly higher than that by the pigeon pea in both the pigeon pea-cowpea and pigeon pea-maize intercrops by 31 and 36%, respectively. On the other hand, comparison of the overall cropping system contribution per unit area, the total sum of the amounts of biologically fixed N (82.9 kg ha^{-1}) from two component crops in the pigeon pea-cowpea "doubled-up" was comparable to that by the sole cropped pigeon pea but was significantly higher than the amounts of N_2 fixed by sole cowpea (62.5 kg N ha^{-1}), pigeon pea in the pigeon pea-maize intercrop (59.9 kg N ha^{-1}) or cowpea in the cowpea-maize intercrop (13.1 kg N ha^{-1}). However, the trend was different at the Lilongwe site. Although the biologically fixed N (85.7 kg ha^{-1}) by the sole cropped pigeon pea was similarly the highest, the total sum of the amounts of N_2 fixed (57.4 kg N ha^{-1}) by the component crops in the pigeon pea-cowpea "doubled-up" was significantly lower than that by the sole pigeon pea, by 33%. In this study it was noted that competition for resources due to type of cropping system and differences in environmental factors can be important factors influencing the performance of legume components in legume-legume, legume-cereal and sole cropped legume systems. Therefore, implementation of cropping systems that integrate legumes should follow a thorough evaluation of site-specific soil and other environmental conditions.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Abbreviations

AFNETA, Alley Farming Network for Tropical Africa; **ICRISAT,** International Crops Research Institute for Semi-Arid Tropics; **MAI,** Ministry of Agriculture and Irrigation; **MoAFS,** Minitry of Agriculture and Food Security; **SSSA,** Soil Science Society of America.

REFERENCES

Adu-Gyamfi JJ, Ito O (1997). Nitrogen management in sorghum/pigeonpea intercrop. In: Extending nitrogen fixation research to farmers' fields: Proceedings of an International Workshop on Managing Legume Nitrogen Fixation in the Cropping Systems of Asia, 20-24 August 1996, ICRISAT Asia Center, Patancheru, Andhra Pradesh, India pp. 3-15.

Ahmed AE, Mukhtar NO, Babiker HM, Adam AI (2014). Effect of nitrogen fertilization and *Bradyrhizobium* inoculation on the growth, symbiotic properties and yield of pigeon peas. J. Nat. Resourc. Environ. Stud. 3:27-31.

Ajayi OC, Akinifesi FK, Sileshi G, Chakeredza S (2007). Adoption of soil fertility replenishment technologies in southern Africa: Lessons learnt and the way forward. Nat. Resourc. Forum 31:306-317.

Alliance for Green Revolution in Africa (2014). Africa Agriculture Status Report: Climate Change and Smallholder Agriculture in Sub-Saharan Africa, Nairobi, Kenya.

Anderson JM, Ingram JSI (1989). Tropical Soil Biology and Fertility: A Handbook of Methods of Analysis. Commonwealth for Agriculture Bureau International, Wallingford, UK.

Anderson JM, Ingraham JSI (1993). Tropical Soil Biology and Fertility: A Handbook of Methods. 2nd ed. Commonwealth for Agriculture Bureau International, Wallingford, UK.

Berrada H, Fikri-Benbrahim K (2014). Taxonomy of rhizobia: current perspectives. Brit. Microbiol. Res. J. 4(6):616-639.

Bouyoucos GJ (1962). Hydrometer method improved for making particle size analyses of soils. Agron. J. 54(5):464-465.

Brady NC, Weil RR (2008). The Nature and Properties of Soils. Revised 14th Ed., Pearson Prentice Hall, New Jersey, USA.

Bremner JM, Mulvaney CS (1982). Nitrogen total. In: Page, A. (ed). Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties. ASA and SSSA. Madison, Wisconsin pp. 595-624.

Chilimba ADC (2007). Methods of Soils, Plants, Fertilizers and Misclaneous Analyses: A Working Manual for Chitedze and Bvumbwe Research Stations Soils Laboratories. Ministry of Agriculture. Lilongwe, Malawi.

Chilimba ADC, Young, SD Black CR, Rogerson KB, Ander EL, Watts MJ, Lammel, J Broadly MR (2011). Maize grain and soil surveys reveal suboptimal dietary selenium intake is widespread in Malawi. Scientific Reports 1:72.

Coskan A, Dogan K (2011). Symbiotic nitrogen fixation in soybean, soybean physiology and biochemistry. http://www.intechopen.com/books/soybean-physiology-andiochemis try/ symb iotic-nitrogen-fixation-insoybean

Danso SKA, Bowen GD, Sanginga N (1992). Biological nitrogen fixation in trees in agroecosystems. In: Ladha JK, George T, Bohlool BB (eds). Biological Nitrogen Fixation for Sustainable Agriculture. Kluwer Academic Publishers. Dordrecht pp. 177-196.

Druille Z, Barreto-Hurle J (2012). Fertilizer subsidies in sub-Saharan Africa. Agricultural Development and Economics Working Paper No. 4. Food and Agriculture Organization, Rome.

Egbe MO, Ibrahim NB, Aor FT (2015). Effect of low rates of nitrogen and phophorus fertilizers on growth and yield of intercropped pigeonpea with sorghum in Makurdi, Nigeria. J. Biol. Agric. Health. 5(8):156-162.

Egbe OM (2007). Assessment of biological nitrogen fixation potential of pigeon pea genotypes intercropped with sorghum for soil fertility improvement in Southern Guinea Savanna of Nigeria. J. Agric. Food Environ. Ext. 6(1):33-45.

Ghosh PK, Mohanty M, Bandayopadhy KK, Painuli DK, Misra AK (2006). Growth, competition, yields advantage and economics in soybean/pigeon pea Intercropping system in semi-arid tropics of India II. Effect of nutrient management. Field Crops Res. 96:90-97.

Gomez KA, Gomez AA (1984). Statistical Procedures for Agricultural Research. 2nded. John Wiley and Sons, New York. USA.

Havlin JL, Beaton JD, Tisdale SL, Nelson WL (2005). Soil Fertility and Fertilizers: An Introduction to Nutrient Management. 7thed., Pearson Prentice Hall, New Jersey, USA.

Hayat R, Iftikhar-ul-Hassan M, Akram S, Sheirdill RA, Ahmad M (2012).

Evaluation of compost application for improving legumes yield and N_2-fixation. Afr. J. Biotechnol. 11(41):9758-9764.

International Crops Research Institute for Semi-Arid Tropics/Ministry of Agriculture and Irrigation–ICRISAT/MAI (2000). Cost-effective Soil Fertility Options for Smallholder Farmers in Malawi. ICRISAT, Bulawayo, Zimbabwe.

Katayama K, Ito O, Matsunanga R, Adu-Gyamfi JJ, Rao TP, Anders MM, Lee KK (1995). Nitrogen balance and root behaviour in four pigeon pea intercropping systems. Fert. Res. 42:315-319.

Kumwenda JDT, Waddington S, Snapp SS, Jones RB, Blackie MJ (1997). Soil fertility management in smallholder maize-based cropping systems of Eastern and Southern Africa: In: Ficher C (ed). The Emerging Maize Revolution. Michigan State University, USA pp. 153-172.

Landon JR (ed) (1991) Booker Tropical Soil Manual. A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics. John Wiley and Sons, Inc., New York, USA.

Lawson IYD, Muramatsu K Nioh I (1995). Effect of organic matter on growth, nodulation and nitrogen fixation of soybean growth under acid and saline conditions. Soil Sci. Plant Nutr. 41(4):724-728.

Makumba W (2003). Nitrogen use efficiency and carbon sequestration in legume tree-based agroforestry system: A case study of Malawi. PhD Thesis. Wageningen University, The Netherlands.

Mangla S, Sheley RL, James JJ, Radosevich SR (2011). Intra and interspecific competition among invasive and native species during early stages of plant growth. Plant Ecol. 212:531-542.

Mehlich A (1984). Mehlich 3 soil test extractant: A modification of Mehlich 2 extractant. Commun. Soil Sci. Plant Anal. 15(12):1409-1416.

Mhango WG (2011). Nitrogen budgets in legume based cropping systems in Northern Malawi. PhD Thesis. Michigan State University, USA.

Mhango WG, Snapp SS, Kanyama-Phiri GY (2012). Opportunities and constraints to legume diversification for sustainable maize production on smallholder farms in Malawi. Ren. Agric. Food Syst. 28:234-244.

Ministry of Agriculture and Food Security (MoAFS) (2012). Guide to Agricultural Production and Natural Resource Management in Malawi. Agricultural Communications Branch, Lilongwe, Malawi.

Mloza-Banda HR (1994). Principles and Practices of Crop Management: Field Study Guide. Crop Science Department, Bunda College of Agriculture, Malawi.

Mulongoy K (1992). Technical paper 2: Biological nitrogen fixation. The AFNETA Alley Farming Training Manual Volume. Alley Farming Network for Tropical Africa. http://www.fao.org/wairdocs/ILRI/x5546E/x5546e05.htm

Mutegi J, Kabambe V, Zingore S, Harawa R, Wairegi L (2015). The Fertilizer Reccomendation Issues in Malawi: Gaps, Challenges, Opportunities and Guidelines. Soil Health Consortium, Malawi.

Nelson DW, Sommers LE (1996). Total carbon and organic matter. In: Sparks DL (ed). Methods of Soil Analysis. Part 3. Chemical Methods. SSSA Book Series No. 51. Soil Science Society of America, Madison, Wisconsin, USA pp. 961-1010.

Ngwira AR, Kabambe VH, Kambauwa G, Mhango WG, Mwale CD, (2012). Scaling out best fit legume technologies for soil fertility enhancement among smallholder farmers in Malawi. Afr. J. Agric. Res. 7(6):918-228.

Nielsen RB (2010). A practical guide to on-farm research. Purdue University Department of Agronomy. http://www.kingcorn.org/news/timeless/On FarmResearch.pdf

Njira KOW, Nalivata PC, Kanyama-Phiri GY, Lowole MW. (2012). Biological nitrogen fixation in sole and doubled-up legume cropping systems in the sandy soils of Kasungu, Central Malawi. J. Soil Sci. Manage. 3(9):224-230.

Palm CA, Myers RJK, Nandwa SM (1997). Combined use of organic and inorganic nutrient sources for soil fertility maintenance and replenishment. In: Buresh RJ, Sanchez PA,Calhoun F (eds). Replenishing Soil Fertility in Africa. SSSA Special Publication Number 51. Soil Science Society of America, Madison, Wisconsin pp. 151-192.

Peoples MB, Faizah AW, Rerkasem B, Herritedge DF (1989). Methods for Evaluating Nitrogen Fixation by Nodulating Legumes in the Field. Australian Centre for International Agriculture Research, Canberra.

Phiri AT, Mhango WG, Njoloma JP, Kanyama-Phiri GY, Lowole MW (2012). Farmers evaluation of integrated soil fertility management methods in Northern Kasungu, Central Malawi. J. Agric. Ext. Rural Dev. 4(11):340-346.

Phiri AT, Msaky JJ, Mrema J, Kanyama-Phiri GY, Msanya BM (2014). Effect of pigeon pea-groundnut intercropping system on selected soil properties. IJPSS. 3(4):397-407.

Reynolds TW, Waddington SR, Anderson CL, Chew A, True Z, Cullen A (2015). Environmental impacts and constraints associated with the production of major food crops in sub-Saharan Africa and South Asia. Food Sec. 7:795-822.

Snapp SS, Jayne TS, Mhango W, Benson T Ricker-Gilbert J (2014). Maize yield response to nitrogen in Malawi's smallholder production systems. Paper Prepared for The National Symposium Eight Years of FISP- Impact and What Next? Bingu International Conference Centre, Lilongwe 14 – 15 July 2014 pp. 1-22.

Sylvia DM, Furhmann JJ, Hartel PG, Zuberer DA (2005). Principles and Application of Soil Mmicrobiology. 2ndedition, Pearson Prentice Hall, New Jersey. USA.

Thomas GW (1996). Soil pH and soil acidity. In: Sparks DL (ed). Methods of Soil Analysis. Part 3. Chemical Methods. SSSA Book Series No. 5. Soil Science Society of America, Madison, Wisconsin, pp. 475-490.

Van Kassel C, Roskoski JP (1988). Row spacing effects on N_2-fixation, N-yield and soil N uptake of intercropped cowpea and maize. Plant Soil 111:11-23.

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