AMHARA REGIONAL AGRICULTURAL RESEARCH INSTITUTE (ARARI)

Proceedings of the 7th and 8th Annual Regional Conferences on Completed Research Activities on Soil and Water Management Research, 25 – 31, January, 2013 and 13 – 20, February, 2014, Bahir Dar, Ethiopia

Editor

Tesfaye Feyisa

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Editor

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Soil Test Based Phosphorus Fertilizer Recommendation Equation for Bread Wheat (*Triticum aestivum* L) for North Gonder highlands

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Abstract

Soil test based fertilizer recommendation plays a vital role in ensuring balanced nutrition to crops and fertilizer schedules on the magnitude of crop response to applied nutrients at different soil fertility level. An experiment was conducted in north Gondar Zone, Ethiopia on soil test based phosphorus response to see the response of bread wheat. In the first phase of the experiment, determination of the optimum rate of P_2O_5 kg ha^{-1} was done keeping nitrogen fertilizer constant at 92 kg ha^{-1}. The experiment contains five treatments arranged in Randomized Complete Block Design with three replications. Five rates of phosphorous fertilizer (0, 46, 92, 138 and 184 P_2O_5 kg ha^{-1}) with the agronomic recommendation of Nitrogen fertilizer (92 N kg ha^{-1}) were used. In the second phase of the experiment, verification of soil test based P fertilizer recommendation equation model was tested on 10 m by 10 m plots. One plot for agronomic fertilizer recommendation and the other plot for the calibrated fertilizer recommendation. The results of the experiment showed that the equation was proven and verified that it can estimate the phosphorus fertilizer requirement of wheat in the highlands of North Gondar.

Key words: Nitrogen, Phosphorous, soil test, bread wheat, verification

Introduction

Ethiopia is the second largest wheat producer in sub-Saharan Africa, after South Africa. Wheat is mainly grown in the highlands, planted in the summer before the main rainy season, and harvested in October-November. Wheat is one of the major cereal crops in the Ethiopian highlands, which range between 6 and 16°N, 35 and 42°E, and from an altitude of 1500 to 2800 m.a.s.l. Soil types used for wheat production vary from well-drained fertile soils to waterlogged heavy Vertisols.

According to an estimate, the global grain demand would double by the year 2050 (Tilman et al., 2002). Cereal producers are under pressure to increase the yields and maintain their profitability despite several environmental restrictions and escalating fertilizer prices (Semenov *et al*., 2007). Due to inefficient agricultural production system, the yield of most agricultural crops like wheat is far below their demonstrated achievable potential. Numerous factors are responsible for low yields; amongst them improper use of fertilizers is the major one (Aslam *et al*., 2011a).

Proper nutrient management increases soil productivity and helps in sustainable crop production (Dilshad *et al*., 2010; Sarwar *et al*., 2012). Application fertilizer nutrients by the farmer without information on soil fertility status and nutrient requirement by crop affect soil and crop adversely Once existing nutrient levels are established, producers can use the data to best management what nutrients are applied, decide the application rate, and make decisions concerning the profitability of their operations while managing for impacts such as erosion, nutrient runoff, and water quality (Mallarino *et al*., 2000). However, in sub Saharan countries including Ethiopia, over the years blanket fertilizer recommendation have been applied for crops and crop mixtures. A study showed that Blanket recommendation gave a lowest cassava yield over soil test based recommendation (Fondufe, *et al*., 2001).

Modern soil testing was developed in the 1940s, and improvements in, and the use of, soil testing have increased in contemporary times (Watson and Mullen, 2007). Soil tests are developed to help producers predict their soil's available nutrient status in relation to crop production and fertilizer management program. Soil test based fertilizer recommendation plays a vital role in ensuring balanced nutrition to crops and fertilizer schedules should therefore be based on the magnitude of crop response to applied nutrients at different soil fertility level. Based on this concept, soil test based phosphorus response studies were undertaken in North Gondar zone, Ethiopia.

Materials and Methods

Geographic Location of the study Area

The study area is located in the Amhara National Regional State, in North Gondar zone at Dabat and Debark Woredas. The altitude of the experimental site of Dabat and Debark are 2580 m and 2770 m above mean sea level, respectively. It is located between 37.77'and 37.9' longitude 12.98' and 13.19' latitude, respectively. The maximum temperature of the areas was about 24.5 °C and 23.1°C. While the minimum temperature was about 4.6°C and 3.7, respectively. The mean annual rainfall in the area is about 1254 and 1231 mm, respectively.

Experimental design and procedures

The study was conducted in 2010–2012 cropping seasons on farmers' field in two phases.

Phase 1:

In the first phase of the experiment, determination of the optimum rate of P_2O_5 kg ha^{-1} was done. The experiment contains five treatments arranged in Randomized Complete Block Design with three replications. Five rate of phosphorous fertilizer (0, 46, 92, 138 and 184 P_2O_5 kg ha^{-1}) with the agronomic recommendation of Nitrogen fertilizer (92 N kg ha^{-1}) were used. Triple Super Phosphate (TSP), Di-ammonium phosphate (DAP) and Urea fertilizers were used as fertilizer source to supply phosphorous (P) and nitrogen (N). Split application of equal amount of nitrogen fertilizer was given to all plots. The gross plot size was 16 m^2 net plot size was 9 m^2. Improved bread wheat variety (TAY) was used with seed rate 125 kg ha^{-1} and planted in rows. Plots were kept weed free by hand weeding. All other agronomic practices were applied. Composite soil samples were collected before planting.

Soil Sampling and Analysis

Prior to planting surface (0 - 40 cm) soil samples, from five spots across the experimental field were collected to know the initial soil status of the soil. After three weeks from the day of planting and phosphorus fertilizer application, soil samples were collected from each treatment plot by replication for determination of available P. The soil samples were air dried, thoroughly mixed and grounded to pass 2 mm sieve to determine necessary soil physical and chemicals parameters. Available P was extracted with sodium bicarbonate solution at pH 8.5 following the procedure described by Olsen et al. (1954). Total nitrogen was determined by the micro-Kjeldahl digestion, distillation and titration method as described by Jackson (1958). Soil pH was measured potentiometrically in the supernatant suspension of a 1:2.5 soil:water mixture using a pH meter according to method outlined by Sahlemedhin and Taye (2000). Organic carbon was determined following the Walkley and Black wet oxidation method as described by Jackson (1958). The soil CEC was determined at pH 7 after displacement of the cations by using 1 N ammonium acetate; thereafter, the ammonium was estimated titrimetrically by distillation of ammonium that was displaced by sodium following the procedure of Sahlemedhin and Taye (2000). Total exchangeable bases were determined after leaching the soils with ammonium acetate; Ca^{2+} and Mg^{2+} in the leachate were analyzed by atomic absorption spectrophotometer and K^+ and Na^+ were analyzed flame photometrically following the procedure of Sahlemedhin and Taye (2000).

Yield and yield related data

Data were collected on plant height, effective tiller per plant, grain yield and stover yield. Randomly chosen ten plants per row, which were assumed representative for the plot excluding boarder plants, were taken to determine plant height just at harvesting time. Plant height was recorded in each of the central rows by measuring the height from the ground to the tip of the panicle. Similarly, ten randomly selected plants in the plot were taken to count the effective tiller per plant at maturity. Stover yield were determined by weighing after cutting the plants just at the surface of the soil and after air-drying. Observations made during crop growth were used to explain the results.

Determination of Critical P levels

The Cate-Nelson graphical technique (Cate and Nelson, 1965) was used to determine the P critical level. It was determined from the relationship between relative yields (which is this yield x (100/ maximum yield)) and soil test P values of each replication. The maximum yield was taken from each site and for every replication to determine the relative yield.

Determination of P Requirement Factor

P requirement factor is the measure of the quantity of P nutrient per hectare required to raise the soil P level measured by selected P availability indices by 1 mg kg^{-1} (ppm).This was calculated from the difference between available P values in soil samples of the control plots and the plots that received fertilizer as indicated in Table 1.

Table1 P requirement factor

P fertilizer treatment (P_2O_5 kg ha^{-1})	Olsen and Bray II P levels after incubation (mg kg^{-1})	P level increase over the control by Olsen and Bray II methods (mg kg^{-1})	P requirement factor (Pf)
0	A	-	-
46	B	b-a	46/ (b-a)
92	C	c-a	92/ (c-a)
138	D	d-a	138/ (d-a)
184	E	e-a	184/ (e-a)
Mean	-	[(b-a)+ (c-a) + (d-a) + (e-a)]/4	[(46/(b-a))+ (92/(c-a)) + (138/(d-a)) + (184/(e-a))]/4

Developing the Equation

To develop the equation for calculating the P fertilizer requirement, three parameters were required. They were P critical level (P_c), Soil test value of P (P_0) and P requirement factor (P_f). P_c was determined from the Cate-Nelson graph, P_0 was the measurement of soil P and P_f is calculated according to Table 1. Therefore, P fertilizer requirement (P_r) was the amount of P required to raise the soil P from the existing level to the critical level. It was calculated by the formula:

$$P_r = (P_c - P_0) * P_f$$

Where P_r = P fertilizer requirement (kg ha^{-1})

P_c = Critical P level by Olsen or Bray=II methods (mg kg^{-1})

P_0 = Soil test value of P of the field (mg kg^{-1})

P_f = P requirement factor determined by the experiment

Phase 2:

The second phase of the experiment was verification of soil test based P fertilizer recommendation equation model. Bi-plot (10 m * 10 m) experimental area was used. One plot for agronomic fertilizer recommendation and the other plot was the calibrated fertilizer recommendation. Bread wheat response data from field experiments conducted in 2012 were used in the present investigation. Soil and fertilizer nutrient efficiencies for the amount of fertilizer required for specified bread wheat yield targets were computed from this data by two procedures, agronomic recommendation and calibrated recommendation using Cate-Nelson graphic technique.

Agronomic fertilizer recommendation was obtained in the first phase of this experiment which was 92 kg P_2O_5 ha^{-1} whereas the calibrated fertilizer recommendation was obtained based on the results of soil test P in the laboratory soil analysis.

Soil Sampling and analysis

Composite soil samples were collected for laboratory chemical analysis at the depth of 0-30cm from each field before planting and soil analysis for available P was done at Gondar Soil testing laboratory. The results of available P were calculated from the equation using the equation obtained from the model.

$$P_r = (P_c - P_0) * P_f$$

Statistical Analysis

The collected data was analyzed using SAS software (SAS V9.0, SAS Institute Inc., Cary, NC, USA). Whenever significant differences between treatments are detected, mean separation was done using least significant difference (LSD).

Results and Discussions

Physical and chemical Properties of the Soil

The analytical results indicated that the experimental soil was low in its organic matter content according to Landon (1991) ratings (> 20 % very high, 10-20 % high, 4-10 % medium, 2-4 % low and < 2 % very low) (Table 2). The low organic matter content of the soils in Ethiopian highlands has been attributed to factors such as sever soil erosion, continuous cultivation, frequent and complete removal of farm residues commonly carried out by farmers in the area which tends to destroy much of the organic materials that could have been added to the soil. The CEC of the soil was 58.18 $cmol_c\ kg^{-1}$ which is very high (Landon, 1991). According to Olsen *et al.* (1954) P rating (mg kg^{-1}), the available P content of < 3 is very low, 4 to 7 is low, 8 to 11 is medium, and > 11 is high. Thus, available P content the experimental site of is low to medium. The pH of the soil was 6.13, which is suitable for wheat production (Landon, 1991).

Table 2 Initial status of soil chemical properties of experimental site

Parameters	Soil analysis results
pH	6.13
Available P (ppm)	3.2- 8.98
Organic matter (%)	1.42
CEC cmol(+)kg^{-1}	58.16
Exchangeable Ca, cmol(+)kg^{-1}	41.52
Exchangeable Mg, cmol(+)kg^{-1}	25.19
Exchangeable k, cmol(+)kg^{-1}	2.21
Exchangeable Na, cmol(+)kg^{-1}	0.31

Phase 1:

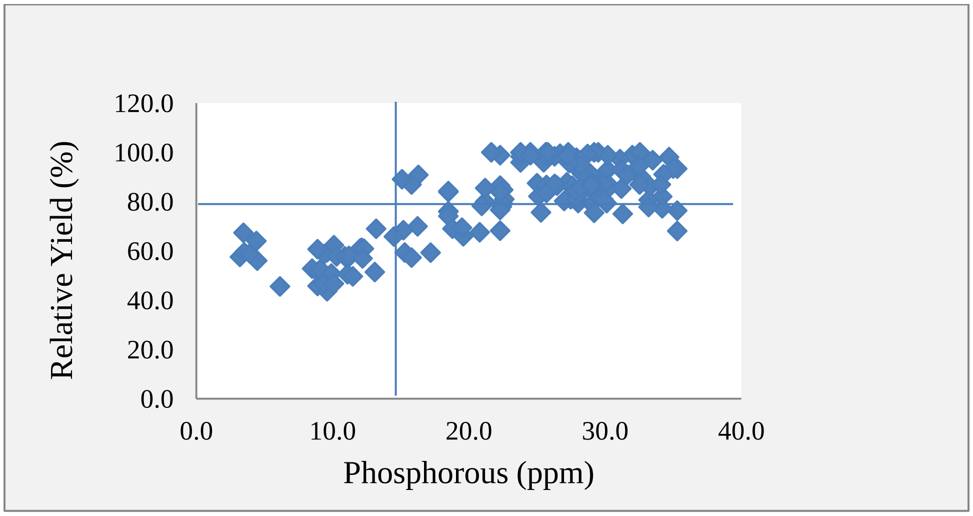
The results of the combined analysis showed that there was highly statistically significant difference (p <0.01) among the treatments (Table 3). Plant height, tiller number, biomass yield and grain yield were significantly (P <0.01) influenced by the rates of phosphorous fertilizer application. 92 kg ha^{-1} P_2O_5 with 92 kg ha^{-1} nitrogen fertilizer gave the highest grain yield whereas the lowest grain yield was obtained from 0 kg ha^{-1} P_2O_5 with 92 kg ha^{-1} nitrogen fertilizer rate.

Table 3 Soil test based phosphorous fertilizer with N against bread wheat yield, North Gondar

Treatments					
P_2O_5 (kg ha^{-1})	N(kg ha^{-1})	Plant height (cm)	tiller number	Biomass yield (kg/ha)	Yield (kg/ha)
0	92	96.7[c]	4.5[b]	7638.8[c]	2295.3[d]
46	92	98.4[b]	4.9[ab]	8535.4[b]	3102.1[c]
92	92	99.3[a]	5.2[a]	9218.9[a]	3864.3[a]
138	92	99.0[ab]	5.2[a]	9259.6[a]	3600.8[b]
184	92	99.4[a]	4.9[ab]	9643.7[a]	3429.0[b]
CV (%)		2.7	6.2	11.4	12.2
LSD (0.05)		0.86	0.55	515.23	208.45

Determination of the critical soil P Concentration

Based on the Cate-Nelson graphic technique (Graph 1) the critical soil P concentration, beyond which applied P fertilizer becomes non-responsive, was identified at 15.8 mg kg^{-1} (ppm). Different researches reported different critical P values. SPAC (1992) reported that 12 mg kg^{-1} was the critical P limit above which plants do not respond to applied P. Taye *et al*, (2000) also reported 10 mg kg^{-1} to be critical Olson P level for wheat in soils of Hetosa district, Ethiopia. Similarlry, Yihenew (2003) reported that 11 to 14 mg kg^{-1} critical soil P for maize in North Western Ethiopia. The variation in critical soil P concentration values among different soil is an indication that the soil plant relationship is governed by various physical and chemical characteristics of soils besides to the indigenous P availability in the soil and the type of crop grown and other conditions. It is apparent in acidic soils that the inherently low P content coupled with high rainfall and high P fixation capacity makes the application of P fertilizer larger amount.



Graph 1. Cate-Nelson graph

Determination of P Requirement Factor:

The results from Table 4 showed that the P requirement factor (P_f) was found to be 5.4 and the critical soil P concentration was 15.8 mg kg^{-1} (ppm). Therefore, the equation becomes:

$$Pr = (15.8 - Po) * 5.4$$

Where

P_r = P fertilizer requirement

P_o = Soil test value of P

Table 4 Determination of P requirement for the high lands of North Gondar

Treatment (P_2O_5 level)	P level after incubation	p increase	Pf
0	8.97	-	-
46	22.02	13.05	3.5
92	26.19	17.22	5.3
138	29.28	20.31	4.7
192	31.46	22.49	8.2
Mean			**5.4**

Phase 2: Verification

Results from the verification of the equation developed on soil test based P fertilizer recommendation for bread wheat showed that the Model gave better estimates of P fertilizer determined by Cate-Nelson graphic technique procedure. The differences in the predicted amounts of P fertilizer and the agronomic fertilizer recommendation were adequate to explain the variation indicating that this approaches can be followed for the amount of phosphorous required for specified yield targets (Figure 1 and 2).

The results in this model estimates the actual situation in the field in respect of the relationship between soil and fertilizer P availabilities and P uptake by the crop providing usefulness of this model for assessing the amount of P required for specified grain yield targets (Figure 1 and 2).

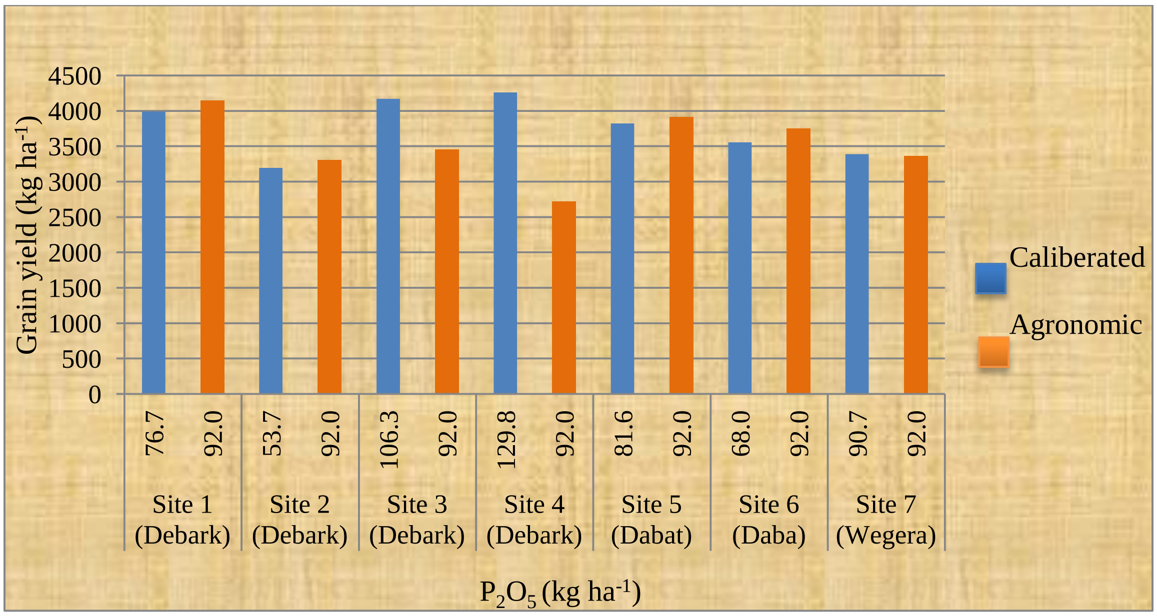


Figure 1. Verification of soil test base phosphorous fertilizer (P_2O_5) recommendation equation for bread wheat grain yield in 2012

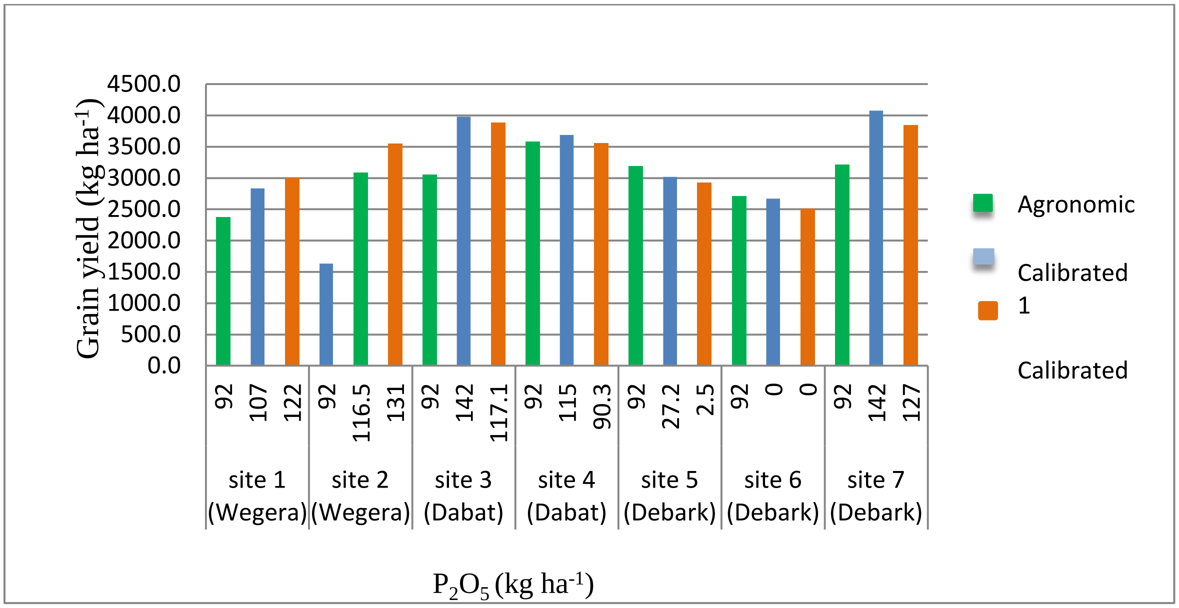


Figure 2. Verification of soil test base phosphorous fertilizer (P_2O_5) recommendation equation for bread wheat grain yield in 2013

Conclusions and Recommendations

The critical soil P concentration beyond which applied fertilizer becomes non-responsive estimated by Cate-Nelson graphic method was 15.8 mg kg^{-1}. Results also showed that the P requirement factor (P_f) was 5.4 and the critical soil P concentration was 15.8 mg kg^{-1} (ppm). Therefore, the equation becomes:

Pr = (15.8-Po)*5.4

This equation can be used for the high lands of North Gondar to determine the optimum P fertilizer recommendation. This recommendation can be further refined, and should result in better allocation of phosphorous fertilizer and major savings to the farmers and agricultural sectors in the region.

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Soil Test Based P-fertilizer Recommendation Equation for Eastern Amhara Region

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Abstract

An on-farm experiment was conducted from 2009 to 2011 in Jamma and Wadla Districts of Eastern Amhara. The purpose of the study was to develop soil-test based P fertilizer recommendations for wheat. The experiment was comprised of 5 rates of P (0, 46, 92, 138 and 184 kg P_2O_5 ha^{-1}) applied three weeks before planting to soils of varying available soil P values. A uniform nitrogen rate of 138 kg ha^{-1} was applied in split to all experimental plots at planting and tillering. Treatments were laid in RCBD with three replications. Soil samples were collected from each plot before P fertilizer application and at planting and were analyzed for Olsen extractable P. The result obtained at both locations in both years showed that there was highly significant ($P \leq 0.01$) difference in grain and biomass yields among the P rates. The soil test results of both locations indicated that there was highly significant ($P \leq 0.01$) difference in available soil P among treatments. The regression analysis of available P with grain and biomass yields combined over years also showed significant ($P \leq 0.05$) quadratic (r=0.54) relation between the grain yield and available soil P at Jamma. While, there was no significant ($P>0.05$) relation between grain yield and available P in both years at Kon. This might be attributed to high P fixation due to acidic soil reaction at Kon. Based on the Cate and Nelson graphical model, the critical soil test P (Pc) at Jamma and Kon was 11.0 mg kg^{-1} and 11.3 mg kg^{-1}, respectively. While, the P requirement factor (Pf) for Jamma and Kon was 13.4 and 35.0, respectively. Finally, the equation developed for P fertilizer recommendation (Pr (kg P_2O_5 ha^{-1})) is (11.0-Po) x 13.4 for Jamma and (11.3-Po) x 35.0 for Kon.

Key words: Cate and Nelson, Critical, Jamma and Kon, Recommendation, Whea

Introduction

Low soil fertility is recognized as an important constraint to increased food production and farm incomes in Ethiopia (Henao and Baanante, 1999; Heluf, 2005). Phosphorus is often one of the most limiting nutrients for crop production in tropical soils. Phosphorus deficiency is particularly widespread and remains to be a major plant nutrient constraint in rain-fed upland farming systems throughout the tropics. Most Ethiopian soils are deficient in P when assayed by chemical methods (Tekalign and Haque, 1991; Tekalign et al., 1993; Sanchez et al., 1997). This deficiency is mainly caused either by the inherent characteristics of the parent material or by the strong sorption of PO_4^{3-} to Al and Fe-(hydr)oxides, which turns large proportions of total soil P into unavailable forms. The problem is further exacerbated by nutrient mining due to the low-input agriculture practiced in the country.

Therefore, inorganic/organic P containing fertilizers should be supplied to the soil to counterbalance the P mined by crop production and removal with runoff along with the top soil. The role of chemical fertilizers in increasing yield is evident. Fertilizers accounted for more than 50% of the increase in yield (FAO, 1984). The N and P blanket fertilizer recommendations, which was developed by FAO and extrapolated to different agro-ecologies in the country do not consider the difference in the nutrient demand of different crop types, variation in nutrient availability in different soil types and effect of climate on nutrient availability.

This approach has lead to over- or under-application of fertilizers in different agro-ecologies which in turn resulted in either an economic loss or low crop yields. Hence, fertilizer recommendations should take into account the existing nutrient availability in the soil and should be developed for different crops in different agro-ecologies (Mengel, 1982). Different research findings conducted on yield response calibration of wheat crop against available P content of surface soil indicated that the critical levels of soil P extracted by Olsen method fall in the range of 10 - 17 mg kg^{-1} (Cottenie A., 1980). However, critical levels of soil P for yield vary depending on soil reaction, soil sorption capacity of P and P-use efficiency of the crop. The objective of this study was, therefore, to calibrate soil P test against yield response of wheat and in due course develop soil-test based P fertilizer recommendation equations for wheat crop in Jamma and Wadla Districts of Eastern Amhara.

Materials and Methods

Experimental Site Description

The study was conducted in Jamma and Wadla (Kon) Districts of Eastern Amhara from 2009 - 2011 during the main cropping seasons. Jamma District lies between the geographical coordinates of 10^o 23' to 10^o 27' N and 39^o 07' to 39^o 24' E at an altitude of 2630 meters above sea level (masl). The mean annual rainfall, annual mean minimum and maximum temperatures of the District are 868.2 mm, 9 and 21.6 ^{o}C, respectively. The dominant soil type in the district is Vertisols. While, Wadla District, particularly the study area - Kon is situated at an altitude ranges of 2000 - 2800 masl. The mean annual rainfall ranges from 800-1200 mm, and the mean minimum and maximum temperature of the District are 17 and 22 ^{o}C, respectively (WWARDO, 2010). The dominant soil types in the District are Regosols and Lithosols.

Site Selection and Experimental Procedure

Phase I (Determination of Optimum N fertilizer)

The experiment was conducted in two phases; In the first phase of the experiment (year 1), based on the low of minimum principle and considering N as the other most plant growth limiting nutrient, investigation of the optimum rate of N that could interact best with phosphorus (P) and gave highest yield was conducted. In this phase, a total of 8 treatments, comprised four levels of N (0, 46, 92 and 138 kg N ha^{-1}) and two levels of P (46 and 92 kg P_2O_5 ha^{-1}) combined in a factorial arrangement, were tested.

Two farmers' fields per location with different cropping history, slope and management practices were selected. Composite surface (0-30) soil samples were collected before planting and were analyzed for available P content by Olsen method (Olsen and Sommers, 1982). At each site, the field experiment was arranged in randomized complete block design with three replications. The test crop, wheat, was sown by broadcasting (farmers' practice). The N fertilizer was applied by broadcasting in split, half at planting and the rest half was top dressed at tillering. While, the P fertilizer was applied all as basal by broadcasting.

Phase II (P-Calibration Phase)

The second phase, P-calibration, of the experiment was conducted in the second and third year of the experiment. Five on farm experimental sites in each district were selected based on difference in cropping history, slope and management practices. Five rates of P (0, 46, 92, 138 and 184 kg P_2O_5 ha^{-1}) were tested in randomized completed block design with three replications. A uniform rate of the N fertilizer that was determined and found optimum in the first phase was applied to all experimental plots in split (half at planting and half at tillering). While, P fertilizer were applied and incubated in the soil three weeks before planting. Planting was done by broadcasting method (farmers' practice).

Soil Sampling and Analysis

Composite surface soil samples were collected before P fertilizer application (three weeks before planting). Surface soil samples were also collected at the time of planting (after three weeks of P incubation period in the soil) from each experimental plot. The soil samples collected before and after incubation of the P-fertilizer were analyzed using Olsen's method (Olsen and Sommers, 1982) with the procedure outlined by Sahlemdihin and Taye (2000).

Yield Data Collection

Grain yield data was collected from the harvestable plots, adjusted to 12.5% seed moisture level. Fresh and dry biomass yield and plant height were also measured from the harvestable rows.

Determination of Critical P levels

The Cate-Nelson graphical technique (Cate and Nelson, 1965) was used to determine the P critical level. It was determined from the relationship between relative yields (yield x (100/ maximum yield)) and soil test P (available soil P) values of each treatment after incubation. All the relative yield values against the available soil P of each treatment were laid out on a scatter diagram. Vertical and horizontal lines were superimposed on the scatter diagram so as to maximize the number of points in the first and third quadrants. The horizontal line on the X-Y coordinate is purposely drawn at the point on the Y-axis where 90% of the relative maximum yield was obtained. The vertical line divides the data into two classes (high probability of response and low probability of response). The point where the vertical line intersects the X-axis has been termed as the critical soil test level.

Determination of P Requirement Factor

The measure of the quantity of P nutrient per hectare required to raise the soil test P level by 1 mg kg^{-1} is known as P requirement factor (Pf). It was calculated by dividing each fertilizer rates to the respective differences between available P values in the soil samples of the control plots and the plots that received the respective P fertilizer rates (Table 1).

Table 1. Table for calculating P requirement factor (Pf)

P fertilizer rates (kg P_2O_5 ha^{-1})	Olsen AVAILABLE SOIL P levels after incubation (mg kg^{-1})	P level increase over the control (mg kg^{-1})	P requirement factor (Pf)
0	a	-	-
46	b	b-a	46/ (b-a)
92	c	c-a	92/ (c-a)
138	d	d-a	138/ (d-a)
184	e	e-a	184/ (e-a)
Mean	-	[(b-a)+ (c-a) + (d-a) + (e-a)]/4	[(46/(b-a))+ (92/(c-a)) + (138/(d-a)) + (184/(e-a))]/4

Developing the Equation

To develop the equation for the determination of the P fertilizer requirement, three parameters were required: P critical level (P_c), Soil test P level (P_0) and P requirement factor (P_f). P_c is determined from the Cate-Nelson graph, P_0 is the existing level of avail. P in the given soil by the appropriate method of analysis and P_f is calculated as shown above in Table 1. Therefore, P fertilizer requirement (P_r) is the amount of P required to raise the available soil P from the existing level to the critical level. It was calculated with the formula:

$P_r = (P_c - P_0) \times P_f$

Where P_r = P fertilizer requirement (kg P_2O_5 ha^{-1})

P_c = Critical P level by Olsen's method (mg kg^{-1})

P_o = Soil test value of available P of the field (mg kg^{-1})

P_f = P requirement factor determined by the experiment

Results and Discussions

Phase I (Determination of Optimum N fertilizer)

The first year experimental result showed that there were highly significant differences ($P \leq 0.01$) in grain and biomass yields among the treatments for both locations (Kon and Jamma). As it is elucidated in Table 2, the main effects of N and P fertilizer rates had significant ($P \leq 0.05$) effect on grain and biomass yields at Kon trial site. While, at Jamma, the grain and biomass yields were significantly ($P \leq 0.05$) affected by the interaction of N and P (Table 3). The highest grain (4.2 t ha^{-1}) and biomass (11.1 t ha^{-1}) yields (Table 2) were obtained from 138 kg N ha^{-1} followed by 92 kg N ha^{-1} at Kon.

Table 2. Main effects of N and P fertilizers rates on the grain and biomass yields (kg ha^{-1}) of wheat at Kon trial site

N level (kg ha^{-1})*	**Grain yield**	**Biomass weight**
0	2787.7c	7479.2c
46	3445.6b	9260.4b
92	3876.7ab	10145.8ab
138	4211.6a	11072.9a
GM	3580.4	9489.6
CV (%)	16.1	13.0
LSD (0.05)	480.1	1029.4
P level (kg P_2O_5 ha^{-1})*		
46	3402.6b	9052.1b
92	3758.1a	9927.1a
GM	3580.4	9489.6
CV (%)	16.1	13.0
LSD (0.05)	339.5	727.9

**Treatment means followed by the same letter are not significantly (P>0.05) different.*

While, at Jamma (Table 3), the highest grain and biomass yields were obtained from 138/92 N/P_2O_5 kg ha^{-1} followed by 138/46 N/P_2O_5 kg ha^{-1}. Accordingly, N fertilizer rate of 138 kg ha^{-1} was selected as an optimum rate for the second phase of the study at both locations.

Table 3. Interaction effects of N and P fertilizer rates on the grain and biomass yields (kg ha^{-1}) of wheat at Jamma trial site

Treatment* (P_2O_5/N kg ha^{-1})	Grain yield	Biomass weight
46/0/46	1078.1de	3604.4e
46/46	1298.4cd	3975.6e
92/46	1998.3b	6355.6c
138/46	3032.9a	7455.6b
0/92	701.1e	2583.2f
46/92	1616.3bc	4924.4d
92/92	1653.0bc	4933.3d
138/92	3273.4a	8688.9a
GM	1790.9	5132.6
CV (%)	19.3	10.7
LSD (0.05)	345.2	549.2

**Treatment means followed by the same letter are not significantly (P>0.05) different.*

Phase II (P-Calibration Phase)

Jamma study site

Effect of the P fertilizer applied on available soil P

Analysis of variance on available soil P after incubation in both years showed highly significant ($P \leq 0.01$) difference among treatments (Table 4). Combined over years, the highest significant available soil P was recorded from the treatment which received 184 kg P_2O_5 ha^{-1} followed by 138, 92 and 46 kg P_2O_5 ha^{-1} (Table 4).

Table 4. Effect of different levels of P fertilizer applied on available soil P

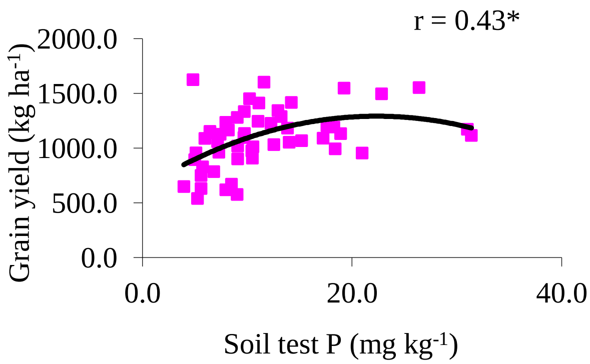
P levels* (kg P_2O_5 ha^{-1})	Available Soil P (mg kg^{-1})		
	2010	2011	Combined over years
0	6.5d	7.0c	6.7e
46	8.4c	13.9bc	10.6d
92	11.0b	16.3b	13.2c
138	11.4b	25.5a	15.7b
184	20.9a	29.5a	21.6a
GM	11.8	16.0	13.2
CV (%)	12.3	24.2	18.4
LSD (0.05)	1.3	7.2	1.8

**Treatment means followed by the same letter are not significantly (P > 0.05) different.*

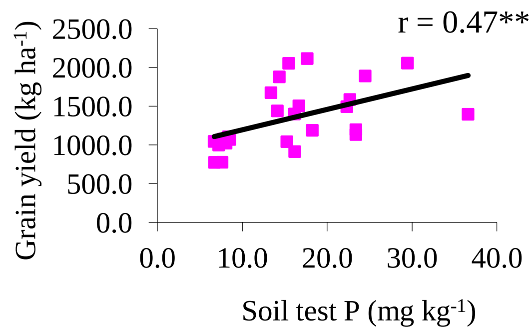
Relationship between yield and available soil P

The regression analysis results of the data collected in the first and second experimental years showed that there were significant ($p \leq 0.05$) weak quadratic ($r = 0.43$) and linear ($r = 0.47$) relations between the grain yield and available soil P, respectively (Fig. 1. a and b). While, the combined analyses over the two experimental years, as shown in Fig. 1 (c) revealed that there was a significant ($P \leq 0.05$) quadratic ($r=0.54$) relation between the grain yield and available soil P.

a)



b)



c)

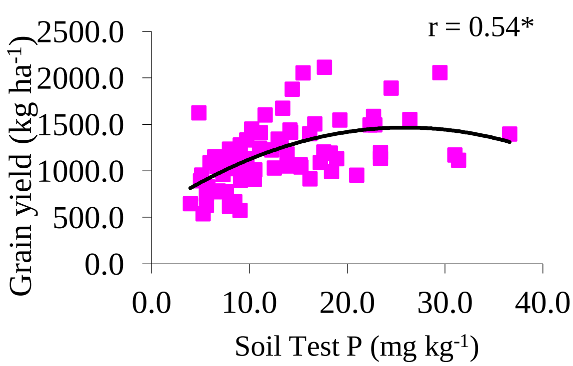


Figure 1. Relationships between available soil P and grain yield in a) 2010, b) 2011 and c) combined over years (* and ** significant at 5% and 1% probability levels).

Unlike the grain yield, biomass yield didn't show significant relationship ($P > 0.05$) with available soil P in both years (Fig. 2).

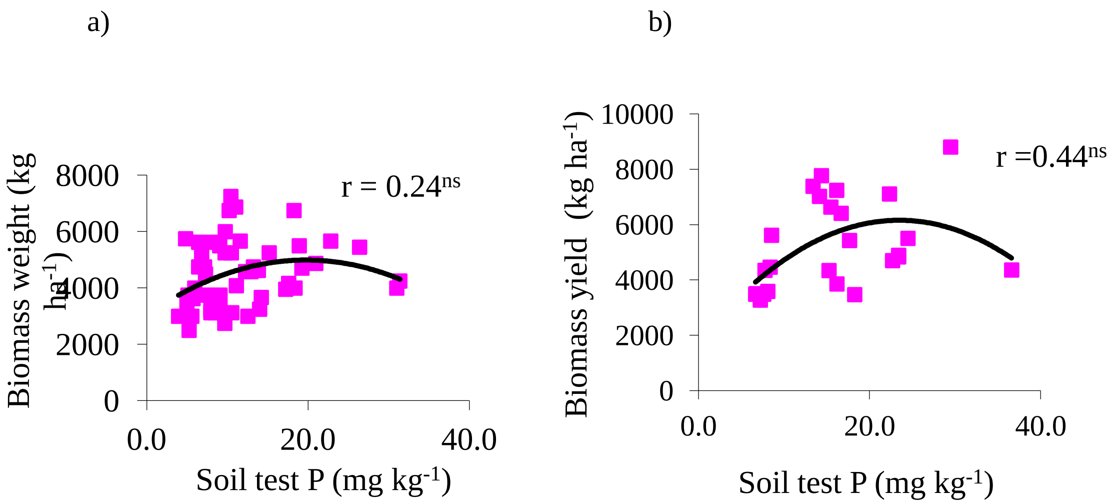


Figure 2. Relationship between available soil P and biomass weight in a) 2010 and b) 2011 growing seasons (ns-non significant at 5% probability level)

Critical P Concentration

The critical soil test P beyond which there is little probability of significant yield response to P fertilizer applied based on the Cate and Nelson graphical model, as shown in Fig. 3, is found to be 11.0 mg kg^{-1}.

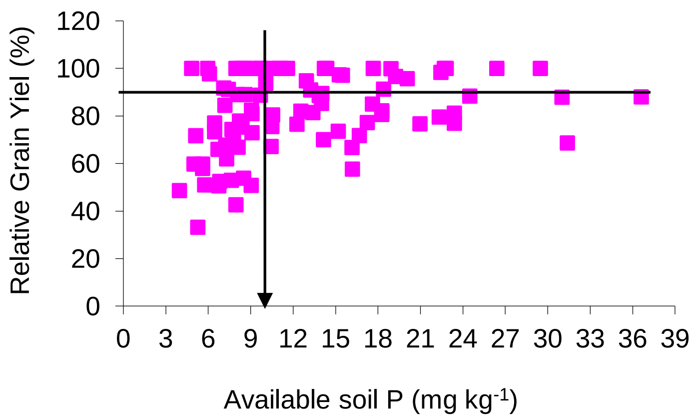


Figure 3. A scatter diagram showing the relationship between soil test P (mg kg^{-1}), relative grain yield (%) and P-critical

Determination of P Requirement Factor (Pf)

The amount of P fertilizer needed to increase the soil test P level by 1 mg kg^{-1} is known as the P requirement factor (Pf). The Pf, as shown Table 5, is 13.4 kg P_2O_5 ha^{-1}, which implies 13.4 kg P_2O_5 ha^{-1} is required to increase the soil test P level by 1 mg kg^{-1}.

Table 5. Calculation of the P requirement factor (Pf)

P level (kg P_2O_5 ha^{-1})	Available Soil P (mg kg^{-1})	Available Soil P difference from the control (mg kg^{-1})	P requirement Factor (Pf)
0	6.7036	-	-
46	10.5948	3.8912	11.82155
92	13.2122	6.5086	14.13514
138	15.7474	9.0438	15.25907
184	21.5752	14.8716	12.37258
Mean		8.6	13.4

Thus, finally, the P fertilizer rate recommendation for Jamma can be made using the following equation:

Pr = 13.4 x (11.0 - Po), where Pr = The P fertilizer required (kg P_2O_5 ha^{-1}) and Po = the soil test P level (mg kg^{-1}).

Phosphorus fertilizer recommendation

Based on the equation developed by this study, the soil analysis results, nine out of the ten farmers' fields at Jamma required P application. However, there was no response for one farmer's field and thus only some P fertilizer is required to apply to maintain the soil P reserve stay optimum. The calculated result of the P fertilizer required for the nine farmers' fields is given below (Table 6).

Table 6. P fertilizer recommendations

Farmer	Available Soil P (mg kg^{-1})	P fertilizer required (kg P_2O_5 ha^{-1})	TSP/DAP required (qt ha^{-1})
1	8.8	29.5	0.64
2	10.2	11.0	0.24
3	5.0	79.9	1.73
4	3.1	106.0	2.30
5	6.2	63.8	1.39
6	10.5	6.8	0.15
7	7.3	49.2	1.07
8	8.1	39.0	0.85
9	13.2	-	-
10	6.6	59.6	1.30

Kon study site

Effect of P fertilizer applied on available soil P

Analysis of variance of the available soil P after incubation revealed significant ($P \leq 0.05$) to different P rates on plant available soil P (Table 7). The highest plant available soil P was obtained from 184 kg P_2O_5 ha^{-1} followed by 138 P_2O_5 ha^{-1}.

Table 7. Effect of different levels of P fertilizer applied on plant available soil P

	Available Soil P (mg kg^{-1})		
P fertilizer levels* (kg P_2O_5 ha^{-1})	2010	2011	Combined over years
0	8.8c	9.6c	9.2c
46	9.6bc	11.3bc	10.8bc
92	10.2bc	12.5bc	11.5b
138	10.7b	13.5b	11.9b
184	16.8a	19.7a	18.3a
GM	11.1	13.1	12.2
CV (%)	15.6	21.4	19.9
LSD (0.05)	1.8	2.9	1.7

**Treatment means followed by the same letter are not significantly (P > 0.05) different.*

Relationship between yield and available soil P

The regression analysis, as shown in Fig. 4, revealed that there was no significant ($P > 0.05$) relation between the relative grain yield and available soil P in both experimental years. These might be attributed to acidic soil reaction of the study site which might lead to fixation of available P.

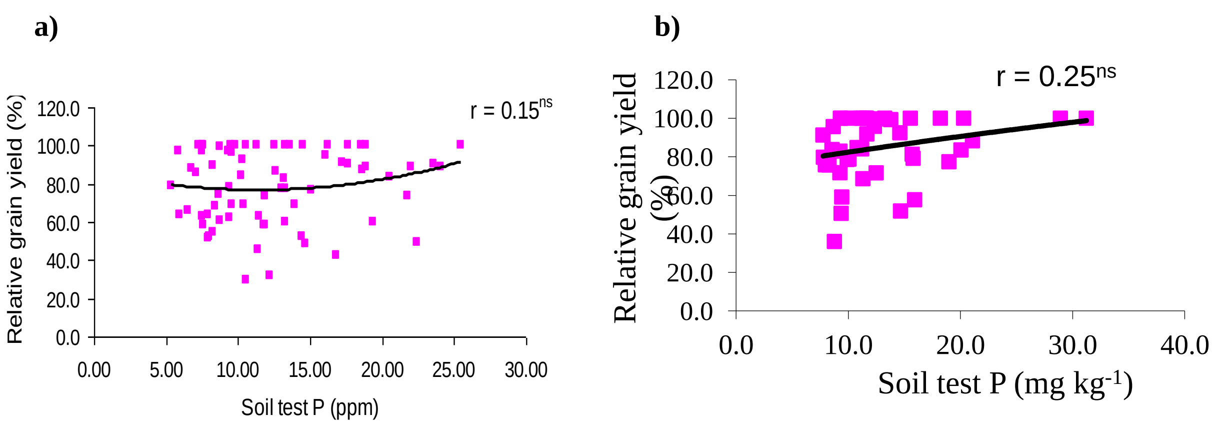


Figure 4. Relationships between Available Soil P and grain yield in the a) 2010 and b) 2011 growing seasons (ns-non significant)

Critical P concentration (Pc)

The critical soil P (Pc) level is determined by using the Cate-Nelson graphical model (Fig. 7). As it is illustrated in the graph below, the Pc beyond which there is little probability of yield response to fertilizer application is found to be 11.3 mg kg-1 (11.3 mg kg^{-1}).

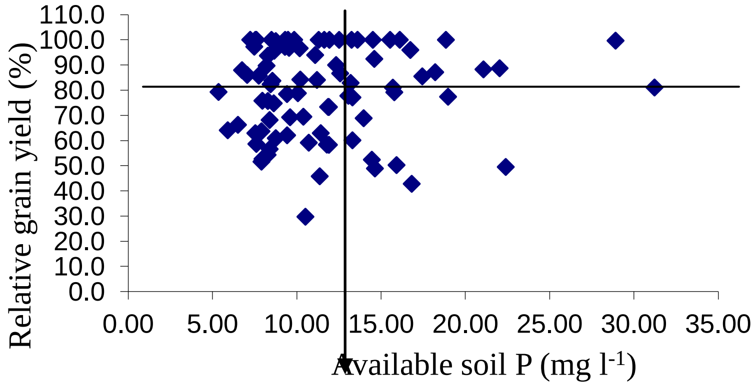


Figure 5. A scatter diagram showing the relationship between soil test P (mg kg^{-1}), relative grain yield (%) and P-critical

Phosphorus Requirement Factor (Pf)

The Pf i.e. the P fertilizer required to increase the soil test P level by 1 mg kg^{-1} was calculated as shown in Table 8 and was 35.01 kg P_2O_5 ha^{-1}.

Table 8. Calculation of the P requirement factor

P level (kg P2O5 ha^{-1})	Soil test P (mg kg^{-1})	Available Soil P difference from the control (mg kg^{-1})	P requirement Factor (Pf)
0	9.2	-	-
46	10.8	1.6	28.75
92	11.5	2.3	40.00
138	11.9	2.7	51.11
184	18.3	9.1	20.22
Mean	12.2	3.9	35.01

Thus, to increase the Olsen's available soil P level by 1 mg kg^{-1} (mg kg^{-1}) at Kon, 35 kg P_2O_5 should be added per hectare. Therefore, the P fertilizer recommendation for wheat at Kon can be made using the following equation; **Pr = (11.3-Po) x 35.01**, where Pr = The P fertilizer required (kg P_2O_5 ha^{-1}) and Po = The available soil P level (mg kg^{-1}).

Phosphorus fertilizer recommendation

Based on the equation and the P-critical (Pc) developed in this study site, seven (7) farmers' fields required P fertilizer application. While, no yield response to P fertilizer on two farmers' fields. Based on the equation, the P fertilizer requirement of those farmer's fields considered in the study is given in Table 11 below.

Table 9. P fertilizer recommendations

Farmers	Available Soil P (mg kg^{-1})	P fertilizer required (kg P_2O_5 ha^{-1})	TSP/DAP required (qt ha^{-1})
1	7.65	127.9	2.8
2	11.83	-	-
3	10.41	31.0	0.68
4	15.50	-	-
5	9.95	47.1	1.02
6	8.84	86.0	1.87
7	10.19	38.9	0.85
8	8.84	86.0	1.87
9	8.84	86.2	1.88

Conclusion and Recommendation

Phosphorus is known as one of the most growth limiting nutrients in crop production next to nitrogen. Thus, P should be supplied to the soil in the form of organic or inorganic fertilizers to counterbalance the P removed by the crops, leached and washed away with runoff. Crop response to fertilizers varies depending upon the climate, soil type and the crop variety. Thus, location- and soil-test based fertilizer recommendations should be made for each crop to develop economically and environmentally sound optimum fertilizer recommendation.

Thus, this study was conducted to develop soil test based P fertilizer recommendation for wheat crop at Jamma and Kon Districts. The result obtained in the study at Jamma showed that except one farmer's field, the rest farmers' fields included in the study (90% of the farmers' fields included in the study) showed significant yield response to P fertilizer. While, 80% of the farmers' fields included in the Kon study site showed significant yield response to P fertilizer. The soil test based P fertilizer rate determination equations developed for Jamma was Pr = (11.0-Po) x 13.4 and for Kon was Pr = (11.3-Po) x 35.3. Therefore, using the equations developed, it is possible to make P fertilizer recommendations for wheat crop for Jamma, Kon and similar agro-ecological areas.

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Effects of Lime and Phosphorus on Wheat (*Triticum aestivum* L.), Teff (*Eragrostis teff*) and Barley (*Hordium vulgar* L) Yields in the Amhara Highlands

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Abstract

The success in soil management to maintain soil quality depends on an understanding of how soils respond to agricultural practices over time. A Field experiment was done on farmers' field in 2011 and 2012 to determine lime and phosphorus rates for higher teff wheat and barley yields. The experiment was arranged in randomized complete block design with three replications. The treatments were factorial combinations of 3 levels of lime (0, 1, 2 t ha^{-1}*) at Tarmaber and 4 levels of lime (0, 1, 2 and 3 t ha*$^{-1}$*) at Banja, Mecha and Gozamen and 4 levels of P (0, 10, 20, 30 kg ha*$^{-1}$*) for all locations. Composite soil samples were collected from 0-20 cm before planting and from all plots at sixty days after planting and at harvest to determine some soil chemical properties. All data were subjected to statistical analysis using SAS software and the mean separation was done using LSD (0.05) whenever the difference between treatments was significant. The result showed that maximum grain yield was obtained from 30 kg P ha*$^{-1}$ *with 2 t lime ha*$^{-1}$ *while the lowest was from the control (no input). Therefore, 30 kg P ha*$^{-1}$ *with 2 t lime ha*$^{-1}$ *is recommended for the study sites and similar agro ecologies.*

Keywords: Barley, Wheat, Teff, lime, Phosphorus

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Introduction

The success in soil management to maintain soil quality depends on an understanding of how soils respond to agricultural practices over time. However, land degradation is one of the challenges facing Ethiopian agriculture. Among the land degradations soil erosion and soil fertility depletion are current problems to boost production in Ethiopia. One of soil chemical degradation challenging the Ethiopian highland soils is soil acidity which can be caused by leaching and plant uptake of basic cations (Ca and Mg), production of organic acids from organic matter decomposition, and application of acidifying N fertilizers (Ammonium/ammonia N sources including products like urea) (Bierman and Carl, 2005).

Acid soils are rampant and occupy about 40.9 percent of the country agricultural fields (Schlede, H., 1989). They extend from south-west to north-west with east-west distribution. They are concentrated mainly in the western part of the country including the lowlands but are limited by the eastern escarpments of the Rift Valley (Mesfine A., 2007). Out of the 40.9 percent total coverage, 27.7 percent are moderate to weakly acidic (pH of 5.5 - 6.7); 13.2 percent are strong to moderately acidic (pH< 5.5) and nearly one-third have aluminum toxicity problem (Schlede, H., 1989). From the soil analysis result by Bahir Dar, Debremarkos and Gonder soil laboratories indicate that south west Ethiopia especially the highlands of Gojam and Gonder are dominated by soil acidity problems (unpublished data). Soil acidity affects productivity of the soil through its effect on nutrient availability and toxicity by some elements like aluminum and manganese; most plant nutrients become more limited in supply, and a few micronutrients become more soluble and toxic. These problems are particularly acute in humid tropical regions that have been highly weathered (Harter, 2002). As soils become more acid, particularly when pH drops below 4.5, it becomes increasingly difficult to produce food crops.

Aluminum and manganese become more soluble (i.e. more of the solid form of these elements will dissolve in water when the soil is acid) and toxic to plants, most plant nutrients become more limited in supply, and a few micronutrients become more soluble and toxic. The ideal soil pH for most crops is slightly acidic to neutral (pH in water 6-7). Favorable soil pH in water for wheat production is 5.5 -7.0 below this pH ranges especially below 5.1- 5.5 wheat production is severely affected due to toxicity of aluminum and unavailability of macronutrients. The critical aluminum level extracted by $CaCl_2$ solution for wheat production is 0.4-0.8 ppm in which aluminum toxicity will affect wheat production (Fenton and Helyar, 2007). High levels of soil acidity (low soil pH) can cause reduction of root growth, nutrient availability, affect crop protecting activity (The Pennsylvania State University, 1995), reduction and total failure of crop yields and deterioration of soil physical properties. In general it affects the biological, chemical and physical properties of soil, which in turn affect the sustainability of crop production in both managed and natural ecosystem.

Reclamation and maintenance of soil acidity is very important soil management practices for crop production. Lime is the major means of ameliorating soil acidity (Anetor and Ezekiel, 2007) because it has very strong acid neutralizing capacity, which can effectively remove existing acid. Liming increases the uptake of nutrients, stimulate biological activity and reduce toxicity of heavy metals. Liming raises the soil pH and causes the aluminum and manganese to go from the soil solution back into solid (non-toxic) chemical forms. Regular applications of lime are required on many soils to maintain soil pH in the desired range, because soil acidification is an ongoing process (Bierman and Carl, 2005). Limestone is the most commonly used material to increase soil pH. However, for most efficient crop production on acid soils, application of both lime and fertilizer are required. Since lime make minerals more available to plants, in addition to the liming, applying fertilizer to correct nutrient constraints caused by acidity is necessary.

Lime and fertilizer management practices are primary important for proper management of acid soils. Some research attempts were made at Arekain Boloso Sore Wereda of Wolaita Zone of the Southern Nations Nationalities and People Regional States (Abay A. 2011), and a green house experiment was conducted by Chimdi and his associates at Guto-Gida District (East Wollega Zone) of Oromia Regional State (Chimeda et al. 2012), the latter reported that incubation of soil with applied lime rate at 10 t ha^{-1} showed considerable drop of the acid saturation percentage and reduced soil acidity thereby increasing soils pH and available P in soils in three land uses. In addition to the aforementioned studies in Ethiopia, Currently there are different research activities going on to determine the liming factor and the interaction of lime and phosphorous fertilizer by the federal and regional research institutes. However, there is scanty information available about the response of lime and fertilizer and the rates of these inputs for bread wheat, food barley and teff production in the Amhara highlands. Hence, this experiment was conducted to determine the lime and phosphorus rates to reclaim acid soils and improve its productivity.

Materials and methods

Description of the study area

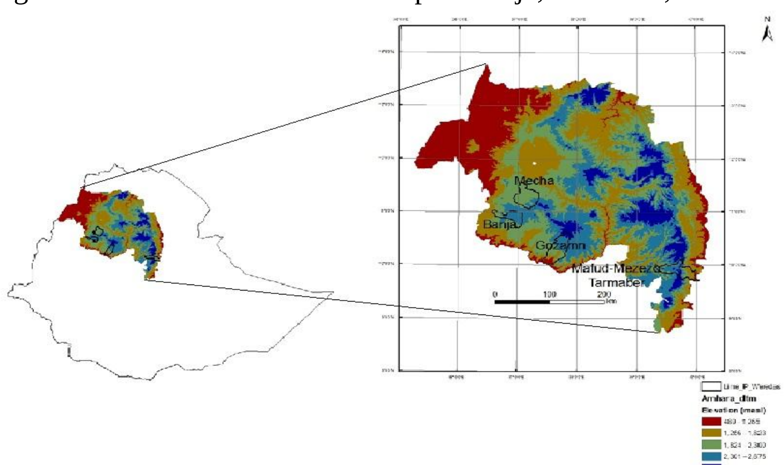
The study was conducted at Banja which is located in Awi Zone, Gozamen at East Gojam Zone, Mafud-Mezezo-Tarmeber at North Shewa Zone and Mecha at West Gojam Zone of the Amahara Regional State which are known for high soil acidity (Figure 1). The test crops were bread wheat for Banja and Gozamen Woredas, Teff for Mecha Woreda and Barley for Mafud-Mezezo-Tarmaber Woreda.

Table1. Physiographic characteristics of the Woredas.

Parameter	Woredas			
	Banja	Gozamen	Mecha	Mafud-Mezezo-Tarmaber
Soil Type	Acrisols	Nitosols	Nitosols	Cambisols
Altitude	2700	2920	Na	2580
Mean Annual Rain fall	1295	1320	Na	984
Min Temp	4.1	8.3	Na	6.8
Max Temp	28.6	24.8	Na	23.6

Na = data not available

Figure 1: Location and elevation map of Banja, Gozamen, Mecha and Mafud-Mezezo-Tarmaber weredas.



Experimental Set up

Bread wheat at Banja and Gozamen; and teff at Mecha

The experiment was done for two consecutive years (2011 and 2012) on farmers' fields. Four rates of lime (0, 1, 2 and 3 t lime ha^{-1}) were combined with four rates of phosphorous (0, 10, 20 and 30 kg P ha^{-1}) factorially arranged in a randomized complete block design (RCBD) with three replications.

Barley at Mafud-Mezezo-Tarmaber

The experiment was conducted at four location for two consecutive years with three rates of lime (0, 1 and 2 t ha^{-1}) combined with four rates of phosphorous fertilizer (0, 10, 20 and 30 kg P ha^{-1}) factorially arranged in randomized complete block design (RCBD) with three replications. For all locations urea and DAP were used as the sources of N and P respectively, whereas calcic limestone was used as the source of lime. The lime was incorporated in to the soil one month before sowing. Nitrogen was applied in split; half at planting and half at tillering. The whole doses of DAP was applied during planting. Bread wheat and Barley were drilled in row with spacing of 20 cm while Teff was broadcasted in a well prepared seed bed. The seed rate for wheat, Barley and teff were 150, 175 and 30 kg ha^{-1} respectively.

Soil sampling and analysis

Soil samples were collected from 0-20 cm i.e. one composite sample from the experimental site before planting and from each plot sixty days after planting and at harvest to determine different soil chemical properties. Samples were air dried, grinded, and passed through a 2 mm sieve and prepared for laboratory analysis. Soil pH was measured by using 1M KCl solution in the supernatant suspension of soil to solution ratio of 1:2.5 mixtures by using pH meter. The total exchangeable acidity was measured according to McLean (1965) while cation exchange capacity (CEC) was determined by the 1M ammonium acetate (pH 7) method according to the percolation tube procedure (Van Reeuwijk, 1993).

Data Analysis

The soil data collected were subjected to mean comparison using descriptive statistics and yield parameter for analysis of variance using statistical analysis software (SAS, 2002). Whenever treatment effects were significant, mean comparison were made using least significant difference at 0.05 % probability level.

Results and Discussions

At Banja Woreda, the soil type was Acrisols with pH (H_2O) ranging from 4.64-5.08, While at Gozamen and Mecha Woredas, the soil type was Nitisols with pH(H_2O) ranging from 4.3-4.77 in and 4.3-5.3 respectively. Similarly, the soil type at Mafud-Mezezo-Tarmaber was Cambisols with pH (H_2O) ranging from 4.6-5.41. The acidity level of the soils of the study sites were categorized as moderately to strongly acidic (Tekalign, 1991). The combined analysis of variance over years at all locations indicated that application of lime and phosphorus fertilizer had contributed to the improvement of the yield of the test crops compared to the recommended fertilizer rate without lime and the control.

Bread wheat

At Gozamen

There was an interaction effect between lime and phosphorous fertilizer on dry biomass and grain yield. The analysis of variance revealed that there was significant difference ($p \leq 0.05$) in all the parameters between years. Therefore, it is better to analyze the individual years independently. The statistical analysis in 2011 revealed that there was significant difference among lime and P fertilizer combinations. Maximum grain and biomass yields were recorded by applying 30 kg P ha^{-1} with 2 t lime ha^{-1} while the lowest grain yield was recorded by the control (no input) (Table 1). However there was no statistically significant difference among 10/2, 10/3, 20/3, 30/1, 30/2 and 30/3 P/lime (kg/t) rates in grain yield (Table 1).

Table 2: Effects of lime and P on the grain (a) and biomass (b) yields of bread wheat at Gozamen in 2011.

(a)

	Grain Yield kg ha^{-1} Lime t ha^{-1}			
P kg ha^{-1}	0	1	2	3
0	314.48[i]	439.50[hi]	540.51[gh]	804.37[de]
10	628.42[fg]	730.06[ef]	1067.87[abc]	1120.26[ab]
20	762.25[ef]	930.56[cd]	1030.53[bc]	1133.42[ab]
30	829.36[de]	1114.01[ab]	1202.33[a]	1196.09[a]
CV	9.97			

(b)

	Biomass t ha^{-1} Lime t ha^{-1}			
	0	1	2	3
0	1.01[g]	1.20[fg]	2.03[bcde]	1.50[efg]
10	1.43[efg]	2.00[cde]	2.50[abcd]	1.93[cdef]
20	2.37[abcd]	2.40[abcd]	2.80[ab]	2.53[abc]
30	1.73[defg]	2.67[abc]	2.93[a]	2.50[abcd]
CV	22.61			

The 2012 analysis of variance showed that there was significant difference among the treatments in all the variables considered in 2012 (Table 2). Similar to 2011, the maximum dry biomass and grain yields were obtained from 30 kg P ha^{-1} with 2 t lime ha^{-1} followed by 30 kg P ha^{-1} with 3 t lime ha^{-1} and 20 kg P ha^{-1} (Table 3). The lowest grain and biomass yields were obtained from the control. The yield advantage of using 30 kg P ha^{-1} fertilizer with 2 t lime ha^{-1} was 282.32% (887.85 kg ha^{-1}) in 2011 and 363.19 % (917.59 kg ha^{-1}) in 2012 compared to the control while the yield advantage over the recommended fertilizer alone was 44.97% (372.97 kg ha^{-1}) in 2011 and 111.09 % (615.86 kg ha^{-1}) in 2012 (Table 2 and 3).

Table 3: Effects of lime and P on grain (a) biomass (b) yields on bread wheat at Gozamen in 2012.

(a)

	Grain Yield kg ha^{-1} Lime t ha^{-1}			
P kg ha^{-1}	0	1	2	3
0	252.65^{g}	327.87^{fg}	511.52^{de}	396.39^{ef}
10	350.85^{fg}	743.45^{c}	701.13^{c}	957.52^{b}
20	384.87^{fg}	714.96^{c}	813.26^{c}	962.66^{b}
30	554.38^{d}	808.76^{c}	1170.24^{a}	1020.16^{b}
CV	12.83			

(b)

	Biomass t ha^{-1} Lime t ha^{-1}			
P kg ha^{-1}	0	1	2	3
0	0.37^{hi}	0.33^{i}	0.60^{fgh}	0.60^{fgh}
10	0.40^{hi}	0.53^{fghi}	0.87^{cde}	1.93^{cdef}
20	0.47^{ghi}	0.77^{def}	1.00^{bcd}	1.13^{b}
30	0.67^{efg}	1.20^{ab}	1.43^{a}	1.13^{b}
CV	19.90			

The pH improvement and decrement in exchangeable acidity and aluminum by applying 3 t ha^{-1} in moderately acidic soil was high in 2011 and very low in 2012 as the initial soil acidity was very severe. As shown Table 4, the experiment was conducted on different farms with different soil acidity extent, which is reflected through the improvement on soil pH, exchangeable acidity and Aluminum contents. The improvement in soil chemical properties was less in 2012 which indicates the extent of soil acidity is sever and 3t lime ha^{-1} was not enough to increase the pH above 5.5 and reduce the exchangeable acidity below 0.8 Cmolegm^{-1}. The pH above 5.5 and exchangeable acidity below 0.8 Cmolegm^{-1}are favorable for bread wheat production.

Table 4: Effect of lime on selected soil chemical properties at Gozamen

	2011				2012				
lime rate t/ha	pH (H2O)	EX.AL (cmol kg^{-1})	EX.H (cmol kg^{-1})	EX. Ac (cmol kg^{-1})	pH	Ex.Al (cmol kg^{-1})	Ex.H (cmol kg^{-1})	Ex.acidity (cmol kg^{-1})	CEC
0	5.07	1.37	0.50	1.87	4.46	2.48	1.01	3.50	18.82
1	5.12	1.01	0.50	1.51	4.48	1.54	0.63	2.17	17.17
2	5.31	0.83	0.48	1.31	4.50	0.82	0.53	1.34	17.67
3	5.38	0.47	0.53	1.00	4.58	0.63	0.42	1.04	18.50

At Banja

Similarly, at Banja Woreda, there was significant difference among the treatments (Table 5). The two years combined analysis result showed that the highest fresh and dry biomass as well as grain yield was recorded by using 20 kg P ha^{-1} and 3 t lime ha^{-1} followed by 10 kg P ha^{-1} and 3 t lime ha^{-1} (Table 5). This shows that at Banja, using lime is a good option to reclaim acidic soils and make it productive. As compared to the control plot, applying 20 kg P ha^{-1} and 3 t lime ha^{-1} gave an advantage of 84.8 % in grain yield.

Table 5: Response of bread wheat to lime and P combined over years at Banja.

Rates		Dry biomass (t ha^{-1})	Grain yield (kg ha^{-1})
Lime (t ha^{-1})	0	6.26^{b}	1874.9^{b}
	1	6.79^{ab}	2108.7^{ab}
	2	6.55^{ab}	2151.0^{ab}
	3	7.0^{a}	2483.1^{a}
	CV	19.51	35.37
P kg/ha	0	5.51^{c}	1699.5^{b}
	10	6.72^{b}	2316.6^{a}
	20	7.36^{a}	2461.8^{a}
	30	7.03^{ab}	2140.0^{ab}
	CV	19.51	35.37

Table 6: Effect of lime on selected soil chemical properties at Banja in 2012.

Lime rate t ha^{-1}	Soil sample after 90 days of lime application				Soil sample at harvest days of lime application			
	pH (H_2O)	EX.acidity (cmol kg^{-1})	EX.H (cmol kg^{-1})	EX. Al (cmol kg^{-1})	pH	Ex.Acidity (cmol kg^{-1})	Ex.H (cmol kg^{-1})	Ex. Al (cmol kg^{-1})
0	4.98	1.60	1.13	0.48	5.37	0.93	0.55	0.38
1	5.00	1.44	1.01	0.44	5.44	0.48	0.12	0.36
2	5.04	1.46	1.01	0.46	5.59	0.26	0	0.26
3	5.09	1.10	0.70	0.40	5.86	0.10	0	0.10

On the contrary, greenhouse experiment conducted by Chimdi *et.al.* (2012), to observe the response of barley on lime rate and particle size revealed that maximum yield was recorded by applying 10 t lime ha^{-1}. Since the area is severely affected by soil acidity, application of fertilizer without soil amendments might lead to phosphorous fixation and phosphorous nutrient may not be available to plants. From the result, it can be shown that addition of more phosphorous fertilizer in acidic soils like Gozamen wereda might not increase yield and yield components. Therefore amendment of soil acidity using lime is very crucial to boost yield.

Similarly, application of lime alone without fertilizer did not make any difference on yield and yield components at Gozamen wereda. So, integration of lime and chemical fertilizer is by paramount important to enhance crop production and productivity. This result was in conformity with Abaye A. (2011) who reported that application of lime alone did not influence maize production at Areka and application of lime with fertilizer generally increased maize production. The researcher added that he received maximum maize grain yield by applying 69 kg ha^{-1} N, 20 kg ha^{-1} P and 1.8 t lime ha^{-1} at the aforementioned location. Inconformity with our study, the research conducted at Nigeria on acidic soils also indicated that application of lime in combination with P was very important to increase the fruit production of Okra (Oluwatoyinbo *et al.*, 2005). Anetor and Akinrinde, (2006) approved that combined application of lime and P positively highly affected Soybean yield in Nigeria.

Teff at Mecha

The combined analysis of variance showed that there was a significant interaction effect of lime and phosphorus rates on teff yield at Mecha (Table 7). The maximum grain yield was obtained from 3 t lime ha^{-1} with 20 kg P ha^{-1} with 118.8% yield advantage over the control (Table 7). This result indicated that application of 3 t lime ha^{-1} with 20 kg P ha^{-1} has doubled the productivity of teff. This can approve the vertical yield increment for land is scarce due to population pressure and can ultimately increases the GDP of the country.

Table 7: Effect of lime and P on teff grain yield combined over years at Mecha

Phosphorous	Lime (t ha^{-1})				
fertilizer (kg ha^{-1})	0	1	2	3	Mean
0	625.8^{e}	640.0^{e}	606.7^{e}	827.5^{cde}	675
10	845.8^{cde}	779.2^{de}	710.8^{de}	863.7^{cde}	799.88
20	947.5^{bcd}	808.0^{de}	1174.2^{ab}	1327.5^{a}	1064.3
30	1288.7^{a}	1124.2^{abc}	1286.0^{a}	1226.3^{ab}	1213.07
Mean	926.95	837.85	830.57	1061.25	938.06
CV	27.93				

Table 8: Effect of lime on soil chemical properties at Mecha in 2011 at 45 days of planting.

lime rate t/ha	pH (H2O)	Ex.Al(Cmole kg^{-1})	Ex.H(Cmole kg^{-1})	Ex.Acidity (Cmole kg^{-1})
0	4.90	0.21	0.34	0.54
1	4.91	0.12	0.34	0.47
2	5.01	0.06	0.28	0.35
3	5.06	0. 057	0.24	0.30

Barley at Mafud-Mezezo-Tarmaber

The pH-H_2O of composite soil sample ranged from 4.6 to 5.41 (Table 9) which is in the range of highly acidic to moderately acidic soils (Tekalign, 1991).

Table 9. Initial chemical properties of soil from Mafud-Mezezo-Tarmaber

Parameters	2010/11				2011/12			
	Site 1	Site 2	Site 3	Site 4	Site 1	Site 2	Site 3	Site 4
pH-H_2O (1:2.5)	5.20	4.90	5.32	5.41	5.00	5.30	4.60	4.80
Exch. acidity (Cmole kg^{-1})	2.11	2.23	0.83	1.61	2.56	1.05	1.20	1.15

The main effect of lime and P were significant on barley biomass and grain yield. The highest grain yield (1926.28 kg ha^{-1}) was recorded from the highest level of lime and P while the lowest (844.92 kg ha^{-1}) was obtained from the control plot (Table 10). Even though lime has ameliorative effect on acid soil, initially this experiment was designed to observe one year effect of lime and P with half recommended fertilizer rate. But, this may not be representative because of the nature of the experiment that the effect of lime cannot be explained within a year. The second year result showed that application of 1 and 2 t lime ha^{-1} with 30 kg P ha^{-1} gave the highest barley grain yield while application of 2 t lime ha^{-1} alone gave the second highest and non significant biomass yield compared to the application of 2 t lime ha^{-1} with 30 kg P ha^{-1} (Table 11 and 12).

Table 10: Effect of lime and P on grain yield (kg ha^{-1}) of barley combined years at Mezezo.

	P (kg ha^{-1})			
Lime (t ha^{-1})	0	10	20	30
0	844.92^{h}	1209.33^{f}	1376.73^{e}	1654.24^{c}
1	953.58^{g}	1322.98^{e}	1673.65^{c}	1852.88^{ab}
2	1204.03^{f}	1495.46^{d}	1783.07^{b}	1926.28^{a}
CV (%)	11.97			
LSD (0.05)	98.27			

Table 11: Effect of lime and P on barley dry biomass yield (kg ha^{-1}) combined years at Mezezo.

	P (kg ha^{-1})			
Lime (t ha^{-1})	0	10	20	30
0	2100.8^{g}	2332.6^{g}	2886.8^{ef}	2850.5^{f}
1	3093.0^{de}	3445.2^{c}	3139.0^{d}	3862.0^{b}
2	4084.4^{ab}	3611.2^{c}	3950.5^{ab}	4120.4^{a}
CV (%)	12.60			
LSD (0.05)	236.12			

As the level of lime increased, the pH increased. The highest pH (6.03) was recorded at the highest level of lime (Table 12).

Table 12: Effect of lime on soil pH after 45 days of lime application at Mezezo.

	P (kg ha^{-1})			
Lime (t ha^{-1})	0	10	20	30
0	5.36	5.41	5.29	5.35
1	5.90	5.81	5.81	5.82
2	6.03	6.00	5.97	5.86

Conclusion and Recommendation

The soils of Banja, Gozamen and Mecha are severely affected by soil acidity, application of fertilizer without soil amendments might lead to phosphorous fixation and phosphorous nutrient may not be available to plants. In addition, application of lime without fertilizer application will not improve crop yield except soil pH and exchangeable acidity in severely acidic Nitisols and Acrisols. On the contrary on soils like Cambisols with less acidity, application of lime may decrease P fixation and improve barley yield even without the application of P fertilizer. Of-course, it is advisable to use soil test P requirement of barley to decide to use lime alone or with P. The pH improvement, decrement in exchangeable acidity and aluminum at Banja, Gozamen and Mecha experimental sites were higher by applying 3 t lime ha^{-1}; however the amendment in these soil properties is minimum in strongly acidic soils and maximum in moderately acidic soil.

From the results, it can be concluded that addition of more phosphorous fertilizer in acidic soils did not increase crop yield. Therefore, amendment of soil acidity using lime is very crucial to boost yield. Applying 30 kg P ha^{-1} fertilizer with 2 t lime ha^{-1} for bread wheat at Banja and Gozamen gave a consistent grain yield and hence recommended for these Woredas. At Mecha, the result indicated that 30 kg P ha^{-1} can be applied solely for teff production as well as lower rates of lime application with phosphorus fertilizers can be applied for improving teff productivity. At Mafud-Mezezo-Tarmaber, for barley productivity, application 30 kg P ha^{-1} with 2 t lime ha^{-1} can give better grain yield.

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Effect of lime and Phosphorus on soil health and bread wheat productivity on acidic soils of South Gonder.

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Abstract

A Field experiment was conducted at Farta, South Gondar in 2012 and 2013 to determine the lime correction factor using exchangeable acidity. A total of seven treatments including: lime determined using 1X and 1.5X of exchangeable acidity with half and full recommended P (23 and 46 kg P_2O_5 ha^{-1}), full recommended P alone (46 kg P_2O_5 ha^{-1}), full recommended P (46 kg P_2O_5 ha^{-1}) + blanket recommended lime (2 t ha^{-1}) and control (without lime and fertilizer) were arranged in a randomized complete block design with three replications. Recommended N was applied to all plots except the control (without input). Data were analyzed using SAS statistical software (SAS 2002) and the soil analysis was done following standard laboratory procedures. Economic analysis was also done using net present values with incremental net benefit. The result showed that lime (1.5X) + 46 kg P_2O_5 ha^{-1} + recommended N gave 20 % and 35% grain yield increment over the recommended NP at Minet and Tsegure respectively. Liming was also proved to improve the soil pH from 5.24 to 5.77 at Minet and from 5.24 to 5.75 at Tsegure. The exchangeable acidity and Aluminum was also significantly reduced at both sites. The maximum NPV (1019.2 Birr at Minet and 206.05 Birr at Tsegure) and incremental net benefits (36692.5 Birr at Minet and 7417.7 Birr at Tsegure) were obtained from lime (1.5X) + 46 kg P_2O_5 ha^{-1}. Therefore, lime (1.5X) + (recommended P and N) are recommended for Minet and Tsegure to improve soil chemical properties and increase wheat yield.

Keywords: Lime; acid soil, phosphorus, exchangeable acidity, bread wheat

Introduction

The success in soil management to maintain soil quality depends on an understanding of how soils respond to agricultural practices over time. However, land degradation is one of the challenges facing Ethiopian agriculture. Among the land degradations soil erosion and soil fertility depletion are current problems to boost production in Ethiopia. One of soil chemical degradation challenging the highland soils of the country is soil acidity which can be caused by leaching and plant uptake of basic cations (Ca and Mg), production of organic acids from organic matter decomposition, and application of acidifying N fertilizers (Ammonium/ammonia N sources including products like urea) (Bierman and Carl, 2005). The coverage of acid soils in Ethiopian highlands is widespread and occupies about 40.9 percent of the country (Schlede, 1989). The extent is extending from south-west to north-west with east-west distribution (Abebe, 2007). They are concentrated mainly in the western part of the country including the lowlands but are limited by the eastern escarpments of the Rift Valley (Abebe, 2007). Out of the 40.9 percent total coverage, 27.7 percent are moderate to weakly acidic (pH of 5.5 - 6.7); 13.2 percent are strong to moderately acidic (pH< 5.5) and nearly one-third have aluminum toxicity problem (Schlede, 1989). Western Amhara especially the highlands of Gojam, Awi and Gonder are dominated by soil acidity (Endalewu *et al.*, 2014, Tessema *et al*., 2008). Soil acidity affects productivity of the soil through its effect on nutrient availability and toxicity by some elements like aluminum and manganese; most plant nutrients become more limited in supply, and a few micronutrients become more soluble and toxic. These problems are particularly acute in humid tropical regions that have been highly weathered (Harter, 2002). As soils become more acidic, particularly when pH drops below 4.5, it becomes increasingly difficult to produce food crops. Aluminum and manganese become more soluble (i.e. more of the solid form of these elements will dissolve in water when the soil is acidic) and toxic to plants, most plant nutrients become more limited in supply, and a few micronutrients become more soluble and toxic. The ideal soil pH for most crops is slightly acidic to neutral (pH in water 6-7). Favorable soil pH in water for wheat production is 5.5 -7 below this pH ranges especially below 5.1- 5.5 wheat production is severely affected due to toxicity of aluminum and unavailability of macronutrients (Fenton and Helyar, 2007). The critical aluminum level extracted by CaCl2 solution for wheat production is 0.4-0.8 ppm in which aluminum toxicity will affect wheat production (Fenton and Helyar, 2007).

High levels of soil acidity (low soil pH) can cause reduction of root growth, nutrient availability, affect crop protecting activity (Harter, 2002), reduction and total failure of crops and deterioration of soil physical properties. In general, it affects the biological, chemical and physical properties of soil, which in turn affects the sustainability of crop production in both managed and natural ecosystem.

Reclamation and maintenance of soil acidity is very important soil management practices for crop production. Liming is the major mechanism of ameliorating soil acidity (Omogbohu and Ezekiel, 2007); because it has very strong acid neutralizing capacity and can effectively remove existing acid. Liming increases the uptake of nutrients, stimulate biological activity and reduce toxicity of heavy metals. Liming raises the soil pH and causes the aluminum and manganese to go from the soil solution back into solid (non-toxic) chemical forms. Regular applications of lime are required on many soils to maintain soil pH in the desired range, because soil acidification is an ongoing process (Bierman and Carl, 2005). Liming materials are the most commonly used option to increase soil pH. However, for most efficient crop production on acid soils, application of both lime and fertilizer are required. Even though lime makes minerals more available to plants, liming without fertilizers application results in soil fertility decline that might lead to serious problem of production. Therefore, applying fertilizer to correct nutrient constraints caused by acidity is necessary. Through proper lime and fertilizer management, practices, the quality and productivity of acid soils can be improved. Research attempts are made in the Southern Ethiopia to calibrate the lime correction factor based on exchangeable acidity as well as to determine the rate of phosphorus fertilizer (Ayalew, 2011; Achalu *et al*., 2012). However, the research done by Ayalew, (2011) was not comprehensive and hence there is no lime recommendation in the country. Therefore, the objectives of the present study were (1) to find the correction factor of lime requirement for acidic soils using exchangeable acidity techniques, (2) to evaluate the effect of lime and phosphorous fertilizer on bread wheat yield, and soil chemical properties in northwest Ethiopia, (3) to assess the economical feasibility of lime and phosphorous fertilizer for small scale farmers.

Material and methods

Description of the study area

The research was conducted for two years i.e. in 2011-20112 on farmers' field at Tsegure and Minute kebeles of Farta district, Southern Gondar of the Amhara Regional State. Minute kebele is located 18 km from Gassay on the way to Estie traversed by gravel roads while Tsegure kebele is located around 10.5 km from Debretabur town on the way to Bahir Dar. The study sites were situated within the Lake Tana Basin. According to the Ethiopian agro ecological zonation, the area was categorized under Moist Dega (2300 to 3200 masl with a rainfall ranging from 900 to 1400 mm) with a uni-modal rainfall season.

Table 1. Soil properties of the experimental sites.

location	Initial pH	Exchangeable Al	Exchangeable H	Exchangeable Acidity	Organic matter (%)	Textural class (%)		
						clay	Silt	Sand
Tsegure	5.24	0.16	0.29	0.69	1.88	43	37	20
Minet	5.24	1.02	0.53	1.31	2.17	63	27	10

Experimental setup

Composite soil samples were collected from 0 - 15 cm soil depth and analyzed for exchangeable acidity, pH, organic matter and texture prior to planting. The amount of lime was calculated based on soil mass per hectare at soil depth of 15 cm, soil sample density and exchangeable Al^{+3} as well as H^{+} for each site. The amount of lime applied was calculated based on the following equation.

$$LR, CaCO_3\ (kg/ha) = \frac{cmolEA/kg\ of\ soil * 0.15\,m * 10^4\ m^2 * B.D.\,(Mg/m^3) * 1000}{2000} * 1.5$$

……….equation 1

Where: Cmol EA = cent mole of exchangeable acidity of the soil sample (exchangeable aluminum and hydrogen), B.D = bulk density of the soil in mega gram per meter cube

Fixed plots with the following treatments were used for 2 years in randomized complete block design (RCBD)

1. Control (without lime and fertilizer)
2. 138 kg N ha^{-1} and 23 kg P_2O_5 ha^{-1}
3. 2 t ha^{-1} lime+138 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1}
4. 138 kg N ha^{-1} + 23 kg P_2O_5 ha^{-1} with 1X exchangeable acidity of lime
5. 138 kg N ha^{-1} + 23 kg ha^{-1} with lime by 1.5 X exchangeable acidity
6. 138 kg N ha^{-1} + 46 kg P_2O_5 ha^{-1} with lime by 1X exchangeable acidity
7. 138 kg N ha^{-1} + 46 kg P_2O_5 ha^{-1} with 1.5 X exchangeable acidity of lime

The total amount of lime was applied once in the first year. The lime was applied by broadcasting and incorporated into the soil two weeks before planting. Urea and DAP were used as the sources of fertilizer for N and P respectively. Nitrogen was applied in splits half at planting and half at tillering while all phosphorus was applied at planting. Improved bread wheat variety (TAY) was used as a test crop. Lime was not applied during the second year while the rate of nitrogen and phosphorus were similar to the first year. The amount of lime required based on the extent of soil acidity in the first year (before planting) was indicated in Table 1.

Table 1. Extent of soil acidity and required lime for each sites based on equation 1

location	pH	Ex. Al	EX.H	Ex. Acidity	OM	BD	Textural class (%)			Lime kg ha^{-1}	Lime kg ha^{-1} (1.5x)
							clay	silt	Sand		
Tsegure	5.24	0.16	0.29	0.69	1.88		43	37	20	637	1009
Miynet	5.24	1.02	0.53	1.31	2.17		63	27	10	1277	1916

Economic analysis

To support the biological responses with economic justification, the net present value was used. The return to farmers from wheat production under different lime and phosphorous rates was estimated by net present value (NPV) over the two years. NPV is defined as “present worth of benefits less present cost of a project’’ (Vincent et al., 2010; Macharia et al., 2006; Gittinger, 1982). It is mathematically expressed as:

$$NPV=\sum_{t=2}^{n} (B_t-C_t)/(1+i)^t \quad \text{..... equation 2}$$

Where: $(B_t – C_t)$ = Net Benefits at time t years

$(1 + i)^t$ = Discounting Factor

i = interest rate (%)

Costs of phosphorous fertilizers, lime, Wage for lime and fertilizer application and production prices were collected. The discount rate was taken as the opportunity cost of capital, which is defined as “that rate which will result in the utilization of all capital if all possible investments were undertaken”. Interest rate of capital was taken as 5 percent per year and the time (t) for two years. Different treatments were ranked on basis of their NPV value and those with NPV > 0 were acceptable as economically viable investments. The mean cost of Urea, DAP and lime were, 6.49, 7.67 and 0.85 Ethiopian Birr per kilogram respectively in 2011/2012 and 12.11, 13.91 and 1.55 respectively in 2012/2013. The cost of labor was 40 birr/man/day. The price of wheat was 6.17 Birr in 2011/2013 and 8.36 Birr in 2012/2013.

To make strong economic feasible recommendation incremental benefit analysis was also conducted based on the following equation

$INB^i_j = NB^i_j - NB^i_0$ .... Equation 3

Where:

INB^i_j = the incremental net benefit of option j over the farmer's practice in season (i) in birr ha^{-1}.

NB^i_j =the net benefit of option j, in season i, in birr ha^{-1}.

NB^i_0= the net benefit from the farmer's practice (without any lime and fertilizer) in season i, in birr ha^{-1}.

Results and discussions

Influence of lime and phosphorous fertilizer on yield and yield components of bread wheat

The soil analysis result showed that the two locations were different in exchangeable acidity, organic matter (OM) and texture (Table 1). According to Hazelton and Murph (2007), suitable soil pH for wheat production was 5.5 to 7 (Fenton and Helyar, 2007). The pH of the testing sites was below 5.5 indicating that wheat production was greatly affected by soil acidity. Similarly, the critical aluminum levels extracted by $CaCl_2$ solution for wheat were 0.4 to 0.8 ppm, above which aluminum becomes toxic and affects wheat production (Fenton and Helyar, 2007). The soil analysis result showed that aluminum content of the soil was greater than the critical level at Minet (1.31 ppm) whereas at within the range (0.69 ppm) at Tsegure (Table 1).

Statistical analysis of variance revealed that there was significant variation among the treatments and locations as well as the interactions. Addition of lime equivalent to 150% of the soil exchangeable acidity with 46 kg P_2O_5 ha^{-1} gave the maximum gain yield (Table 2; Table4) in 2012 cropping season. However, there was no significant difference among phosphorus rates at Minet. In the second year the result followed similar trends in grain yield. The maximum grain yield was recorded by applying lime (1.5X) + 46 kg P_2O_5 ha^{-1}. The yield advantage of lime (1.5X) + 46 P_2O_5 kg ha^{-1} over the recommended N and P was 20% (750 kg ha^{-1}) (Table 2). The grain yield was increased by 3290 kg (261%) compared to the control. The result indicates that wheat yield can be improved in acidic soils through the integrated use of chemical fertilizer and lime.

Table 2. Response of wheat grain yield (t ha^{-1}) to lime and P fertilizer at Minet

	Year		
Treatment	2012	2013	Combined
1	1.98^{d}	0.54^{d}	1.26c
2	5.06^{c}	2.06^{bc}	3.80b
3	5.62^{abc}	2.49^{ab}	4.06ab
4	5.39^{bc}	1.92^{c}	3.64b
5	5.83^{ab}	2.26^{bc}	3.82b
6	5.59^{abc}	2.11^{bc}	3.85b
7	6.19^{a}	2.92^{a}	4.55a
CV (%)	7.97	14.83	14.33
LSD (0.05)	0.72	0.54	0.60

Considering the straw yield at Minet, there was significant variation among treatments (Table 3). The maximum straw yield was obtained from lime (1.5 X) + 46 kg P_2O_5 ha^{-1} combined over years (Table 3). However there was no significant difference between using lime (1.5 X) lime (blanket recommendation). Straw yield was increased by 19% using lime (1.5X) + 46 kg P_2O_5 ha^{-1} compared to using recommended fertilizer alone (Table 3). Using no lime and fertilizer resulted in a straw yield penalty of 239%. The result indicates that farmers could reclaim their soils and significantly enhanced the productivity of the crop.

Table 3. Response of straw (t ha^{-1}) to lime and Phosphorous fertilizer at Minet

	Year		
Treatment	2012	2013	Combined
1	3.50^{d}	1.16^{c}	2.33^{d}
2	9.39^{bc}	3.92^{ab}	6.65^{bc}
3	10.28^{ab}	4.56^{a}	7.42^{ab}
4	9.30^{bc}	3.53^{b}	6.42^{bc}
5	8.55^{c}	3.99^{ab}	6.27^{c}
6	110.24ab	4.57^{a}	7.40^{ab}
7	11.17^{a}	4.60^{a}	7.89^{a}
CV (%)	7.48	22.68	18.54
LSD (0.05)	0.60	0.77	0.70

Similarly, there was significant difference among treatments for grain and straw yields at Tsegure (Table 4; Table 5). The highest grain yield was obtained from lime (1.5X) + 46 kg P_2O_5 ha^{-1} combined over years. A grain yield advantage of 1190 kg ha^{-1} (125 %) was observed from lime (1.5X) + 46 kg P_2O_5 ha^{-1} compared to the control. Likewise, 560 kg ha^{-1} (35%) grain yield advantage was obtained from lime (1.5X) + 46 kg P_2O_5 ha^{-1} compared to the recommended NP alone (Table 4).

Table 4. Response of grain yield (t ha^{-1}) to lime and P fertilizer at Tsegure

	Yield		
Treatments	2012	2013	Combined
1	1.39^{d}	0.42^{d}	0.95^{c}
2	2.74^{c}	0.49^{cd}	1.58^{b}
3	3.05^{bc}	0.73^{b}	1.82^{ab}
4	3.01^{bc}	0.61^{bc}	1.83^{ab}
5	3.09^{abc}	0.65^{b}	1.73^{ab}
6	3.40^{a}	0.60^{bc}	1.79^{ab}
7	3.24^{ab}	1.04^{a}	2.14^{a}
CV (%)	7.04	11.80	22.50
LSD (0.05)	0.36		0.45

The maximum straw yield was recorded from lime (1.5X) + 46 kg P_2O_5 ha^{-1} while the lower was from the control at Tsegure (Table 5). There was 169% straw yield advantages by lime (1.5X) + 46 kg P_2O_5 ha^{-1} over recommended NP alone and 269% straw yield advantage over the control. Generally the grain and straw yield at Tsegure were lower than at Minet related to the inherent soil fertility difference between the two sites.

Table 5. Response of straw (t ha^{-1}) to lime and phosphorous fertilizer at Tsegure

	Year		
Treatment	2012	2013	Combined
1	2.53^{d}	1.03^{c}	1.78^{d}
2	4.01^{c}	1.50^{bc}	2.78^{c}
3	4.70^{b}	1.92^{b}	3.31^{bc}
4	4.87^{b}	2.20^{b}	3.53^{ab}
5	5.25^{ab}	1.61^{bc}	3.43^{abc}
6	4.72^{b}	1.89^{b}	3.64^{ab}
7	5.67^{a}	3.26^{a}	4.47^{a}
CV (%)	7.48	22.68	18.54
LSD(0.05)	0.60	0.77	0.70

The result of this finding was in conformity with Abaye (2011) who reported that application of lime alone did not influence maize production at Areka; however, application of lime with fertilizer generally increased maize production. He indicated that the maximum maize grain yield was obtained from the integrated application of NP and lime. Reports from Ethiopian Institute of Agricultural Research also indicated that 1.5X exchangeable acidity with 20 and or 40 kg ha^{-1} P was recommended in Banja, Endibir, Nejo and similar agro-ecologies (unpublished data). Report in Nigeria, also showed that combination of lime and P brought optimum plant growth (Oluwatoyinbo *et al*., .2005). A green house experiment conducted by Achalu *et.al*. (2012) also revealed that 10 t lime ha^{-1} with phosphorus gave maximum yield. Legesse *et al*., (2013) also indicated that lime increase yield of common bean by 26 % at Nejo, in Western Ethiopia. Furthermore, Kidanemariam *et al*., (2013) obtained 233-239 % grain yield from lime and recommended fertilizer over the control (no input) which is inline with our finding.

Effect of lime on soil chemical properties

Soil pH of the surface soil (0-20 cm) increased from 5.24 to 5.73-5.77 and exchangeable acidity was reduced from 1.31-1.92 to 0.71 using liming at Minet (Table 6). Exchangeable aluminum (very toxic and hinders crop growth) was lowered from 1.02 cm mole kg^{-1} of soil to 0 due to lime application at Minet. Similarly, at Tsegure, soil pH was increased from 5.24 to 5.75 and exchangeable acidity was reduced from 0.81to 0.71 due to lime (Table 6). Exchangeable aluminum concentration was lower than exchangeable hydrogen at Tsegure and could not be toxic to crop. It becomes zero after lime application and hence the effect on crop yield may rather be from hydrogen.

In general, application of lime increased soil pH and reduced exchangeable aluminum and hydrogen and increased grain and biomass yield of wheat. According to the present study, the significant improvement of soil pH and exchangeable acidity was due to high rate of lime in Minet. The amount of lime required in Minet was doubled as compared to Tsegure due to varied soil buffering capacity of the two (Table 1). Soil buffering capacity governs the amount of lime required and it is governed by soil texture, cation exchange capacity and organic matter content. The soil textural class of the study sites was 63% clay. The exchangeable aluminum concentration of the soil was very high and organic matter content was better at Minet than Tsegure which might increased lime requirement.

Table 6. Extent of soil acidity at harvest in 2012

		Minet		
Treatment	pH	Ex. Al	Ex. H	Ex. Acidity
1	5.24	1.02	0.53	1.31
2	5.28	1.02	0.90	1.92
3	5. 77	0	0.71	0.71
4	5.40	0	0.71	0.71
5	5.77	0.07	0.75	0.82
6	5.66	0	0.71	0.71
7	5.73	0	0.71	0.71
		Tsegure		
Treatment	pH	Ex. Al	Ex. H	Ex. Acidity
1	5.24	0.29	0.75	0.81
2	5.23	0.30	0.73	0.76
3	5.75	0	0.71	0.71
4	5.72	0	0.71	0.71
5	5.71	0	0.71	0.71
6	5.72	0	0.71	0.71
7	5.68	0	0.71	0.71

Economic analysis

NPV was positive for all tested treatments except the control at Minet and Tsegure (Table 7).

Table 7. Net present value and benefit analysis for lime and phosphorous fertilizer rate at Minet and Tsegure

Treatments	Location					
	Minet			Tsegure		
	NPV	INB	Rank	NPV	INB	Rank
1	0.00	0.00	7	0.00	0.00	7
2	684.43	24639.40	6	51.20	1843.30	5
3	819.71	29509.40	3	30.40	1094.40	6
4	689.08	24806.85	5	105.95	3814.15	4
5	823.91	29660.90	2	109.42	3939.00	3
6	749.25	26973.05	4	152.24	5480.65	2
7	1019.2	36692.50	1	206.05	7417.70	1

For all the study sites the NPV of lime and phosphorus application showed a positive value leading to rejection of null hypothesis (H_0) that lime technologies are less cost-efficient to enhance soil fertility, crop yields and finally livelihoods within short time (Table 7). Accordingly these results suggested that all treatments at Minet and Tsegure are economically feasible as the NPVs are greater than zero (NPV > 0). Maximum NPV (1019.2 Birr) with incremental benefit (36692.5 Birr) was obtained from lime (1.5X) + 46 kg P_2O_5 ha^{-1} at Minet while the lower NPV was obtained from the control (Table 7). The second highest NPV (823.91 Birr) with incremental benefit (29660.9 Birr) was obtained from lime (1.5X) + 23 kg P_2O_5 ha^{-1}. Similarly, at Tsegure, the highest NPV (206.05 Birr) with an incremental net benefit (7417.7 Birr) was obtained from lime (1.5X) + 46 kg P_2O_5 ha^{-1}while the second highest NPV (152.24 Birr) with incremental benefit (548.65 Birr) was obtained from lime (1X) + 46 kg P_2O_5 ha^{-1} (Table 7). The result is inconformity with the findings of Macharia *et al.,* (2006). The difference in NPV and incremental benefit between the study sites was related to the soil fertility status of the sites. Minet site has better fertility status compared to Tsegure site which is highly degraded.

Conclusion and recommendation

From the biological yield, soil and economic analysis results, it is possible to conclude that the liming factor is 1.5 times the exchangeable acidity. The result also confirmed that lime has great influence on grain and straw yield as well as improving chemical soil properties. The improvement in yield and economic return due to lime and phosphorous fertilizer in acidic soils of the west Amhara highlands is appreciable. However, farmers' knowledge on the effect of lime on soil properties, how to use lime to reclaim acidic soils, source of lime and the like should be upgraded. The policy makers should take the lead in availing lime in required amount to the farm gate so that the farmers can get it easily with affordable price.

Therefore, from the result, it is possible to recommend lime amount determined using 1.5X exchangeable acidity can be used as correction factor for lime calculation using exchangeable acidity. This finding should be further refined for different soil types and agro-ecologies. The calcium carbonate equivalency and finesse of Ethiopian liming materials should be studied. Fertilizer rate studies for acidic soils should also be integrated with lime.

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Evaluation of Togo blended fertilizer on Teff and bread wheat yields in the Amhara Highlands

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Abstract

A field experiment was conducted on farmers' field in 2010/11 to evaluate the effect of Togo blended fertilizer on teff and bread wheat yields in the Amhara highlands, Ethiopia. The experiment was conducted on Vertisols and Nitisols and arranged in a randomized complete block design in three replications. Analysis of variance was implemented using SAS statistical software and LSD was used for the mean separation. The result revealed that there was significant difference among treatments on grain and biomass yields for both crops at all locations. The maximum teff grain yield was obtained from the blanket recommended nitrogen and phosphorus at Gonjikollela, Moretnajiru and Jamma and from Togo blended fertilizer at Enemay. The maximum grain and straw yields of bread wheat were also obtained from the plots that received from the blanket recommended nitrogen and phosphorus at all locations. From the multi location results it is visible/can be concluded/ that using this blend has no yield advantage over the blanket recommended nitrogen and phosphorus fertilizers. Thus, further studies shall be done for other blends based on soil test crop response.

Key words: Togo, blend, grain yield, nitrogen, phosphorus.

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Introduction

Inorganic fertilizer is one of the best agricultural technologies that have immense potential for raising the productivity of poor smallholders, enabling them to increase income, accumulate assets, and set themselves economically on a pathway out of poverty. In Ethiopia enhancing the productivity of the agricultural sector by wisely exploiting its existing human and natural resources is critical option to avert the existing situation. Ethiopia is one of the sub-Saharan African countries where severe soil nutrient depletion restrains agricultural crop production and economic growth. The annual per-hectare net loss of nutrients is estimated to be at least 40 kg N, 6.6 kg P and 33.2 kg K (Scoones and Toulmin, 1999). Continuous cropping, high proportions of cereals in the cropping system, and the application of suboptimal levels of mineral fertilizers aggravate the decline in soil fertility (Hailu et al., 1991; Amsal et al., 2000). The identification of the proper fertilizer mix is beneficial at the macroeconomic level by improving the efficiency of fertilizer procurement and resource allocation. It is generally understood that crop response to fertilizer inevitably declines, if nutrient applications are continually unbalanced. But if harvested nutrients are replaced, intensive agricultural systems can be sustained indefinitely, provided that measures are taken to halt soil erosion and to minimize detrimental changes in soil pH.

To address the problem of macro and micro nutrients imbalance, an experiment was conducted on blended fertilizers in the year 2010/2011cropping season in Amhara region, Ethiopia. Blended fertilizers have been available for much of this century but the early forms of fertilizers have left much to be desired. The practice of blending started in the early 1950s, and grew slowly at first, but then grew rapidly throughout the 1960s and into the 1970s. In 1980 blended fertilizer accounted for 40% of the finished fertilizer in the developed nations and now-a-days blended fertilizers accounted for 55% of the total dry compound fertilizers (unpublished working paper). Blending system incorporated the different raw materials into a multi-nutrient granule and mad one physically mixed product. The equipment to produce these mixed granules, however, was cumbersome and expensive and mixed granulated fertilizers were soon supplanted by bulk blends (unpublished working paper). Blended fertilizers are made by physically mixing fertilizer materials to give a desired grade. The individual particles remain separate in the mixture, and segregation may occur. This problem can be reduced by using materials with the same particle size. Blends are equal in agronomic efficiency as far as the blending of fertilizers is done properly that can reduce segregation problem. Blends have the added advantage of allowing a very wide range of fertilizer grades, thus making it possible to match a fertilizer exactly to a soil test recommendation. Micronutrients can enhance plant growth and stress tolerance – if they are absorbed into the plant and transported where they can do their job. One of the blended fertilizers called Togo 26-11-11 N-$P_2O_5K_2O$ (Togo blend) was evaluated for a year in different districts of the Amhara region, Ethiopia. Therefore the objective of the experiment was to evaluate the effects of Togo 26-11-11 N-$P_2O_5K_2O$ (Togo blended) fertilizer on yields of bread wheat and teff.

Materials and Methods

Table 1. Description of the Study Area

parameters	Districts						
	YilmanaDensa	Gonjikollela	Enemay	Debre Elias	Moretinajiru	Jamma	Wereyilu
Soil type	Nitisols	Nitisols	Vertisols	Nitisols	Vertisols	Vertisols	Vertisols
Altitude (mm)	2240	2000	2650	2200	2635-2669	2600-2630	2600-2630
Mean annual rain fall (mm/annum)	1200	1200	1187	1320	910	868.2	868.2
Max Temp	22.5-29 ^{O}C	30.7 ^{O}C	34.5 ^{O}C	24.8^{o}c	25.5 ^{O}C	21.6 ^{o}C	21.6 ^{o}C
Min Temp	5.4-12.1 ^{O}C	11.9 ^{O}C	13.7 ^{O}C	8.3 ^{o}c	11.9 ^{O}C	9 ^{o}C	9 ^{o}C
Longitude	37^{0}28’ 38” to 37^{0} 29’ 50”		38^{0} 23’	37^{o}27’54”	39^{o} 9’7.9” to 39^{o} 11’4.6”	39^{o} 15’	
Latitude	11^{o} 16’19” to 11^{o} 17’28”		10 ^{o} 47’	10^{o} 17’ 47”	9^{o} 52’22.6” to 9^{o} 55’10.6”	10^{o} 27’	

Treatments, experimental design and field layout

The experiment was laid down in a randomized complete block design in three replications. The treatments were (1) Control (without any fertilizer), (2). Blanket recommended N and P (64/46 kg N/P_2O_5 ha^{-1}) (3) Togo blended fertilizer @ 200 Kg ha^{-1} (Togo 26-11-11 N-P2O5 -K2O + 3.5S + 0.15 B2O3 0.6 Zn), (4) Togo blended fertilizer @ 200 Kg ha^{-1}+ N adjusted to the blanket recommendation using urea and (5) Togo blended @ 200 Kg ha^{-1}+ NP adjusted to the blanket recommendation using urea and DAP respectively. Nitrogen was applied in split i.e. half at planting and half at tillering whereas all P (DAP) and Togo blend were applied at planting. The plot size was 3mx5m. The locations for teff were GonjiKollella, Enemay, Moretnajiru, and Jamma. While the locations for bread wheat were GonjiKollella, Debre Elias, Wereyilu and Moretnajiru. The varieties used were Kuncho for Teff at all locations except Jamma (where local teff variety was used) and for the bread wheat TAY variety was used at Yilmana Densa, GonjiKollella and Debre Elias, Menzie variety at Moretnajiru and Dinkinesh variety at Wereyilu. Teff was broadcasted while bread wheat was drilled on 20 cm row spacing.

Data analysis

Analysis of variance was carried out for yield and yield components using SAS statistical package (SAS Institute, 2002) following statistical procedure appropriate for the experimental design. Whenever, treatment effects were found statistically significant, the means separation was done using Least Significant Difference (LSD) at 5% significant probability level.

Results and discussions

Effect of Togo blended fertilizer on Teff (*Eragerostis tef* (Zucor…) **yield**

The statistical analysis revealed that there was significant difference among the treatments on teff grain yield at all locations (Table 2). However, there was no statistically significant difference between the blanket recommended N and P (64/46 N/P_2O_5), Togo blend @ 200 kg ha^{-1}+ N adjusted to the blanket recommended N (64 kg N ha^{-1}) using urea and Togo blend @200 kg ha^{-1}+ N/P adjusted to blanket recommended N and P (64/46 kg N/P_2O_5 ha^{-1}) using urea and DAP respectively at Enemay, Moretnajiru and Jamma districts. However, at Gonjikollela Togo blend was inferior to the blanket recommended N and P when it was used alone and with N and NP adjusted to the blanket recommendations (Table 2).

Even though, there was no significant difference between the blanket recommended N and P and Togo blend @200kg ha^{-1} N and NP adjusted to blanket recommendation at Enemay, high yield was recorded using Togo blend @200 kg ha^{-1} + N and P adjusted to the blanket recommendation using using and DAP respectively. On the contrary high yield was obtained from the blanket recommended N and P in Gonji Koellela, Moretinajiru and Jamma. The lowest yield at all locations and soil types was obtained from the control plots (without fertilizer) (Table2). Togo blend @200 kg ha^{-1} alone gave lower yield compared to 64 kg ha N and 46 kg $ha^{-1}P_2O_5$ at all locations (Table 2).

Table 2. Effect of Togo blended fertilizer on teff grain yield (kg ha^{-1}) in different locations in 2010/2011

treatments	Grain yield kg ha^{-1}			
	Enemay	Gonjikollela	Moretnajiru	Jamma
Control (without any fertilizer)	496.7[c]	176.7[c]	784.1[c]	507b
NP recommended (100/100 urea/DAP)	1215.0[ab]	1770.0[a]	1338.1[a]	815a
Togo blend @ 200Kg/ha	950.0[b]	1061.7[b]	1151.0[b]	758a
Togo blend @ 200Kg/ha + N adj	1351.7[a]	1171.7[b]	1249.3[ab]	730a
Togo blend @200Kg/ha + NP adj	1446.7[a]	1351.7[b]	1247.6[ab]	776a
CV (%)	14.95	14.50	14.4	12.4
LSD (0.05)	307.46	302.18	137.9	

Similarly, there was statistically significant difference ($P<0.05$) among the treatments in teff straw yield. At Gonji kollela and Moretnajiru the highest straw yield was obtained from blanket recommended N and P (64/46 N/P_2O_5) (Table 3). While, the highest straw yield was obtained from Togo blend @ 200 Kg ha^{-1} + N and P adjusted at Enemay and Jamma (Table 3). The lowest straw yield was obtained from the control (without fertilizer) at all locations (Table 3). However, there was no significant difference in straw yield among the blanket recommended N and P, Togo blend @ 200 Kg ha^{-1} + N adjusted to the blanket recommendation using urea and Togo blend @ 200 kg ha^{-1} adjusted with N and P in Moretnajiru and Jamma (Table 3).

Table 3. Effect of Togo blended fertilizer on teff straw yield (kg ha^{-1}) combined over locations.

Treatment	Straw kg ha^{-1}			
	Enemay	Gonjikollela	Moretnajiru	Jamma
Control (without fertilizer)	1166.7[d]	350.0[c]	2122.2[c]	1902b
NP recommended (100/100 urea/DAP)	1833.3[c]	5333.3[a]	4167.2[a]	2777a
Togo blend @ 200Kg/ha	2050.0[c]	4000.0[ab]	3421.7[b]	2824a
Togo blend @ 200Kg/ha + adj N	3500.0[b]	3666.7[b]	3885.1a	2495ab
Togo blend @200Kg/ha +adj NP	5000.0[a]	4666.7[ab]	3925.1[a]	2807a
CV (%)	12.77	22.39	13.1	12.4
LSD (0.05)	651.71	1519.6	378.8	

Effect of Togo blended Fertilizer on Wheat (*Triticum aestivum*) yield

The statistical analysis showed that there was significant difference in bread wheat grain yield among the treatments. Higher grain yield was obtained from the blanket recommended N and P (64/46 kg N/P_2O_5 ha^{-1}) at all locations (Table 4). However, there was no statistically significant difference between the blanket recommendation (64/46 N/P_2O_5), Togo blend @ 200 Kg ha^{-1} + N adjusted using Urea and Togo blend @200Kg ha^{-1} +NP adjusted using urea and DAP at Morenajiru and Wereyilu (Table 4). On the contrary there was significant difference between the blanket recommended N and P and Togo blend@ 200 kg ha^{-1}, Togo blend @ 200 kg ha^{-1} + N adjusted to blanket recommendation using urea and Togo blend @ 200 kg ha^{-1} + NP adjusted to blanket recommendation using urea and DAP at Gonjikollela. At Debre Elias there was no significant difference between the recommended N and P fertilizer and Togo blend @200 kg ha^{-1} + NP adjusted. The highest grain yield was obtained from blanket recommended N and P in the aforementioned districts (Table 4).

Table 4. Effect of Togo blended fertilizer on wheat grain yield combined over locations in each district.

treatments	Grain yield (kg ha^{-1})			
	Gonjikollela	DebreElias	Moretnajiru	Wereyilu
Control (without any fertilizer)	929.7^{c}	1202.0^{bc}	838.8^{c}	4363b
NP recommended (100/100 urea/DAP)	2335.5^{a}	1726.3^{a}	2125.2^{a}	6004a
Togo 26-11-11 @ 200Kg/ha	1600.3^{b}	1128.9^{c}	1793.1^{b}	5030.5ab
Togo 26-11-11 @ 200Kg/ha + adjusted for N	1491.1^{b}	1224.6^{bc}	2112.4^{a}	5919.2a
Togo 26-11-17 @200Kg/ha +adjusted for NP	1683.5^{b}	1485.4^{ab}	2023.9^{a}	5586.4a
CV (%)	11.29		9.0	16.8
LSD (0.05)	273.94	287.85	132.7	

There was statistically significant difference among the treatments on straw yield. The highest straw was obtained from the blanket recommended NP (64/46 kg ha^{-1}) followed by Togo blend @200 Kg ha^{-1} + N and NP adjusted to the blanket recommendation using urea and DAP at Moretnajiru and Wereyilu while the lower straw yield was recorded from the control (without fertilizer) at all locations (Table 5). However, the result on mean straw yield indicated that there was no significant difference among the blanket recommendation, Togo blend @ 200 kg ha^{-1} with adjusted N and NP. However, these treatments were significantly different compared to Togo blend@ 200 kg ha^{-1} and the control (Table 5).

Table 5. Effect of Togo blended fertilizers on yield of wheat over locations.

Treatments	Straw yield (kg ha^{-1})			
	Gonjikollela	DebrElias	Enemay	Wereyilu
Control (without any fertilizer)	699.7^{d}	1631.3^{ab}	1966.0^{c}	4363b
Blanket recommended NP (100/100 urea/DAP)	2497.8^{a}	2148.7^{a}	5052.1^{a}	6004a
Togo blend @ 200Kg/ha	720.3^{cd}	1371.2^{b}	4228.4^{b}	5030.5ab
Togo blend @ 200Kg/ha + adjusted for N	1242.3^{c}	1567.0^{ab}	4975.9^{a}	5919.2a
Togo blend @200Kg/ha +adjusted for NP	1816.5^{b}	1931.2^{ab}	4873.5^{a}	5586.4a
CV (%)	20.08	20.75	8	16.8
LSD (0.05)	527.66	675.98	160.8	

Generally, Togo blend was not superior with or without N and P adjusted with urea and DAP to the blanket recommendation in all locations and soil types considered. Even though blended fertilizers have more nutrient composition and expected to give better yield than the straight fertilizers, the result was to the contrary. The lower yield from Togo blend @200 kg ha^{-1} with and without N and NP adjustment might be attributed to segregation in the blended fertilizer as reported by Miserquea and Pirard (2004). The yield obtained from the experiment for both crops (teff and wheat) as a whole at all locations and from all fertilizer types was lower and the crops didn't give higher yield to their potential (Table 2, 3, 4 and 5).

The reason for the lower yield from Togo blend @ 200 kg ha^{-1} with or without adjusted N or NP might be due to antagonistic effect of the nutrients in the blend as reported by Rietra *et al.*, (2015) observing antagonistic effect between potassium and zinc nutrients when they were blended together or applied to the field at the same time. Similarly, Beegle (1985) and Leonard (1996) also reported that using urea and diammonium phosphate during planting as starter fertilizer with blend fertilizer can hinder seed germination and seedling growth. Hence, since in this experiment, Togo blend, urea and DAP were applied during planting this might cause antagonistic effect against each other that might resulted in lower yield (grain and straw) in Togo fertilizer with or without adjustment. Therefore, the negative effects like segregation and antagonism should be further studied in details through applying the blend, urea and DAP at the same and/or different time. The straw and grain yields were not proportional at all locations and this might be due to the fact that the experiment was implemented late and may lack proper rainfall amount for full seed set and maturity. In addition, the amount of applied blanket recommended N and P fertilizer was so obsolete and didn't consider the area specific crop response fertilizer recommendation and hence might result in the lower yield. Therefore, before conducting on farm experiments, the blended fertilizers should be evaluated at laboratory and green house condition for appropriate formulation. Segregation of non-uniform particles can occur in a number of different aspects of manufacturing, distribution, transport and final spreading. Fertilizer flowing characteristics may vary and led to segregation within heaps in store depending on if tipped or use of elevators. Vibration may also lead to segregation in transport from ship to the site, or from site to the farm.

Conclusion and recommendations

Togo blended fertilizer with a composition of 26-11-11 N-P_2O_5 -K_2O + 3.5S + 0.15 B_2O_3 0.6 Zn did not outsmart urea and DAP fertilizers in all experimental sites and soil types. Even though the blanket recommended N and P (64/46 N and P_2O_5) was not the site specific recommendation, Togo blended fertilizer didn't give higher yield compared to this blanket recommendation which is widely recognized outdated in the potential wheat and teff growing areas of the Region. There might be different suggestions that need detailed research justifications and evidences like the status of potassium in those soils, the uniformity of size and shape of the blend and the antagonistic effect of different fertilizer compositions in the blend. Therefore, before conducting such country wide experiments detailed research should be conducted in laboratory and green house experiments to see whether there is segregation and or antagonistic effect on this blended fertilizers even though this procedure is time taking.

Generally, the experiment showed that Togo blended fertilizer with the composition of -11-11 N-P_2O_5 -K2O + 3.5S + 0.15 B_2O_3 0.6 Zn at 200 kg ha^{-1} with or without N and NP adjustment was unable to outsmart the blanket recommended N and P (64/46 kg N/P_2O_5) so as to replace the existing NP fertilizers. Though there was no significant yield difference between the blanket recommended N and P fertilizer Togo blend @200 kg ha^{-1} can't be used as an alternate fertilizer due to its bulkiness i.e. double in weight compared to the N and P and incurred transporaion cost. In addition, with no yield advantage it might have additional cost to N and P due to the blends since the blend was adjusted by N and NP. Hence, it is advisable to study the biological requirement of the crops and the economics of using the additions.

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Evaluation of Yara Mila Cereal on Wheat (*Triticum aestivum*) and Teff (*Eragrostis tef*) Yield in Amhara Region

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Abstract

A field experiment was conducted in North Shewa, East and West Gojam, and South Wello administrative zones on farmers' fields to evaluate the effects of Yara Mila cereal fertilizer on yield of wheat and teff. The treatments were control without fertilizer, Urea and DAP at 100/100 kg ha^{-1} (as NP blanket Recommendation), Yara Mila at 150 kg ha^{-1}, Yara Mila at 200 kg ha^{-1}, and Yara Mila at 200 kg ha^{-1} + Adjusted NPK requirements. The wheat varieties used were Menzie for North Shewa, TAY for East and West Gojam and Dinknesh for South Wello while Kuncho teff variety was used for all sites. The seed rate was 175 kg ha^{-1} for wheat and 30 kg ha^{-1} for teff. All agronomic data were collected and subjected to statistical analysis using SAS version 9. The results showed significant differences in mean straw and grain yield for wheat and tef compared to the control (no fertilizer) treatment at all locations. But, application of Yara Mila at 200 kg ha^{-1} with and without adjusted NPK didn't give additional yield in both crops compared to the blanket recommended NP fertilizers. This may be due to the fact that the NP content of fertilizer was low. Yara Mila at 200 kg ha^{-1} with adjusted NPK has no difference in yield compared to blanket recommended NP but it couldn't be used as alternate fertilizer source due its bulkiness that adds about 100% of the blanket recommended NP.

Key word: teff, Yara Mila, wheat, NP, yield

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Introduction

Ethiopia is one of the sub-Saharan African countries where severe soil nutrient depletion restrains agricultural crop production and economic growth. The annual per-hectare net loss of nutrients is estimated to be at least 40 kg ha^{-1} N, 6.6 kg ha^{-1} P and 33.2 kg ha^{-1} K (Scoones and Toulmin, 1999). Continuous cropping, high proportions of cereals in the cropping system, and the application of suboptimal levels of mineral fertilizers aggravate the decline in soil fertility (Hailu *et al.,* 1991; Amsal *et al.,* 2000). Due to the presumed sufficiency of other nutrients in the past, more research emphasis was given to the replenishment of N and P. Other important major nutrients like K, and secondary nutrients like S and some important micronutrients like Zn and Cu received less attention. However, the importance of these nutrients in yield enhancement and quality improvement has been reported by few studies in the country. In addition to these factors that contributing to low productivity of cereals is low soil fertility through nutrient depletion by nutrient removal with harvest, tillage, weeding, and losses in runoff and soil erosion (Oldeman *et al.,* 1991; Gebregziabher *et al.,* 2006). Most of the time in cereals production areas of Ethiopia compensating of the loss of nutrients is not practiced to mitigate the negative nutrient balances (Stoorvogel *et al.,* 1991)

Low cereal productivity problem can be alleviated through the improvement of nutrient availability through the application of inorganic or organic fertilizer or their combination (Kaizzi *et al.,* 2007). Even though the great efforts had been done on the use on N and P sources fertilizers to improve the yield of tef and wheat by farmers, the non affordable cost of inorganic fertilizer and high risk in utilization of fertilizer technology is a major challenge

The identification of the proper fertilizer mix is beneficial at the macroeconomic level by improving the efficiency of fertilizer procurement and resource allocation. It is generally understood that crop response to fertilizer inevitably declines if nutrient applications are continually unbalanced. But if harvested nutrients are replaced, intensive agricultural systems can be sustained indefinitely, provided that measures are taken to halt soil erosion and to minimize detrimental changes in soil pH.

Based on this consensus, fertilizers containing different macro and micro nutrients have been evaluated for their effect on yields of crops. Blends have the added advantage of allowing a very wide range of fertilizer grades, thus making it possible to match a fertilizer exactly to a soil test recommendation (Young, 1987). Micronutrients can enhance plant growth and stress tolerance if they are absorbed into the plant and transported where they can do their job. An example of the blended fertilizers called Yara Mila N-P_2O_5-K_2O containing was evaluated for a year in different districts of the Amhara Region, Ethiopia. Therefore the objective of the experiment was to evaluate the effects of Yara Mila cereal compound fertilizer and comparing with blanket recommended urea and DAP fertilizers on yield and yield components of bread wheat and teff.

Materials and Methods

Description of the Study Area

The field experiment was conducted in 2010/11 cropping season in North Shewa (Enewwari, and Bakelo), East and west Gojam (Enemay, Debre Elias and Gonji kolela) and South Wello (Jamma and Wereillu) on six, nine and six farmer's field respectively. These areas are known for their high rainfall, mid-to-high altitude and potential for wheat production. East Gojam is particularly potential for Tef production on both Vertisols and Nitosols.

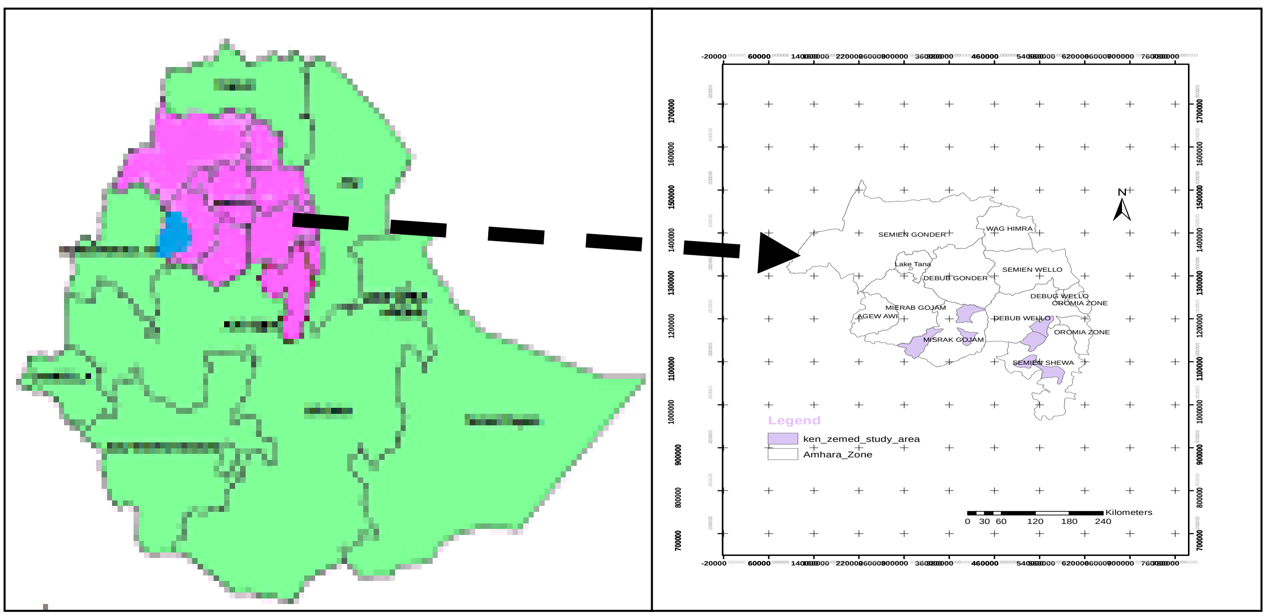

Figure1. Description of the study areas

Table 1 Agro-ecological features of the experimental locations

Parameters	Units	Enewari	Bakelo	Gonji kolela	Debre Elias	Enemay	Jamma	Wereillu
Soil Type	_	Vertisol	Vertisol	Nitosol	Nitosol	Vertisols	Vertisols	Vertisols
Altitude	m	2653	2837.0	2000	2200	2650	2630	2630
Rain fall	mm	899.0	910.0	1200	1320	1187	868.2	868.2
Min Temp	^{o}C	9.7	6.7	30.7	24.8^{o}c	34.5 ^{O}C	21.6 ^{o}C	21.6 ^{o}C
Max Temp	^{o}C	21.5	19.7	11.9	8.3 ^{o}c	13.7 ^{O}C	9·0^{o}C	9.0 ^{o}C

Experimental Design

The experiment contains five treatments in Randomized Complete Bock Design (RCBD) with 3 replications. The test crops used for the experiment were bread wheat (Menzie variety at North Shewa, TAY variety at East and west Gojam and Dinknesh at South Wello) and teff (Kuncho Variety for all sites). The seed rate used for wheat and teff were 175 and 30 kg ha^{-1} respectively. The treatments were; (1) Control (No fertilizer), (2) Recommended fertilizer rate (64/46 N/P_2O_5 kg ha^{-1}), (3) 150 kg ha^{-1}Yara Mila cereal (N-P_2O_5 -K_20-MgO-S-Zn /23-10-5-2-3-3), (4) Yara Mila 200 kg $ha^{-1}$and (5) Yara Mila 200 kg ha^{-1} with adjusted N-P_2O_5 to the recommended rate /23-10-5-2-3-3). The plot size was 3.6m X 4m (three broad bed furrows for wheat and flat for tef). Yara Mila cereal and N were applied by splitting ½ at planting and ½ at tillering stages of test crops while all phosphorus was applied at planting. Data were collected on plot basis and extrapolated in to a hectare basis.

Data Analysis

The data collected from the field study were subjected for analysis of variance (ANOVA) using SAS software (SAS, 2004). Whenever treatment effects were significant, mean comparison were made using least significant difference (LSD (0.05)) statistical technique.

Results and Discussions

Effect of Yara Mila Cereal on Bread Wheat

Analysis of variance showed that wheat grain yield was significantly (P<0.05) affected by the fertilizers for all locations. At all locations, the highest grain yield was obtained from blanket recommended NP followed by Yara Mila cereal @ 200 kg ha^{-1} NP adjusted (Table 2). There was no significant difference between blanket recommended NP and Yara Mila cereal @ 200 kg ha^{-1} NP adjusted except at South Wello where the blanket recommended NP gave significantly higher grain yield (Table 2). At all locations, the lowest grain yield was obtained from the control (without input) and all fertilizer rates significantly differed in grain yield from the control (Table 2). Even though, there was no statistically significant difference in grain yield between the blanket recommended NP and Yara Mila cereal @ 200kg ha^{-1} with NP adjusted for almost all locations, the latter can't be used as an alternate fertilizer because of its bulkiness compared to DAP and urea. That is the amount needed to replace blanket recommended NP is double and incurred additional transportation cost though there is similar or relatively less effect on crop yield compared to blanket recommended NP (Table 2).

Table 2 Effect of Yara Mila chemical fertilizer on wheat grain yield (kg ha^{-1}) in 2010/11

Treatment (kg ha^{-1})	Grain Yield (kg ha^{-1})					
	Enewari	Bakelo	Gonji kolela	Debre Elias	Jamma	Wereillu
Control	1554.2d	968.1c	1553.0c	1132.45c	705e	850d
Urea/DAP 100/100	3088.8a	1868.3a	2570.9a	2033.98a	1957a	2207a
Yara Mila 150	2216.3c	1370.8b	1860.3b	1406.98b	1272d	1428c
Yara Mila 200	2429.3b	1495.7b	1818.0bc	1529.27b	1425c	1592bc
Yara Mila 200 + NPK	3009.7a	1879.5a	2349.5a	1972.84a	1830b	1725b
CV (%)	6.10	13.27	11.39	5.30	12.90	15.40
LSD (0.05)	124.4	166.6	276.16	161.26	124.50	232.00

Similar to the grain yield there was no significant straw yield between the blanket recommended NP and Yara Mila cereal @ 200 kg ha^{-1} NP adjusted at all locations except at South Wello (Table 3) where the blanket recommended NP gave significantly higher straw yield compared to Yara Mila cereal @ 200 kg ha^{-1} NP adjusted (Table 3). In another words, blanket recommended NP and Yara Mila cereal @ 200 kg ha^{-}1NP adjusted significantly affected bread wheat straw yield compared to all fertilizer rates under investigation (Table 3). However, at all locations, application of Yara Mila cereal was inferior to the blanket recommended NP fertilizer except at

Debre Elias where application of Yara Mila @ 200 kg ha^{-1} NP adjusted gave relatively better straw yield (Table 3).

Table 3 Effect of Yara Mila cereal fertilizer on bread wheat straw yield (kg ha^{-1}) in 2010/11

Treatment (kg ha^{-1})	Straw Yield (kg ha^{-1})					
	Enewari	Bakelo	Gonji kolela	Debre Elias	Jamma	Wereillu
Control	1792.3d	1188c	1147.0a	867.55d	1211.3d	1541d
Urea/DAP 100/100	4123.9a	2713a	1629.1a	1499.35a	3312.8a	3951a
Yara Mila 150	2565.9c	1875b	1508.3a	1326.36b	2040.1c	2521c
Yara Mila 200	3093.8b	2029b	1482.0a	1170.73c	2148.4c	2599c
Yara Mila 200 +NP	3934.9a	2608a	1411.7a	1627.16a	3038.7b	3206b
CV (%)	9.56	9.02	29.13	5.79	13.00	12.00
LSD (0.05)	245.58	155.58	499.27	141.47	204.00	232.00

Effect of Yara Mila Cereal on Teff

Analysis of variance showed that significantly higher grain yield was obtained from blanket recommended NP at Bichena compared to all Yara Mila cereal fertilizers followed by Yara Mila cereal @ 200 kg ha^{-1} (Table 4). Though there was no significant difference, relatively higher grain yield was obtained from blanket recommended NP at all other locations followed by Yara Mila cereal @ 200 kg ha^{-1} NP adjusted (Table 4). The other Yara Mila cereal fertilizers gave lower grain or equal grain yield with Yara Mila cereal but significantly lower from blanket recommended NP (Table 4).

There was no significant difference in teff straw yield between blanket recommended NP and Yara Mila cereal @ 200 kg ha^{-1}NP adjusted at Enewari and Gonji Kolela (Table 5). But, the difference in straw yield among the blanket recommended NP and the other fertilizer rates under investigation was statistically significant at all locations (Table 5). Similarly, Yara Mila cereal @ 200 kg ha^{-1} NP adjusted gave significantly higher straw yield at Enewari and at par with the other rates at the other locations (Table 5). At all locations the control plot was inferior in straw yield against the other fertilizer rates (Table 5). Generally, application of Yara Mila cereal NP adjusted or not did not outsmart over the blanket recommended NP fertilizer from DAP and Urea.

Table 4 Effect of Yara Mila chemical fertilizer on teff grain yield (kg ha^{-1}) in 2010/11

Treatment (kg ha^{-1})	Grain Yield (kg ha^{-1})		
	Enewari	Gonji kolela	Bichena
Control	1083.3c	715.0d	1117.50c
Urea/DAP 100/100	1501.7a	1795.0a	1707.50a
Yara Mila 150	1369.7b	1211.7c	1408.33b
Yara Mila 200	1371.7b	1375.0bc	1388.33b
Yara Mila 200 + NPK	1508.0a	1665.0ab	1473.33b
CV (%)	7.63	11.54	7.82
LSD (0.05)	86.38	293.94	208.85

Table 5 Effect of Yara Mila Chemical Fertilizer on teff Straw Yield (Kg ha^{-1}) in 2010/11

Treatment (kg ha^{-1})	Straw Yield (kg ha^{-1})		
	Enewari	Gonji kolela	Bichena
Control	1768.8d	1285.0c	1882.5b
Urea/DAP 100/100	3220.0a	5205.0a	4125.8a
Yara Mila 150	2304.5c	3455.0b	3591.7a
Yara Mila 200	2559.0b	3625.0b	3611.7a
Yara Mila 200 +NPK	3214.5a	4668.3a	4026.7a
CV (%)	7.33	8.50	14.60
LSD (0.05)	158.67	585.30	946.60

Conclusion and Recommendation

Generally, mean grain yield obtained from each independent site depicted that application of Yara Mila cereal fertilizer at different rate were not significantly different from the blanket recommended rate of 100/100 kg ha^{-1} of DAP and Urea. Even in almost all locations, the blanket recommended NP gave better than the Yara Mila cereal fertilizer. Even though the blanket recommended NP was by far below the area specific fertilizer recommendation and incurred yield penalty, it is still by far better than the newly introduced Yara Mila cereal fertilizer in grain and straw yield of bread wheat and teff. Though in most cases Yara Mila cereal @ 200 kg ha^{-1}NP adjusted gave comparable yield to the blanket recommended NP, it can't be used as an alternate fertilizer due to its bulkiness that is double of recommended NP and difficulty in transportation. Though the experiment was approved late, it was done at multi locations and the results reported above were recorded. Therefore, further study shall be done on other better products against the area specific fertilizer rate than the blanket recommendation which was obsolete and not used in the potential areas producing bread wheat and teff for better yield and quality products.

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Current and residual effects of compost and inorganic fertilizer on wheat and soil chemical properties

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Abstract

Restoring soil fertility in smallholder farming systems is essential to sustain crop production. An experiment was conducted in 2011 and 2012 to study the effect of compost and inorganic fertilizer application on soil chemical properties and wheat yield in northwest Ethiopia. Full factorial combinations of four levels of compost (0, 4, 6, 8 t ha^{-1}) and three levels of inorganic fertilizers (0–0, 17.3–5, 34.5–10 kg NP ha^{-1}) were compared in a randomized complete block design with three replications. In 2012, two sets of trials were conducted: one was the repetition of the 2011 experiment on a new experimental plot and the second was a residual effect study conducted on the experimental plots of 2011. Results showed that in the year of application, applying 6 t compost ha^{-1} with 34.5/10 kg N/P ha^{-1} gave the highest significant grain yield. In the residual effect trial, 8 t compost ha^{-1} with 34.5/10 kg N/P ha^{-1}gave 271% increase over the control. Grain protein content increased 21 and 16% in the current and residual effect trials, respectively, when 8 t compost ha^{-1} was applied; it increased 11 and 14% in the current and residual effect trials, respectively, when 34.5/10 kg N/P ha^{-1} was applied. Under the current and residual effects of 8 t compost ha^{-1}, SOM increased by 108 and 104 %; available P by 162 and 173%; exchangeable Ca by 16.7 and 17.4%; and CEC by 15.4 and 17.1%, respectively. Applying 6 t compost ha^{-1} with 34.5/10 kg N/P ha^{-1} is economically profitable with 844 % MRR.

Keywords: Soil fertility, Organic matter, Grain protein, Vertisols

Introduction

Poor soil fertility as a result of unsustainable agricultural practices is one of the major threats to agricultural productivity and food security in the smallholder farming systems in Sub Saharan Africa (Sanchez and Leakey 1997). Agricultural productivity and food security in Sub Saharan Africa (SSA) are seriously jeopardized by the steady decline in soil fertility, It is well recognized that soil organic matter plays a major role in soil fertility by affecting physical and chemical properties, and also controlling soil microbial activity by serving as a source of mineralizable carbon (C) and N (Solomon et al. 2002). Thus, productivity losses in many of the SSA countries are often attributed to loss of soil organic carbon and accelerated water depletion resulting from severe soil degradation (Lakew et al. 2000). Complete residue removal for fodder and fuel, and intensive and excessive tillage have depleted soil organic C stocks which have led to the deterioration of soil fertility and soil water storage capacity, resulting in frequent crop failures. Degraded soils commonly reduce payoffs to agricultural investment as they rarely respond to external inputs, such as mineral fertilizers, and hence reduce the fertilizer use efficiency and return on investment (Tilahun, 2003). Such soils also have very poor water holding capacity, partly because of low soil organic matter content, which in turn reduce fertilizer use efficiency (Tilahun, 2003). Overexploitation of land resources without returning the basic nutrients to the soil is an important factor that contributes most to poor productivity (Bationo et al. 2007).

In the highlands of Ethiopia in general, and the Amhara region in particular declining soil fertility is also immensely constraining to agricultural productivity (Lakew et al. 2000). Even though the farming system in the highlands of Amhara region is a mixed crop–livestock system, nutrient flows between the two system’s components are predominantly one way, with feeding of crop residues to livestock but little or no dung and residue being returned to the soil. Estimates of soil nutrient loss in Ethiopia between 1982 and 1984 show a net removal of 41 kg N ha-1 from agricultural land, and losses for the year 2000 were projected to reach 47 kg N ha-1 (Stoorvogel et al. 1993).

Currently, the situation would be worsened with the ongoing intensive cultivation without due regard to restoring soil organic matter content. Therefore, if agricultural productivity in the smallholder farming is to be improved and food security granted, emphasis should be given to replenishing the soil fertility. On the other hand, although substantial crop yields can be achieved through applying inorganic fertilizers, most smallholder farmers in the Amhara region rarely use them because of high cost and low and variable returns. These soils can no longer be productive with the existing fertility status and if the trend of low inorganic fertilizer use continues, alternative soil fertility management strategies need to be sought. Therefore, an integrated nutrient management approach which acknowledges the need for both organic and inorganic mineral inputs is promoted due to positive interactions and complementarities between them (Abedi et al. 2010). Thus, adopting this strategy should increase crop productivity, prevent soil degradation, enhance carbon storage in the soil and also reduce emissions from nitrogen fertilizer use and thereby help meet future food supply needs. Compost has strong carryover effect, however, the short term benefits of infrequent application to yield and soil qualities in Vertisols have not been evaluated in the watershed. This study was, therefore, conducted at on-farm to evaluate the current and residual effects of different levels of compost and inorganic fertilizer application on wheat grain yield and chemical properties of the soil in the Gumara-Maksegnit watershed.

Materials and methods

Description of the study area

The study was conducted on a farmers' field in the Gumara-Maksegnit watershed in northwest Ethiopia. The watershed is located between 12° 23' 53" to 12° 30' 49" latitude and 37° 33' 39" to 37° 37' 14" longitude and an altitude of 1953 m above sea level. The soil at the experimental site is a Vertisols. The long term average annual rainfall is about 1052 mm. The mean minimum and maximum temperatures of the area are 13.3 °C and 28.5 °C, respectively (NMSA, 2009). The soil had a clay texture with 53% clay, 19% silt and 28% sand contents. The 0–40 cm horizon has on average a pH of 7.5 (1:2.5 in water), 3.96% organic matter, 6.4 ppm available (Olsen) P, 2.16 $cmol^{(+)}\ kg^{-1}$ K, 38.31 $cmol^{(+)}\ kg^{-1}$ Ca, 12.09 $cmol^{(+)}\ kg^{-1}$ Mg, 0.38 $cmol^{(+)}\ kg^{-1}$Na, and CEC of 58.40 $cmol^{(+)}\ kg^{-1}$.

Experimental design and procedures

Treatments comprised factorial combinations of four levels of compost (0, 4, 6, and 8 t ha^{-1} on dry weight basis) and three levels of nitrogen (N) and phosphorus (P) fertilizer combinations [0/0, 17.3/11.5, 34.5/23 kg N/P_2O_5 ha^{-1} which represented 0%, 25%, and 50% of the recommended N (69 N kg ha^{-1}) and P (46 P_2O_5 kg ha^{-1}) fertilizer rates, respectively]. The experimental design was randomized complete block with three replications. The study was conducted in 2011 and 2012. In 2012, the residual effect of treatments was studied on the 2011 experimental plots. Compost was applied on dry weight basis, spread evenly, and incorporated into the soil two weeks before planting. The chemical properties of the compost used for the study are presented in Table 1. Urea and di-ammonium phosphate (DAP) were used as inorganic fertilizer sources. Half of the urea and all the DAP were applied in rows at planting and incorporated into the soil. The remainder of the urea was side dressed at tillering. Bread wheat var. Kubsa in 2011 and var. TAY in 2012 were planted in rows at the seed rate of 125 kg ha^{-1}. Planting was made on broad bed and furrows (BBF) to facilitate water drainage. Gross and net plot sizes were 6 m x 6 m and 5 m x 5 m, respectively in 2011. Weeds were removed manually as needed. No insecticide or fungicide was applied as there was no serious incidence of insect pests or diseases.

Table 1. Chemical properties of the compost used for the study.

Chemical properties	Values
pH	6.46
Available P (ppm)	47.73
Organic matter (%)	5.74
CEC ($cmol^{(+)}$ kg^{-1})	105.0
Exchangeable Ca ($cmol^{(+)}$ kg^{-1})	50.29
Exchangeable Mg ($cmol^{(+)}$ kg^{-1})	14.63
Exchangeable K ($cmol^{(+)}$ kg^{-1})	1.2
Exchangeable Na ($cmol^{(+)}$ kg^{-1})	0.83

Prior to planting, composite surface (0–40 cm) soil samples were collected from five points across the experimental field and analyzed for soil chemical properties. Composite soil samples from the 0–25 cm depth at three points were collected from each plot 15 days after compost application and the composite sample analyzed for soil chemical properties. Similarly, for the residual effect study, soil samples from 0–25 cm depth were collected from three points at each plot just before planting and analyzed for soil chemical contents. Soil samples were mixed, homogenized, air dried in shade, ground and passed through a 2 mm sieve, and analyzed for total N, available P, pH, organic carbon, exchangeable cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) and CEC. Soil texture was determined using Bouyoucos hydrometer method (Tisdale et al. 1993). Available P was extracted with sodium bicarbonate solution at pH 8.5 following the procedure described by Olsen et al. (1954). Total nitrogen was determined by the micro-Kjeldahl digestion, distillation and titration method as described by Jackson (1958). Soil pH was measured potentiometrically in the supernatant suspension of a 1:2.5 soil:water mixture using a pH meter according to method outlined by Sahlemedhin and Taye (2000). Organic carbon was determined following the Walkley and Black wet oxidation method as described by Jackson (1958). The soil CEC was determined at pH 7 after displacement of the cations by using 1 N ammonium acetate; thereafter, the ammonium was estimated titrimetrically by distillation of ammonium that was displaced by sodium following the procedure of Sahlemedhin and Taye (2000). Total exchangeable bases were determined after leaching the soils with ammonium acetate; Ca^{2+} and Mg^{2+} in the leachate were analyzed by atomic absorption spectrophotometer and K^+ and Na^+ were analyzed flame photometrically following the procedure of Sahlemedhin and Taye (2000).

Data on grain and straw yields, grain protein content and soil chemical properties were collected. Grain protein content was determined using near infrared reflectance spectroscopy (NIRS). Analyses of variance (ANOVA) for all data were performed using the SAS statistical program (SAS V9.0, SAS Institute Inc., Cary, NC, USA). Whenever the ANOVA detected significant differences between treatments, mean separation was conducted using least significant difference (LSD). Economic analysis was performed following the CIMMYT partial budget methodology (CIMMYT 1988). Average wheat grain price of US\$0.45 kg^{-1} and straw price of US\$1.05 t^{-1} were considered for the analysis. The prices of DAP, urea and compost were US\$0.78 kg^{-1}, US\$0.65 kg^{-1}, and US\$14.47 t^{-1}, respectively. To apply 4, 6, and 8 t compost ha^{-1}, two, three and four man-days, respectively were needed. The labour cost for compost application was US\$1.58 per man-day. Following CIMMYT's partial budget analysis methodology, total variable costs (TVC), gross benefit and net benefit were calculated. Total variable cost was calculated as the sum of cost of urea, cost of DAP, cost of compost and cost of labor to apply compost. Net benefit was calculated as the difference between gross benefit and the TVC. Grain and straw yields were adjusted downwards by 10% assuming that farmers will obtain yields 10% lower than obtained by researchers. Then treatments were listed in order of increasing total costs that vary and dominance analysis was performed where dominated treatments were eliminated and the marginal rate of return (MRR) calculated for the remaining treatments. A treatment that has net benefits that are less than or equal to those of a treatment with lower costs that vary is dominated. A treatment which is non-dominated and having a MRR of greater or equal to 100% and the highest net benefit is considered to be economically profitable.

Results

Grain and straw yield

Both in the current and residual effects grain yield was significantly affected by the direct and the interaction effect of the combined use of compost and inorganic fertilizers (Table 2).

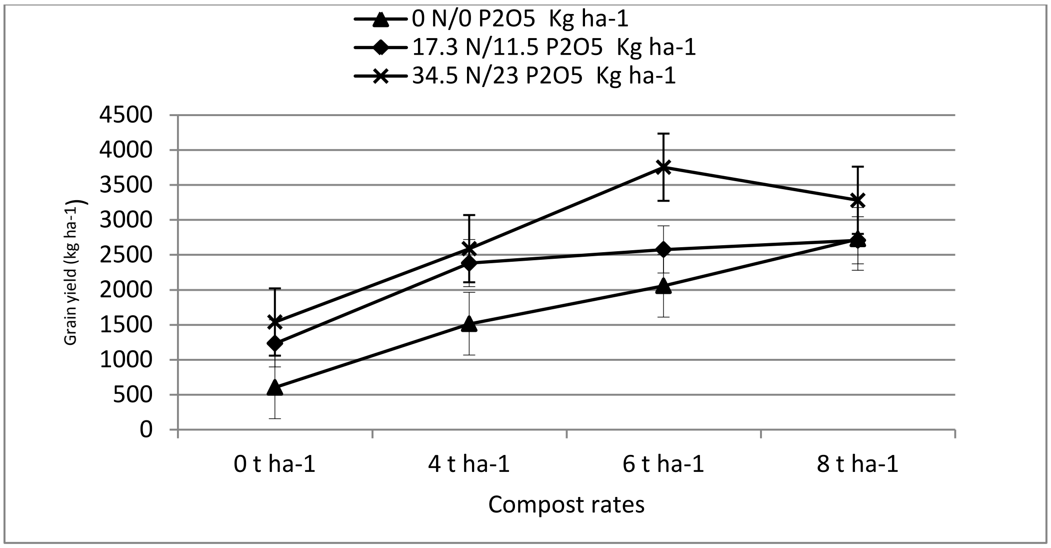
Table 2. Analysis of variance for the effect of compost and inorganic fertilizers on the grain and straw yields and grain protein content of bread wheat in Gumara-Maksegnit watershed

Source of variation	df	Current			Residual		
		Grain yield	Straw yield	GPC	Grain yield	Straw yield	GPC
Compost (C)	3	1276765.05**	4760653.44**	8.92**	1201952.6**	2503855.4**	8.3**
Inorganic fertilizer (F)	2	3872445.98**	7201779.07**	6.04**	3084720.2**	5391588.4**	7.6**
C x F	6	2434768.83**	1181063.74ns	0.63ns	67796.1**	1097806.4.74ns	0.63ns
Error	24	42637.71	980580.57	0.42	42131.7	334585.1	0.48

** and ns denote significant difference at P≤0.01 and non-significant difference, respectively. GPC = Grain protein content.

In the current effect, the highest significant grain yield was obtained applying 6 t compost ha^{-1} with 34.5–23 kg N–P_2O_5 ha^{-1} followed by applying 8 t compost ha^{-1} with 34.5–23 kg N–P_2O_5 ha^{-1} (Fig. 1). Applying compost alone also has significantly increased grain yield with a yield benefit ranging from 151 to 351 %. Across all the N–P levels grain yield has significantly increased with an increase in the compost rate. In the residual effect, the highest significant grain yield was obtained from 8 t compost ha^{-1} with 34.5–23 kg N–P_2O_5 ha^{-1} applied in the preceding season (Fig. 1).

a)



b)

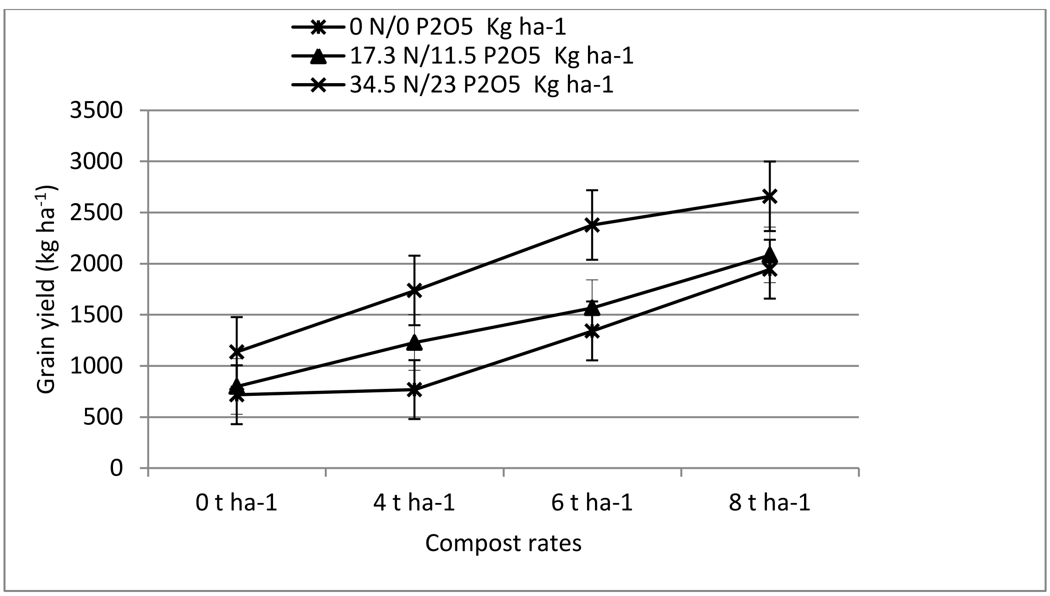
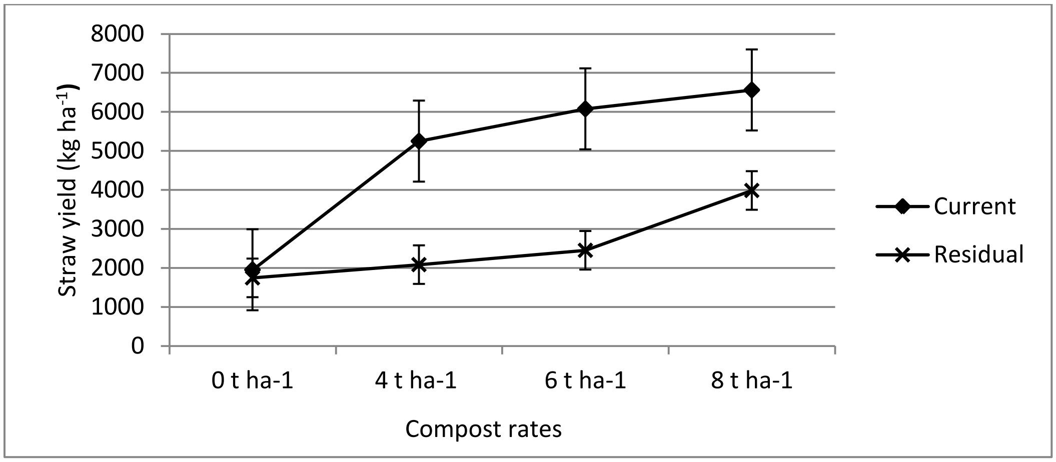


Figure 1. Current (a) and residual (b) effect of compost and inorganic fertilizers on wheat grain yield at Gumara-Maksegnit watershed

Both in the current and residual effects, straw yield responded only to the main treatment effects of compost and inorganic fertilizers, but not to the interaction effect. Averaged over all N/P fertilizer levels, straw yield increased with an increase in compost rate, with the highest significant straw yield recorded with the application of 8 t compost ha^{-1} (Fig. 2a). With regard to response to inorganic fertilizers, both in the current and residual effects, averaged over all compost levels straw yield was significantly higher with the application of 34.5–23 kg N–P_2O_5 ha^{-1}(Fig. 2b). Straw yield in the residual plots was generally low compared to the current application.

a)



b)

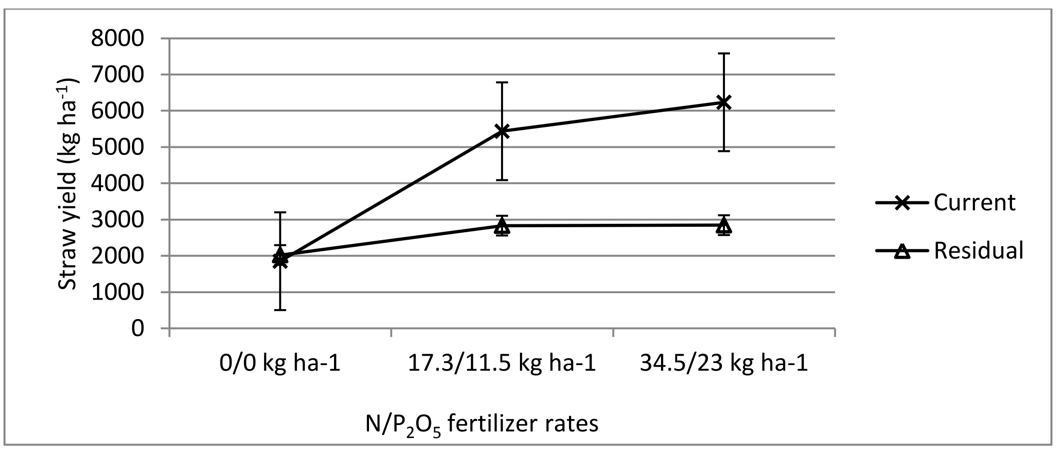


Figure 2. Current and residual effect of compost (a) and inorganic fertilizers (b) on wheat straw yield at Gumara-Maksegnit watershed

Grain protein content

Grain protein content responded to the main effects of compost and inorganic fertilizers, but not to the interaction effect (Table 2). Averaged over the levels of N–P fertilizers, grain protein content increased following the current as well as the residual increase in compost rate. Significantly higher grain protein content was recorded at 8 t compost ha^{-1} (Fig. 3a). Averaged over the levels of compost, grain protein content was significantly higher with the application of 34.5–23 kg N–P_2O_5 ha^{-1} (Fig. 3b).

a)

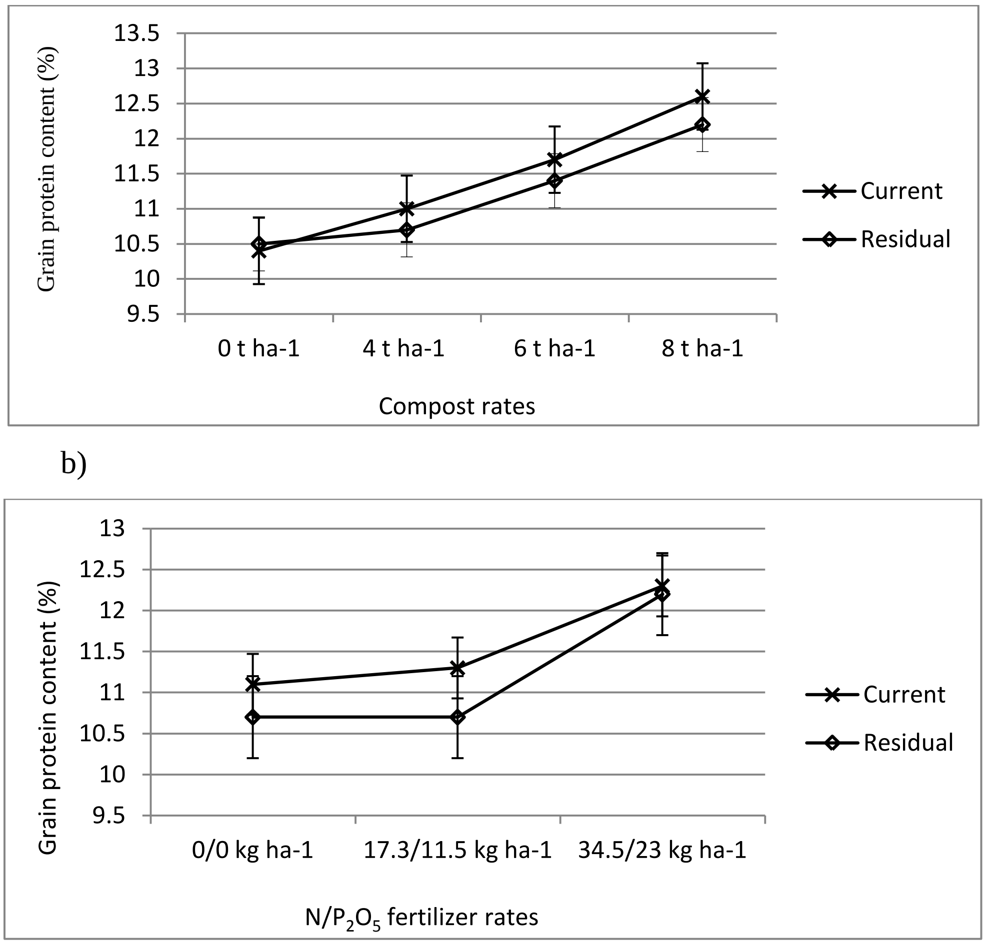


Figure 3. Current and residual effect of compost (a) and inorganic fertilizers (b) on wheat grain protein content at Gumara-Maksegnit watershed

Soil chemical properties

In both the current and residual effects, when averaged over the NP rates compost application significantly increased available P, organic matter, exchangeable Ca contents and CEC of the soil (Fig. 4). Nevertheless, compost application did not have significant effect on soil pH and on exchangeable Mg, K and Na contents. Applying 8 t compost ha^{-1} in the current trial, and 4, 6 and 8 t compost ha^{-1} in the residual effect trial gave significantly higher available P (Fig. 4a). Organic matter content was significantly higher for 4, 6 and 8 t compost ha^{-1} both in the current and residual effects trials (Fig. 4b). Exchangeable Ca content was significantly higher in the current trial when applying 6 and 8 t compost ha^{-1}, and 8 t compost ha^{-1} in the residual effects trial (Fig.

4c). CEC was significantly higher in the current trial when applying 8 t compost ha^{-1} and 6 and 8 t compost ha^{-1} in the residual effects trial (Fig. 4d). In the current effect trial, applying 4, 6 and 8 t compost ha^{-1} increased available P content by 89–161 %, organic matter content by 84–108 %, exchangeable Ca content by 5–17 %, and CEC by 9–15 % over the plot with no compost. Similarly, for the same compost application rates in the residual effects trial, available P increased by 138–173 %, organic matter by 79–104 %, exchangeable Ca by 4–17 % and CEC by 11–17 %.

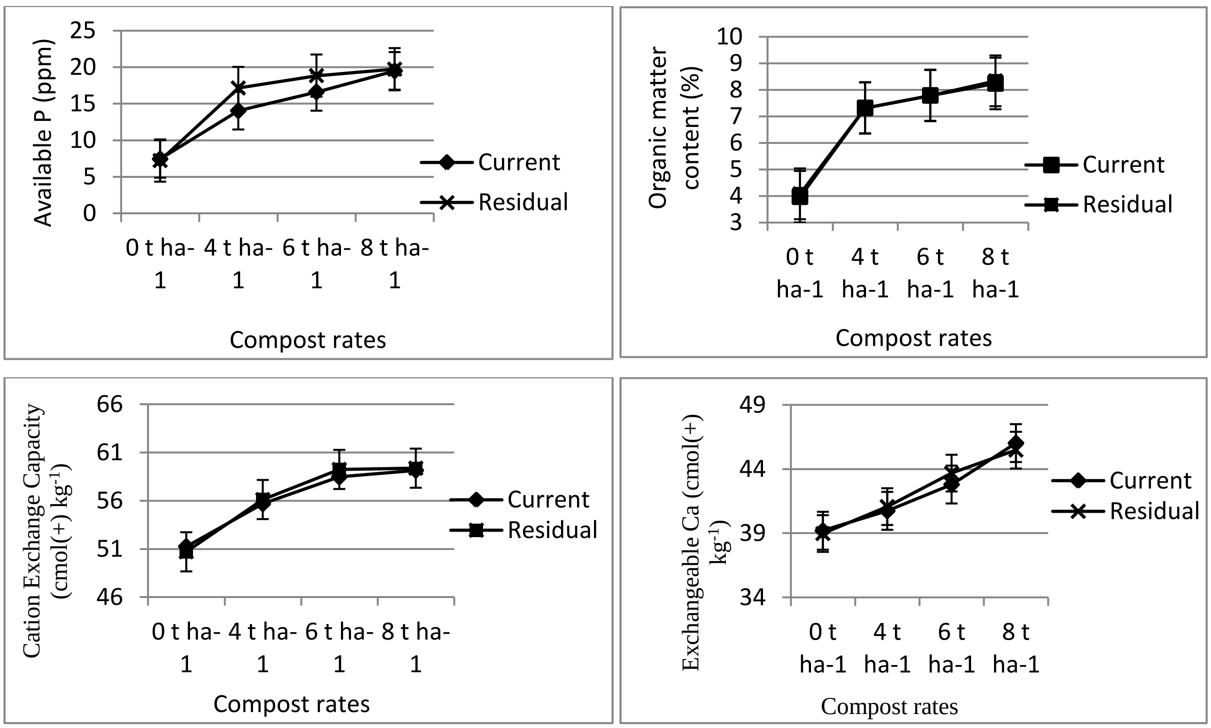


Figure 4. Current and residual effects of compost on soil available P and organic matter content, cation exchange capacity and exchangeable Ca content at Gumara-Maksegnit watershed

Economic analysis

The partial budget analysis showed that treatment combination 6 t ha^{-1} compost and 34.5–23 kg N–P_2O_5 ha^{-1} is economically profitable as it gives a rate of return above the 100 % acceptable rate of return.

Although the highest MRR (1,732 %) was recorded for the treatment combination 4 t ha^{-1} compost and 17.3–11.5 kg N–P_2O_5 ha^{-1}, farmers' overall net income could improve if an additional investment is made further to applying 6 t ha^{-1} compost and 34.5–23 kg N–P_2O_5 ha^{-1} with MRR of 844 % (Table 3). The calculated MRR tells that by using this combination of fertilizers, farmers can get a return of US$8.44 for every US$1.0 of additional investment on organic and inorganic fertilizers. The economic analysis result agrees with the agronomic result.

Table 3 Economic analysis for the use of compost and inorganic fertilizer on bread wheat in Gumara-Maksegnit watershed

Compost (t ha^{-1})	Inorganic fertilizer (N/P_2O_5)	Grain yield (kg ha^{-1})	Straw yield (t ha^{-1})	Adjusted grain yield (kg ha^{-1})	Adjusted straw yield (t ha^{-1})	Gross field benefits (US$ ha^{-1})	Total cost that vary (US$ ha^{-1})	Net benefit (US$ ha^{-1})	Dominance	MRR[a]
0	0–0	604	1.9	543.6	1.71	246.4	0	246.42		
0	17.3–11.5	1,233	2.1	1,109.70	1.89	501.3	37.7	463.65		576
4	0–0	1,514	2.6	1,362.60	2.34	615.6	61.04	554.59		390
0	34.5–23	1,538	2.7	1,384.20	2.43	625.4	74.75	550.69	D	
6	0–0	2,057	2.7	1,851.30	2.43	835.6	91.56	744.08		621
4	17.3–11.5	2,381	3	2,142.90	2.7	967.1	98.74	868.4		1,732
8	0–0	2,727	3.6	2,454.30	3.24	1,107.80	122.08	985.76		503
6	17.3–11.5	2,576	3.6	2,318.40	3.24	1,046.70	129.26	917.42	D	
4	34.5–23	2,587	5.3	2,328.30	4.77	1,052.70	135.79	916.95	D	
8	17.3–11.5	2,707	3.8	2,436.30	3.42	1,099.90	159.78	940.15	D	
6	34.5–23	3,752	6.1	3,376.80	5.49	1,525.30	166.31	1,359.01		844
8	34.5–23	3,279	6.6	2,951.10	5.94	1,334.20	196.83	1,137.40	D	

Discussions

Grain and straw yields

Compost application is reported to have positive effect on the physicochemical and biological properties of the soil which often leads to higher crop growth and yield (Abedi *et al*., 2010; Hafidi *et al*., 2012). Compost provides a steady supply of nutrients to the crop, thus improving productivity (Hafidi *et al*., 2012). In our study, grain yield increased significantly by the application of compost together with inorganic fertilizers. Applying 6 t compost ha^{-1} with 34.5–23 kg N–P_2O_5 ha^{-1} gave a yield increase of 521 % over the control, and the application of 8 t compost ha^{-1} with 34.5–23 kg N–P_2O_5 ha^{-1} gave a yield increase of 442 %. The residual effect from 1 year application of compost and inorganic fertilizers also gave yield benefits ranging from 7 to 271 %. This indicates that farmers who cannot afford to apply compost every year could improve productivity by as much as 271 % by applying compost every other year. These results are in agreement with other reports on rice (Sarwar *et al*., 2007), wheat (Sarwar *et al*., 2007; Abedi *et al*., 2010) and sorghum (Ouedraogo et al. 2001). Nahar *et al*., (1995) reported 97 % yield increase in wheat from residual effects of compost.

Wheat straw yield increased by 169–236 % when the compost was applied and by 19–128 % in the following season, due to the residual effects of compost. Straw yield also increased 193–237 % in the current and 40 % in the residual season, respectively, as a response to inorganic fertilizer application. Similar results, where significant increase in rice and wheat straw due to the combined application of 12 and 24 t compost ha^{-1}, respectively, and N, P, K fertilizers were reported by Sarwar *et al*., (2007). Wheat straw is an important dry season livestock feed in the watershed. Thus, the observed increase in straw yield has implication on livestock feed availability and livestock productivity by ensuring a higher supply of feed. The extra straw achieved as a result of compost application could also be used either for soil application to maintain the organic matter content or could be sold to generate income.

Increase in grain and straw yields from the combined application of compost and inorganic fertilizers could be attributed to better crop growth, due to the readily available nutrients from the inorganic fertilizer sources and the improved nutrient availability and controlled release of nutrients from the compost (Seran *et al*., 2010; Suge *et al*., 2011). Compost application, besides improving the physico-chemical properties of the soil, slowly releases nutrients and prevents nutrient losses from the inorganic fertilizers by binding to nutrients and releasing them with time (Arshad *et al*., 2004; Abedi *et al*., 2010). Consequently, the combined use of organic fertilizers with inorganic fertilizers improves inorganic fertilizer use efficiency and thus reduce the amount of inorganic fertilizer required (Bayu *et al*., 2006a; Abedi *et al*., 2010; Tilahun-Tadesse *et al*., 2013). The increase in yield could be attributed to better root development and nutrient uptake resulting from improved soil structure due to compost effects. Also the positive effects of compost in preventing the loss of nutrients from chemical fertilizers and promoting a slow nutrient release with the passage of time could result in higher crop yields (Arshad *et al*., 2004; Abedi *et al*. 2010). Several reseachers (Bayu *et al*., 2006b; Abedi *et al*., 2010; Tilahun-Tadesse *et al*., 2013) have reported that organic inputs have improved the physical properties of the soil which would have caused increased root development and thus increased nutrient and water uptake.

Grain protein content

It is widely reported that protein content in wheat grain, which is strongly associated with bread-making quality, often improves with sufficient nutrient supply (Takahashi *et al*., 2006; Abedi *et al*., 2010). In this study grain protein content has significantly increased with the compost and inorganic fertilizers application. Grain protein content increased 21 and 16 % with the current and residual effects, respectively, of 8 t compost ha^{-1}. Similarly, grain protein content increased 11 and 14 % with the current and residual effects, respectively, of 34.5–23 kg $N–P_2O_5$ ha^{-1}. Similar

to these results, Abedi *et al*., (2010) reported increase in wheat grain protein content in response to applying 6 t compost ha^{-1}. Hossain *et al*., (2012) also reported a significantly higher grain protein (10.08 %) in maize from applying 22.5 t compost ha^{-1} and N–P–K (30–15–20 kg ha-1), respectively as compared to the protein content in the control (4.85 %). The increase in grain protein content with compost and inorganic fertilizer application could be ascribed to more nutrient availability and increased nutrient uptake as a result of improved soil structure (Abedi *et al*., 2010). In countries where cereal grains are the major source of protein for human consumption, increase in grain protein content by improving soil fertility could be taken as a least-cost approach to improve human nutrition.

Soil chemical properties

Compost addition to soil has long been considered important in maintaining the quality of the soil, basically in terms of improving its physical, chemical and biological properties (Sarwar *et al*., 2008; Hepperly *et al*., 2009; Hafidi *et al*., 2012). In our study, the current and residual effects of compost have improved many soil chemical properties. Soil organic matter (SOM), regarded as a key factor in determining soil fertility and productivity, and increased 108 % in the current and 104 % in the residual effect, respectively, of 8 t compost ha^{-1}. Several research reports have shown improvement in the SOM content with organic fertilizer application. In a rice–wheat rotation Sarwar *et al*., (2008) reported a rise in SOM content from 0.56 to 0.98 % after rice and from 0.67 to 1.30 % after wheat with the application of 24 t compost ha^{-1} with a recommended fertilizer rate (100–70–70 kg ha^{-1} N–P–K). Reeve et al. (2012) reported a 1.6-fold higher total organic C (1.43 vs. 0.89 %, $p < 0.002$), in a soil that was amended with compost 16 years before, compared to a soil that was not amended. Increase in SOM as a result of compost application has great implication in terms of improving soil productivity as SOM is the ultimate source of nutrients and microbial activity in the soil. SOM also has a major role in improving soil structure, water holding capacity, infiltration rate, aeration and porosity of the soil as well as reducing environmental pollution due to the carbon sequestration effect (Sarwar *et al*., 2008).

Compost contains macro and micro nutrients (Eyheraguibel *et al*., 2008; Hafidi *et al*., 2012). Several studies (Abedi *et al*., 2010; Hafidi *et al*., 2012) have shown that humic substances in compost enhance the availability of macro and micro nutrients (N, P, K, Mg, and Ca). In our study, available soil P increased 162 % in the current trial and 173 % in the residual effect trial, respectively, due to the application of 8 t compost ha^{-1}. Similar results were reported by Sarwar et al. (2008) who reported an increase in available P from 5.72 mg kg^{-1} in the control to 27.55 mg $kg^{-1}$with the application of 24 t compost ha^{-1} and 100–70–70 kg N–P–K ha^{-1}. The increase in available P could be, according to Singh et al. (2008), due to the addition of P through compost in excess of removal by the crop. It could also be due to the fact that organic manures, on decomposition, solubilize insoluble organic P fractions through release of various organic acids, thus resulting in a significant improvement in soil available P content (Sharma *et al*., 2013). In this study, exchangeable Ca content increased 16.7 % in the current trial and 17.4 % in the residual effect trial, respectively, due to the application of 8 t compost ha^{-1}. In agreement to this result, Hafidi *et al*., (2012) reported an increase in Ca content from 1,399.7 to 2,109.9 mg kg^{-1} with the application of 28 t compost ha^{-1}. They also reported an increase in the levels of saturation of other alkaline elements (K, Na) with the application of 28 and 42 t compost ha^{-1}, effect that was not observed in this study. According to Sarwar et al. (2008) the increase in Ca and Mg with compost application could be due to the reaction of organic acids with CaCO3 and Mg salts. The increase could also be from the addition of Ca from the compost itself as it has high content of Ca (Table 1). Cation exchange capacity is a key soil chemical property characterizing the adsorption capacity of a soil. Increase in the soil CEC implies that the soil will be able to retain nutrients in the soil–plant system in larger quantities and for longer time. Hence the crop will utilize nutrients more effectively, while reducing nutrient loss by leaching. In this study, CEC of the soil increased 15.4 % in the current trial and 17.1 % in the residual effect trial, respectively, due to the application of 8 t compost ha-1. In line with this result, Ouedraogo *et al*., (2001) reported a significant increase in CEC with the application of 10 t ha^{-1} compost in Burkina Faso. Hafidi *et al*., (2012) have shown an increase in CEC from 35.6 meq/100 g in the control plot to 46.8 meq/100 g, 46.9 meq/100 g and 47.2 meq/ 100 g by applying 14, 28 and 42 t compost ha^{-1}, respectively. The increase in CEC with compost application could be attributed to an increase in soil organic matter content (Ouedraogo *et al*., 2001). The observed increase in the nutrient contents of the soil in the residual plots in this study could be due to the fact that nutrients contained in compost are stored for longer time in the soil and are released more slowly, thereby ensuring a long residual effect (Sharma and Mittra, 1991) and to solubilisation of nutrients from soil minerals due to the effect of compost's organic acids (Sharma *et al*., 2013).

Economic analysis

Financial profitability is the ultimate measure to recommend a technology. Any technology that is agronomically feasible and is beneficial for soil improvement would not be attractive to farmers unless it is financially profitable. In the current study, by applying 6 t compost ha^{-1} with 34.5–23 kg $N–P_2O_5$ ha^{-1} farmers in the watershed will be able to gain US$8.44 for each US$1.0 investment, which implies a very high increase in farmers' income with a simple improvement in soil fertility management. This financial benefit is in addition to the benefit in terms of soil improvement which we could not quantify in terms of monetary value.

Conclusions

Using compost for soil quality and productivity improvement has been receiving much attention by the government of Ethiopia. In this study, it was found that the combined use of compost and inorganic fertilizers improve the overall soil fertility and wheat productivity. Generally, soil quality and productivity may be more sustainable with the integrated application of compost and inorganic fertilizers than with the use of inorganic fertilizers alone. From the results of the current experiment, it could be concluded that combined applications of 6 t compost ha^{-1} with 34.5–23 kg $N–P_2O_5$ ha^{-1} resulted in the improvement of most soil physicochemical properties and yield and grain quality of wheat over 2 years. This implies that by combining compost with inorganic fertilizers farmers would be able to reduce the inorganic fertilizer requirement by 50 %. With these rates of compost and inorganic fertilizer application in the previous year farmers could get a yield benefit as much as 271 % without any compost and inorganic fertilizer application in the current year. The combined use of compost and inorganic fertilizers, therefore, is a viable technology to combat soil degradation and to increase productivity.

However, despite the short term benefits recorded in this study, the viability of using compost in crop production will depend on the willingness and interest of farmers in producing compost. Extensive demonstration and training is required to show farmers the agronomic importance and economic value of compost application on improving the productivity of their soils.

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Effect of Nitrogen and phosphorous on green pod yield of Snap Bean (*Phaseolus vulgaris L.)* at Megech

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Abstract

Snap bean (Phaseolus vulgaris L.) is a rich source of protein, calcium and iron and plays a very important role in human diet mainly as source of protein especially to the vegetarian diet. Snap bean is exportable crop to regional and international markets. In Amhara region, there was limited work started on snap bean though the environment is favorable for its production. Indam-2005 was found adaptive, suitable and high yielder snap bean variety in Amhara region. However, for high scale production its nutrient requirement is not studied. A field experiment was conducted at Dembia Woreda of north western Ethiopia during 2011 and 2012 irrigation seasons to evaluate the response of nitrogen and phosphorous fertilizer. The experiment was laid down in randomized complete block design (RCBD) with three replications. Three rates of nitrogen fertilizer (46, 69 and 92 kg ha^{-1}), five rates of P_2O_5 (23, 46, 69, 92 and 115kg ha^{-1}) and a control –without any fertilizer) were evaluated. The combined analysis of variance of the experiment in both years indicated that the application of 92kg N ha^{-1} with 69kg P_2O_5ha^{-1} gave higher pod yield. Therefore, application of 92 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1} is recommended for farmers in Megech and similar areas.

Key words: Snap bean, nitrogen, phosphorous, fertilizer

Introduction

Snap bean (*Phaseolus vulgaris* L.) belongs to the family Fabaceae. It is also called as French bean, kidney bean, navy bean and green beans or string beans (Aguiar, *et al.,* 2008). Snap bean was originated in South Mexico, Guatemala. It is an important short duration leguminous pod vegetable grown for its tender green pods (Zinabu, 2000). When the beans swell to their maximum size but have not yet started to dry, the seeds are often shelled out and eaten as shelly beans (Ashworth, 2002). Pods of green beans are prepared whole, sliced or cut, and the seeds may be harvested green as a vegetable, or dry as a pulse (Davis, 1997). Both young pods and mature seeds are used as a cooked vegetable. The young leaves are used as cooked, particularly in East Africa (Raymond, 1997). It is a rich source of protein, calcium and iron and plays a very important role in human diet mainly a source of protein especially to the vegetarian diet (Zinabu, 2000). It contains protein (1.7 mg), Carotene (132 mg), Thiamine (0.08mg), Riboflavin (0.06mg) and vitamin C (24mg/100gm of edible pods) (Chadha, 2001).

Snap beans has a short growing period and fresh pods may be harvested from dwarf cultivars 40-60 days from sowing while for climbing cultivars harvesting is possible from 70-90 days (Raymond, 1997). It requires a well-drained soil of medium texture and high fertility can produce best results but production is possible on a wide range of soil types provided drainage is good and the pH is between 6.5 and 7.5. The suitable climatic regime is found at an altitude range of 1000-2000 m.a. s.l. (Seifu and Lemlem, 1992). French bean has deep penetrating root system enables the crop to utilize the limited available moisture efficiently and contributing substantially to the loosening of soil. In general, it is more drought tolerant (Zinabu, 2000).

More than 90 percent of snap bean produced in Eastern Africa is exported to regional and international markets. Snap bean is an important export vegetable crop in Kenya, Tanzania, Uganda, Zambia, Zimbabwe and North Africa. It gained importance in other countries such as Cameroon, Ethiopia, Rwanda and Sudan. (CIAT, 2006). In Ethiopia, large commercial farmers started the production of green beans for export to Europe in the early 1970s (Seifu and Lemlem, 1992). Nationally the Ethiopian Horticultural Development Centre produces green beans in large-scale farms to export it to Europe and other countries. Though there is favorable environmental and edaphic condition for the production of snap bean in the Amhara region, only limited works have been done so far. No works have been done on the determination of optimum nitrogen and phosphorus fertilizer rate for production of snap bean in North Gondar zone, Ethiopia. Hence, there is a need to acquire of information on influences of nitrogen and phosphorus in the growth, yield and yield components of snap bean and know the optimum rate of fertilizers in study area. Therefore, this study was conducted to evaluate the effect of nitrogen and phosphorus fertilizer rates on growth, yield and yield components of snap bean and identify the optimum rate of nitrogen and phosphorous fertilizers.

Materials and methods

Geographic Location of the study Area

The study was conducted on farmers' fields for two years in Megech irrigation area which is located in Dembia Woreda, North Gondar Zone, of the Amhara National Regional State, on 37.30º Longitude and 12.25º Latitude. The area receives an average precipitation of 900 mm per annum, with maximum rainfall occurring from June to September accounting more than 85% of the annual rainfall received. The average daily temperatures range from 18.7°C to 23°C with a mean value of 20 °C. According the survey conducted by Ministry of Water (unpublished), the soil types of the study area include: Eutric Vertisols, Eutric Fluvisols and Eutric Gleysols. The area is characterised by slow drainage – associated with heavy clay texture, flat topography and shallow groundwater table.

Experimental design and procedures

An on-farm experiment was conducted in 2011 and 2012 irrigation season. The experiment contains sixteen treatments in Randomized Complete Block Design with three replications. Three rates of nitrogen fertilizer (46, 69 and 92 kg/ha) and five rates of P_2O_5 (23, 46, 69, 92 and 115kg/ha) with the control (without any fertilizer) were used. Improved snap bean variety (Indam-2005) was sown in rows. Triple Super Phosphate (TSP), Di-ammonium phosphate (DAP) and Urea fertilizers were used as fertilizer source to supply phosphorous (P) and nitrogen (N). Gross plot size was 7.5 m^2 (2.5m*3m). Spacing between blocks and plots were 1.5 m and 1m respectively. Spacing between rows was 50 cm and the seeds were drilled in rows and thinned to 10 cm spacing between plants 15 days after sowing.

Plots were kept weed free by hand weeding. All other agronomic practices were applied.

Data collection

Soil data

Prior to planting surface (0 - 40 cm) soil samples, from five spots across the experimental field were collected. The soil samples were air dried, thoroughly mixed and grounded to pass 2 mm sieve to determine necessary soil physical and chemicals parameters. Available P was extracted with sodium bicarbonate solution at pH 8.5 following the procedure described by Olsen et al. (1954). Total nitrogen was determined by the micro-Kjeldahl digestion, distillation and titration method as described by Jackson (1958). Soil pH was measured potentiometrically in the supernatant suspension of a 1:2.5 soil:water mixture using a pH meter according to method outlined by Sahlemedhin and Taye (2000). Organic carbon was determined following the Walkley and Black wet oxidation method as described by Jackson (1958). The soil CEC was determined at pH 7 after displacement of the cations by using 1 N ammonium acetate; thereafter, the ammonium was estimated titrimetrically by distillation of ammonium that was displaced by sodium following the procedure of Sahlemedhin and Taye (2000). Total exchangeable bases were determined after leaching the soils with ammonium acetate; Ca^{2+} and Mg^{2+} in the leachate were analyzed by atomic absorption spectrophotometer and K^{+} and Na^{+} were analyzed flame photometrically following the procedure of Sahlemedhin and Taye (2000).

Yield data

Data on plant height, pod length, pod diameter, number of pods per plant, average pod weight and green pod yield were taken from ten random plants in the middle rows of the snap bean experiment. The plant height was measured from the base of the plant to the apical bud of plant and expressed in centimeters. The number of pods per plants was counted and average was recorded as number of pods per plant. Pod diameter and pod length were determined by measuring the length and the diameter of pods from ten random snap bean plants in the middle rows. The green pod yield was measured at maturity during harvesting.

Statistical Analysis

The collected data were analyzed using SAS software (SAS V9.0, SAS Institute Inc., Cary, NC, USA). Whenever significant differences between treatments are detected, mean separation was done using least significant difference (LSD).

Results and discussions

Physical and chemical Properties of the Soil

The analytic results indicated that the experimental soil was low in its organic matter which is about 2.53 % according to Landon (1991) ratings (>20 % very high, 10-20 % high, 4-10 % medium, 2-4 % low and < 2 % very low) (Table 1). The low organic matter content of the soils has been attributed to factors such continuous cultivation, frequent and complete removal of farm residues commonly carried out by farmers in the area which tends to destroy much of the organic materials that could have been added to the soil. The CEC of the soil was 65.56 $cmol_c$ kg^{-1} which could be considered as medium (Landon, 1991). According to Olsen et al. (1954) P rating (mg kg-1), P content of < 3 is very low, 4 to 7 is low, 8 to 11 is medium, and > 11 is high. Thus, the available P content of the experimental site was 7.92 and was considered as medium. The pH of the soil was 6.74 (neutral) (Table 1).

Table 1 Results of the Initial soil samples

Parameters	**Soil analysis results**
pH	6.74
Available P (ppm)	7.92
Total N	0.09%
Organic matter (%)	2.53
CEC cmol(+)kg^{-1}	65.56
Exchangeable Ca, cmol(+)kg^{-1}	40.76
Exchangeable Mg, cmol(+)kg^{-1}	23.86
Exchangeable k, cmol(+)kg^{-1}	0.99
Exchangeable Na, cmol(+)kg^{-1}	0.41

Yield and yield related parameters

The results showed that there was statistically significant difference ($p < 0.01$) in plant height, pod length, pod diameter, number of pods per plant, average pod weight and green pod yield. The treatments applied at different stages, significantly affect yield and yield related parameters of snap bean (Table 2). All applied nitrogen and phosphorous fertilizer rates significantly increased yield and yield related components of snap bean over the control. The combined analysis showed that maximum plant height (44.53) was obtained at 92 kg/ha of N and 69 kg/ha P_2O5. While the lowest plant height (31.93 cm kg/ha) was recorded in the control plots 0 kg/ha nitrogen fertilizer and 0 kg/ha P_2O5. Application of Nitrogen and phosphorous fertilizer had significantly increased the number of pod per plant (Table 2). The maximum snap bean pod length and pod diameter were recorded at 92 kg/ha of N and 69 kg/ha P_2O5 and the minimum was recorded in the control plots 0 kg/ha nitrogen fertilizer and 0 kg/ha P2O5.

The results of the combined analysis showed that the highest number of pods per plant was observed at 92 kg/ha of N and 69 kg/ha P_2O5. While the lowest plant height (31.93 cm kg/ha) was recorded in the control plots 0 kg/ha nitrogen fertilizer and 0 kg/ha P_2O5.The result is similar to (Shubhashree K.S., 2007), reported that applications of different rates of nitrogen and phosphorus fertilizer influence number of pod per plant. Similarly, (Veeresh N.K., 2003) observed significantly more number of pods per plant of common bean. Singh A.K. and Singh S.S., 2000 reported significant increase in number of pods per plant, due to increased fertilization. Thus the increment of number of pods per plant due to application of fertilizer application confirms that fertilizer promotes the formation of nodes and pods in snap beans.

The combined analysis also showed that the results were consistent over two years. The applied rates of nitrogen and phosphorus fertilizer had significantly increased the average green pod weight and green pod yield of snap bean. There was a significant difference among the levels nitrogen and phosphorous fertilizer rates (Table 2). The maximum (19.17 t/ha) green pod yield was recorded at the application of 92 kg/ha of N and 69 kg/ha P_2O5, where as the minimum (8.87 t./a) was recorded on control plots. This result is in accordance with Shubhashree, (2007), who reported increase of dry matter accumulation with phosphorus rates. Similarly, significant and linear increase in total dry matter production of common bean plant was observed due to increased phosphorus (Veeresh, 2003). The study result also agrees with the result of the study conducted on soybean by Jenifer, (2000) who reported that increment of the fertilizer concentration in the soil increased the whole plant dry matter accumulation and total leaf area. The increment in dry matter yield with the application of nitrogen and phosphorous might be attributed to the adequate supply of nutrients that could in turn increase the number of branches per plant, and leaf area and increased photosynthetic area and number of pods per plant, which demonstrates a strong correlation with dry matter accumulation and yield.

Table 2 Effect of N and P on snap bean yield and yield traits combined over years

N	P_2O_5	Plant height (cm)	Pod length (cm)	Pod diameter (cm)	Number of pod/plant	Average pod weight (gm)	Green pod yield ($tonha^{-1}$)
0	0	31.93^{f}	7.30^{g}	0.67^{f}	5.06^{g}	3.13^{d}	8.87^{i}
46	23	35.67^{ef}	10.10^{f}	0.71^{ef}	6.86^{f}	4.13^{d}	13.05^{h}
69	23	40.53^{abcd}	11.75^{e}	$0.75d^{ef}$	6.98^{f}	8.20^{abc}	13.80^{h}
92	23	40.87^{abcd}	12.25^{cde}	0.72^{ef}	8.20^{f}	7.40^{bc}	15.44^{efg}
46	46	38.00^{cde}	12.81^{cde}	0.74^{def}	9.63^{e}	7.13^{c}	15.19^{gf}
69	46	40.87^{abcd}	13.13^{cd}	0.81^{bcd}	11.59^{cd}	7.67^{bc}	16.23^{def}
92	46	43.07^{ab}	13.06^{cde}	0.82^{bc}	12.82^{c}	8.27^{abc}	16.67^{cde}
46	69	39.47^{bcde}	12.35^{cde}	0.71^{ef}	9.81^{e}	7.20^{c}	13.72^{h}
69	69	42.80^{ab}	12.89^{cde}	0.71^{ef}	12.50^{c}	8.47^{abc}	15.47^{efg}
92	69	44.53^{a}	16.02^{a}	0.90^{a}	16.65^{a}	9.33^{a}	19.17^{a}
46	92	42.93^{ab}	12.39^{cde}	0.80^{bcd}	12.85^{bc}	8.33^{abc}	14.37^{gh}
69	92	39.87^{bcde}	14.56^{b}	0.84^{ab}	15.30^{ab}	8.27^{abc}	18.47^{ab}
92	92	42.87^{ab}	12.96^{cde}	0.68^{ef}	14.61^{b}	8.13^{abc}	17.88^{abc}
46	115	37.20^{de}	11.85^{de}	0.74^{def}	12.17^{c}	7.40^{bc}	17.53^{bcd}
69	115	42.13^{abc}	13.26^{bc}	0.74^{def}	14.84^{b}	8.67^{ab}	16.49^{def}
92	115	42.00^{abc}	12.43^{cde}	0.70^{ef}	10.54^{de}	7.40^{bc}	14.20^{gh}
CV (%)		6.89	6.48	5.07	7.42	11.71	5.4
LSD (0.05)		4.61	1.34	0.07	1.39	1.45	1.38

Conclusion and recommendation

Application of the correct amount and type of fertilizer is necessary to achieve maximum yield of snap bean crop. In the present study the applied nitrogen and phosphorous fertilizer levels were showed significant difference on plant height, pod length, pod diameter, pod number per plant, average pod weight and green pod yield. Hence, it is possible to conclude that snap bean performs well in terms of overall growth and yield with the application of N and P fertilizers. Application of 92 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1} resulted in vigorous overall plant growth and increased snap bean pod yield. Therefore, application of 92 kg/ha N and 69 kg/ha P_2O_5 is recommended for farmers in Megech and similar areas. Since this study was done in one location for two years only, further investigation is imperative in different locations to have a clear recommendation for the optimum level of nitrogen and phosphorous fertilizer to produce snap beam over different locations.

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Effect of Nitrogen and Phosphorous on Maize (*Zea mays* L.) Green Cob Yield under Irrigation in North Gonder

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Abstract

A field experiment was conducted in 2011 and 2012 irrigation seasons to determine the optimum levels of nitrogen (N) and phosphorus (P) fertilizers for maize production at Megech irrigation area, Dembia District of North Gonder. The experiment was arranged in Randomized Complete Bock Design with three replications. There were 16 treatments (4 rates of N (0, 69, 92 and 115 kg ha^{-1}) and 4 rates of P_2O_5 (0, 23 46 and 69 kg ha^{-1})). Maize variety, HB 545 was used for the experiment. Soil samples were collected from 0-20 cm depth to evaluate the soil fertility. Agronomic data such as plant height, cob length and cob number were collected, and the data were subjected to SAS statistical software. Partial budget analysis was done to evaluate the economic benefit against the fertilizers used. The combined analysis of variance in both years indicated that, N and P had significant effects on plant height, cob length and cob number. Application of 92 kg N and 69 kg P_2O_5 ha^{-1} gave the maximum cob number and cob length while the minimum was obtained from the control. The partial budget analysis for the green maize cob number also revealed that the maximum benefit was obtained from the combination of 92 kg N and 69 kg P_2O_5 ha^{-1}. Therefore, this fertilizer rate is recommended for Megech irrigation site and similar agro-ecologies under irrigation system.

Key words: green maize, nitrogen, phosphorous, fertilizer, green cob

Introduction

Maize (*Zea mays* L.) is an important cereal crop ranking third after wheat and rice in the world (Gibbon and Pain, 1985; FAO., 2011). In Africa, the bulk of maize produced is used as human food and the area coverage of maize in West and Central Africa alone increased from 3.2 in 1961 to 8.9 million ha in 2001. This remarkable expansion increased the quantity of maize production from 2.4 in 1961 to 10.6 million Mt in 2001 (FAO, 2002). Developing countries contribute 67% in the world cultivated land of maize but their share in quantity of production is only about 46%, where approximately 60% of the world maize is produced by USA and China collectively (Ghaffari *et al*., 2011).

In Ethiopia, maize is the major staple food and one of the main sources of calorie (Million and Getahun, 2001; Tolessa *et al*., 2001) being cultivated on about 1.75 million ha and accounts for 20% of the 8.5 million ha (79.98%) of land allocated for cereals. It ranks second after teff (*Eragrostis tef* (Zucc.)) in area coverage and first in total national production and yield per ha (CSA, 2008). Ethiopia has a potential to increase its productivity up to 8 tons per hectare. However, the national average yield, 3.2 t ha^{-1} (CSA, 2014) is still very low compared to the global average of 5.2 t ha^{-1} (FAO, 2011). This low productivity may be attributed to low soil fertility (Worku and Zelleke, 2007) and poor management practices (Tolessa *et al*., 2001) of which nitrogen and phosphorus nutrient deficiency and improper tillage can be mentioned as the most growth and yield limiting factors in the country.

Poor soil fertility is one of the bottlenecks for sustaining maize production and productivity in Ethiopia (Tolessa *et al.*, 2002). In most regions of Ethiopia, soils are deficient in nitrogen (N) and phosphorus (P). This adverse soil conditions prevail, and frequently a combination of these limit crop production. The situation has been further aggravated by the long history of cultivation without any nutrient replenishment including NP, which led to low soil fertility and low crop yields. Maize is heavy nutrient feeder and has high demand for N and P which are often the limiting nutrients for maize production. In Megech irrigation area the farmers usually produce shallot and garlic during the irrigation season and couldn’t benefit from it due to high supply and short shelf life of the crops. Hence, after systematic investigation maize was introduced to the system as an enterprise choice. It is known that maize is a cash, food and feed crop which has multiple uses. The lack of alternate crops to the irrigation system and the importance of maize necessitates the introduction of high yielding varieties adaptive to the system with full package was important. Hence, HB-545 and Wonchi varieties were recommended after variety adaptation trial for higher grain and green cob yield for Megech irrigation area. However, the optimum nitrogen and phosphorus fertilizer rate for optimum production was lacking. Therefore, this experiment was conducted to determine the optimum levels of N and P fertilizers for maize (*Zea mays* L.) production under irrigation in Megech irrigation area.

Materials and methods

Geographic Location of the study Area

The study was conducted on farmers' fields for two years (2011 and 2012) in Megech irrigation area which is located in Dembia Woreda, North Gondar Zone, of the Amhara National Regional State, at 37.30º Longitude and 12.25º Latitude with an altitude of 1800 m.a.s.l. The area receives an average precipitation of 900 mm per annum, with maximum rainfall occurring from June to September when more than 85% of the annual rainfall was received. The average daily temperature ranges from 18.7°C to 23°C with the mean value of 20 °C. According the survey report by Ministry of Water, Irrigation and Energy, the soil types (units) identified in the area were: Eutric Vertisols, Eutric Fluvisols and Eutric Gleysols. The study was conducted on Eutric Fluvisols which occur along the Megech River. The soils are derived from alluvial/lacustrine deposits and are very deep. The texture is dominantly heavy clay with firm, sticky and plastic consistency. The study area is generally characterised by slow/poor drainage, with relatively slow infiltration and permeability associated with heavy clay texture, flat topography and shallow groundwater table.

Experimental design and procedures

The experiment was conducted in 2011 and 2012 irrigation seasons on farmer's field. The experiment was laid down in Randomized Complete Bock Design in factorial arrangement with three replications. The treatments were composed of factorial combinations of four rates of nitrogen (0, 69, 92 and 115 kg ha^{-1}) and four rates of P_2O_5 (0, 23, 46 and 69 kg ha^{-1}). All the phosphorus fertilizer from DAP and TSP was applied at planting while the nitrogen fertilizer from urea was applied in three equal splits at three stages including: 1/3 at planting, 1/3 at knee height and 1/3 at tasseling. Maize variety (BH-545) was used as a test crop and was planted in rows at a spacing of 70 cm between rows and 30 cm between plants. In a week interval, each experimental plot received 31mm irrigation water using furrow irrigation method uniformly. Other agronomic practices such as plowing, thinning, weeding earthling up and pest control were applied to all plots uniformly. The gross and net plot sizes were 9 m^2 (3m*3m) and 6.75 m^2 (3m*2.25m) respectively. The spacing between blocks and plots were 1.5 m and 1 m respectively.

Data collection

Soil sampling and analysis

Prior to planting, composite soil sample from 0 - 20 cm depth was collected following the standard soil sampling procedure (FAO, 2006). The soil samples were air dried, thoroughly mixed and grounded to pass 2 mm sieve to determine necessary soil chemicals parameters. Available P was extracted with sodium bicarbonate solution at pH 8.5 following the procedure described by Olsen *et al*. (1954). Total nitrogen was determined by the micro-Kjeldahl digestion, distillation and titration method as described by Jackson (1958). Soil pH was measured potentiometrically in the supernatant suspension of a 1:2.5 soil:water mixture using a pH meter according to method outlined by Sahlemedhin and Taye (2000). Organic carbon was determined following the Walkley and Black wet oxidation method as described by Jackson (1958). The CEC was determined at pH 7 after displacement of the cations by using 1 N ammonium acetate; thereafter, the ammonium was estimated titrimetrically by distillation of ammonium that was displaced by sodium following the procedure in Sahlemedhin and Taye (2000). Total exchangeable bases were determined after leaching the soils with ammonium acetate; Ca^{2+} and Mg^{2+} in the leachate were analyzed by atomic absorption spectrophotometer and K^+ and Na^+ were analyzed by flame photometer following the procedure in Sahlemedhin and Taye (2000).

Yield and yield component data

Data on plant height, cob length and cob number per plot were taken from ten random plants in the middle rows of the maize experiment. The plant height was measured from the base of the plant to the top of plant and expressed in centimeters. The number of cobs per plot was counted in the middle rows and converted to hectare bases.

Statistical and Partial Budget Analyses

The collected data was analyzed using SAS software (SAS V9.0, SAS Institute Inc., Cary, NC, USA). Whenever significant differences between treatments are detected, mean separation was done using least significant difference (LSD). The partial budget analysis was done to compare the impact of technological change on farm costs to evaluate economic advantage of fertilizer used to boost maize production following the CIMMYT partial budget analysis procedure (CIMMYT, 1988). Following CIMMYT's partial budget analysis methodology, total variable costs (TVC), gross benefit and net benefit were calculated. Net benefit was calculated as the difference between gross benefit and the TVC.

Variable costs include:

- Cost of fertilizers (N and P) which vary between fertilizer rates/treatments).
- Cob numbers per hectare resulted from each treatment which was adjusted by 5% decrement for each treatment
- Farm price i.e. prices of harvested cobs which was 1.25 birr per cob at time of harvesting

Costs for land preparation, weeding, seed, watering, harvesting were uniform for each treatment and were considered as fixed costs.

Results and discussions

Soil chemical properties of the of the study area

The analytic results indicated that the soil of the experimental site was low in its organic matter content which is about 3.17 % (Table 1). According to Landon (1991) organic matter: >20 % is very high, 10-20 % is high, 4-10 % is medium, 2-4 % is low and < 2 % very low. The low organic matter content of the soils of the experimental site may been attributed to continuous mono cropping and frequent and complete removal of farm residues commonly carried out by farmers in the area which tends to destroy much of the organic materials that could have been added to the soil. The CEC of the soil of the experimental site was 62.48 $cmol_c\ kg^{-1}$ which could be considered as very high (Landon, 1991) which may be attributed to high clay content. According to Olsen *et al*. (1954) P rating ($mg\ kg^{-1}$), P content of < 3 is very low, 4 to 7 is low, 8 to 11 is medium, and > 11 is high. Thus, the experimental site of available P content was 6.47 which were considered as low. The soil has very high exchangeable Ca (>20 $cmol_c\ kg^{-1}$ soil) and exchangeable Mg (>8 $cmol_c\ kg^{-1}$ soil) (Table 1). Ca to Mg ratio is 2.5 which indicate the likely inhibition of Ca uptake by the higher amount of exchangeable Mg. Exchangeable K and Na contents were high and low respectively (Table 1). The ratio of K to Mg is 0.06 which showed favorable proportion between the two cations in the soil. The soil pH of the study area was 6.85 (neutral). Maize grows at a pH range of 5 to 8. However, the ideal pH for optimum yield is between 6.5 and 7. Thus the pH of the study site is suitable for maize production. In general, the soil chemical properties including CEC and pH were good for maize production while the others including nitrogen and phosphorus need improvement (amendment) to a level that they could give optimum maize yield.

Table 1 Soil chemical properties of the initial soil samples

Parameters	Values
pH	6.85
Available P (ppm)	6.47
Total nitrogen (%)	0.09
Organic matter (%)	3.17
CEC cmol(+) kg^{-1}	62.48
Exchangeable Ca, cmol(+) kg^{-1}	48.47
Exchangeable Mg, cmol(+) kg^{-1}	11.77
Exchangeable K, cmol(+) kg^{-1}	0.74
Exchangeable Na, cmol(+) kg^{-1}	0.09

Plant height and cob yield

The analysis of variance of the experiment indicated that there was statistically significant difference ($p < 0.05$) among the treatments for parameters such as: plant height, cob length and number of cobs (Table 2, 3 and 4). Plant height was significantly ($P < 0.05$) influenced by levels of nitrogen and phosphorous fertilizers (Table 2). The taller plant height was obtained from the plots applied with of maximum inputs, (115 kg N $ha^{-1}$and 69 kg P ha^{-1}) while the smallest plant height was obtained from the control plot (plot without input). This result clearly revealed that fertilizer application is very important to increase the height of maize plant.

As described in Table 3, the longest cob length was recorded by the application of 92 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1}. Similarly there was significant ($P < 0.05$) response in number of cobs per hectare to the application of nitrogen and phosphorous (Table 4). The maximum cob number (44556 cob ha^{-1}) was obtained from the plots applied with 92 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1} followed by the plots applied with 115 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1} while the smallest cob length and cob number were recorded from the plots receiving no fertilizer (Table 4). In general, increased application of N and P fertilizer was accompanied by increased maize yield. Similar results were reported by Tenaw (2000) Tolessa *et al*., (2002), Jehan *et al*., (2006) and Kolawole and Joce (2009). Tolessa (1999) also found progressive increases in maize grain yield with an increase in the levels of N and P fertilizers.

Table 2. The interaction effect of Nitrogen and Phosphorous fertilizer on maize plant height (cm)

	N rates (kg/ha)			
P_2O_5 rates (kg/ha)	0	23	46	69
0	117.1^{i}	141.9^{gh}	138.0^{h}	139.1^{h}
69	142.7^{gh}	146.5^{fgh}	157.1^{de}	166.4^{bc}
92	143.2^{fgh}	149.2^{efg}	172.2^{b}	170.2^{b}
115	151.8^{def}	159.5^{cd}	174.4^{b}	188.4^{a}
CV (%)	7.2			
LSD (0.05)	9.05			

Table 3. The interaction effect of Nitrogen and Phosphorous fertilizer on maize cob length (cm)

	N rates (kg/ha)			
P_2O_5 rates (kg/ha)	0	23	46	69
0	8.7^{g}	9.8^{fg}	13.4^{de}	10.9^{efg}
69	12.5^{def}	14.3^{d}	17.6^{bc}	15.0^{cd}
92	13.4^{de}	13.6^{de}	17.7^{bc}	22.0^{a}
115	14.1^{d}	14.9^{cd}	17.4^{bc}	20.1^{a}
CV (%)	10.8			
LSD (0.05)	2.76			

Table 4. The interaction effect of Nitrogen and Phosphorous fertilizer on maize cob number

	N rates (kg/ha)			
P_2O_5 rates (kg/ha)	0	23	46	69
0	15555.6^{g}	19333.3^{fg}	19333.3^{fg}	22222.2^{efg}
69	28888.9^{efg}	29555.6^{de}	31777.8^{cd}	33777.8^{bcd}
92	26666.7^{def}	33333.3^{bcd}	384444.4^{abc}	44555.6^{a}
115	29777.8^{de}	40666.7^{ab}	44000.0^{abc}	43777.8^{abc}
LSD (0.05)	10666.6			
CV (%)	4.8			

Partial budget analysis

Economic analysis was done to identify the most profitable nitrogen and phosphorous fertilizer rate. The partial budget analysis showed that application of 92 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1} is economically profitable for sorghum production for it gave a rate of return above 100% acceptable rate of return (Table 5). Similarly, the highest MRR (555.67 %) was recorded by applying 92 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1}. This result indicated that for each 1.ETB additional investment on fertilizer farmers can earn a return of 4.67 ETB (Ethiopian birr). According to Horton (1982), the greater the increase in net income and the higher rate of return, the more economically attractive the fertilizer rate is. The author further explained that the fertilizer rate is accepted only if the return is higher than 1.0. Hence, from the partial budget analysis the maximum benefit 42579.89 ETB per hectare was obtained by the application of 92 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1} (Table 5). The marginal rate of return (MRR) was 555.67%. This indicates that for every 1 ETB invested for fertilizer there will be a net benefit of 4.67 ETB.

Table 5: Partial budget analysis for green cob number

(N, P_2O_5) kg/ha	Adjusted yield kg/ha	Total Revenue birr/ha	P costs birr/ha	Total costs birr/ha	GFB birr/ha	NB birr/ha	V. cost birr/ha	DA	MC birr/ha	MNB birr/ha	MRR %
(0,0)	14777.82	18472.28	6000	6000	12472.28	12472.28	0				
(0,23)	18366.64	22958.29	6000	6676	16958.29	16282.29	676		676	3810.02	563.61
(0,46)	18366.64	22958.29	6000	7352	16958.29	15606.29	1352	D			
(69,0)	21744.46	27180.57	6000	7726.5	21180.57	19454.07	1726.5		1050.5	3171.78	301.93
(0, 69)	21111.09	26388.86	6000	8028	20388.86	18360.86	2028	D			
(92,0)	25333.37	31666.71	6000	8302	25666.71	23364.71	2302		575.5	3910.64	679.52
69, 23	28077.82	35097.28	6000	8402.5	29097.28	26694.78	2402.5		100.5	3330.07	3313.50
(115,0)	28288.91	35361.14	6000	8877.5	29361.14	26483.64	2877.5	D			
(92, 23)	31666.64	39583.29	6000	8978	33583.29	30605.29	2978		575.5	3910.52	679.50
(69, 46)	30188.91	37736.14	6000	9078.5	31736.14	28657.64	3078.5	D			
(115, 23)	38633.37	48291.71	6000	9553.5	42291.71	38738.21	3553.5		575.5	8132.91	1413.19
(92, 46)	36522.18	45652.73	6000	9654	39652.73	35998.73	3654	D			
(69, 69)	32088.91	40111.14	6000	9754.5	34111.14	30356.64	3754.5	D			
(115, 46)	41800.76	52250.95	6000	10229.5	46250.95	42021.45	4229.5		676	3283.24	485.69
(92, 69)	**42327.92**	**52909.89**	**6000**	**10330**	**46909.89**	**42579.89**	**4330**		**100.5**	**558.44**	**555.67**
(115, 69)	41588.91	51986.14	6000	10905.5	45986.14	41080.64	4905.5	D			

Note: *P cost: production cost, GFB: gross field benefit, NB: Net benefit, V. cost: variable cost, DA: dominance Analysis, MC: Marginal cost, MNB: Marginal net benefit, MRR: Marginal rate of return*

Conclusions and Recommendations

The soil data analysis of the study site showed that the pH of the soil neutral which is suitable for the production of many crops including maize. But the content of some of the soil chemical properties need to be amended for optimum maize production. The analysis of variance revealed that fertilizer rates (N and P_2O_5) significantly affected plant height, cob length and cob number. The maximum cob number and the longest cob length were obtained by applying 92 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1}. Application of 115 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1} gave the tallest plant height. Similarly the partial budget analysis result indicated that the maximum net benefit was obtained by the application of 92 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1}. Therefore, it is recommended to apply 92 kg ha^{-1} N and 69 kg P_2O_5 ha^{-1} for profitable green maize production for Megech irrigation area and similar agro-ecologies.

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Response of Irrigated Hot Pepper to Nitrogen and Phosphorus application at Rib

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Abstract

A field experiment was conducted for two years (2011 and 2012) to determine the optimum amount of nitrogen (N) and phosphorus (P) fertilizers for hot pepper (Capsicum frutescens) at Rib under irrigation. The experiment was comprised of a factorial combination of five rates of nitrogen (46, 69, 92, 115,138 kg ha^{-1}) and three rates of phosphorus (20, 30 and 40 kg ha^{-1}). Additionally one treatment without N and P was included as a negative control. The treatments were arranged in a randomized complete block design with three replications. Phosphorus was applied at transplanting while nitrogen was applied in two splits i.e. half at transplanting and half at early flowering. The result showed that the marketable yield was significantly increased by N and P. The highest yield in 2011 (26460 kg ha^{-1}) was obtained from 115 kg N ha^{-1} and 40 kg P ha^{-1} and in 2012 (27857 kg ha^{-1}) was obtained from 115 kg N ha^{-1} and 20 kg P ha^{-1}. The partial budget analysis also showed that applying 115 kg N and 20 kg P ha^{-1} had the highest net benefit (67753.22 ETB ha^{-1}) and MRR of 2011.46 % followed by 46 kg N ha^{-1} and 30 kg P ha^{-1} with a net benefit of 67019.65ETB and MRR of 389.31%. Thus, 115 kg N and 20 kg P ha^{-1} are recommended for pepper for Rib and similar agro-ecologies under irrigation.

Keywords: hot pepper, nitrogen and phosphorus, optimum rate, marketable yield

Introduction

Pepper is belonged to the solanaceous group of plants along with tomatoes, eggplants and some other ornamental plants. It has been a part of the human diet since about 7500 BC (Mac Neish, 1964 cited in Sileshi, 2011). Because of its wide use in Ethiopian diet, the hot pepper is an important traditional crop mainly valued for its pungency and color. The crop is also one of the important spices that serve as the source of income particularly for smallholder producers in many parts of rural Ethiopia. According to the EEPA (2003 cited in Sileshi, 2011), in the major pepper producing regions in the country, that is, Amhara, Southern Nations and Nationality People's Regional State (SNNP) and Oromia, pepper generated an income of 122.80 million Birr for farmers in 2000/01. This value jumped to 509.44 million Birr for smallholder farmers in 2004/05. This indicates that hot pepper serves as one of the important sources of income to smallholder farmers and as exchange earning commodity in the country (Beyene and David, 2007 cited in Sileshi, 2011).

Peppers is a heavy feeders cash crop and needs large amounts of nutrients to produce quality crop, especially from 10 days after the plants flower until just before the fruit begins to ripen, (Zhang et.al. 2002). In intensive planting systems, the hot pepper plant requires fertilizing at transplanting to promote root establishment and shoot development, at flowering to ensure flower set and fruit retention, and during harvest for continued production (FAO, 2004). Pertaining to the different studies done on this crop, pepper fertilizer management recommendations have changed throughout the years in keeping with new developments in research in different corners of the world (Montelaro, 1978 in Hochmuth and Hanlon, 2010). Young pepper plants are often raised indoors in loose soil that gives the roots room to breathe. The soil should be watered often, and supplemented with a fertilizer that's rich in nitrogen, phosphorus, potassium and calcium. Preliminary growth experiments showed that P affected plant height, leaf area, root, stem and leaf dry weights as well as overall plant dry weight (Aldana, 2005). Pepper plants need more than a dozen specific nutrients to survive, including carbon, phosphorus, potassium, calcium, iron, zinc and nitrogen. The plant can get many of these basic nutrients from the air, the soil, or water. Others, such as nitrogen and phosphorus, may be more difficult to access, especially in certain types of soils. It is logical to select a single target rate based on research that avoids excessive fertilizer applications that often reduce crop nutrient efficiency and increase the potential for environmental degradation (Hochmuth and Hanlon, 2010). Such nutrients are required to be supplied by the producers in order to realize higher productivity, and at the precise rates that match the specific growing conditions. In Ethiopia, the blanket recommended fertilizer rate for the hot pepper is, 200 kg ha^{-1} DAP and 100 kg ha^{-1} for urea (EARO, 2004 cited in Sileshi, 2011) for the rainfall condition soil and environmental conditions site specific recommendation under irrigation is vital. However, there was no recommended fertilizer rate for hot pepper under irrigation. Therefore, the objective of this research was to determine site specific optimum nitrogen and phosphorous fertilizer rates for Rib and similar agro-ecologies under irrigation.

Materials and methods

Description of the study site

The experiment was conducted at Rib which is found in Fogera district situated at 11^0 41' to 12^0 02' N latitude and 37^0 29' to 37^0 59' E longitude at an altitude of 1800 m a.s.l. The soil of experimental site was Fluvisols. According to the classification made by Bruce and Rayment (1982), the available phosphorus content of the soil was high while the total nitrogen content was low to very low (Table 1). Cation exchange capacity (CEC) was also high based on the category recommended by Hazelton and Murphy (2007).

Table 1. Chemical soil properties for the testing sites

Sample	Available Phosphorus (ppm)	Total Nitrogen (%)	CEC (cmol kg^{-1})
Farmers' field	24.32-36.71	0.003-0.18	33.00-36.25

Experimental design and procedures

The experiment was conducted on farmers' field for two consecutive years 2011 and 2012. Five rates of N (46, 69, 92, 115,138 kg ha $^{-1}$) and three rates of P (20, 30 and 40 kg ha $^{-1}$) were tested in factorial arrangement including a control treatment (without fertilizer), making the total number of treatments 16. The experimental plot was laid down in randomized complete block design with thee replications. All phosphorus was applied at transplanting while nitrogen was applied in two splits ½ at transplanting and the other ½ at early stage of flowering. The seedlings of pepper (Mareko Fana) were raised at Woramit testing site 50 days prior to transplanting. The spacing during transplanting was 30 cm between plants, 70 cm between rows, 1 m between plots and 1.5 m between blocks. The plot size of the experiment was 2.8 m X 3 m ($8.4m^2$) and the net plot size was 4.5 m^2. Water was supplied every week by furrow irrigation system until saturated.

Composite soil samples for the determination of physicochemical properties of the experimental plots were collected prior to planting. Samples were air dried, ground, and passed through 2 mm sieve and prepared for the analysis of most soil chemical properties except total N which needs to pass through 0.5 mm size sieve. Cation exchange capacity (CEC) was determined by the 1M ammonium acetate (pH 7) method according to the percolation tube procedure (Van Reeuwijk, 1993). Total nitrogen and available phosphorus were determined using Kjeldahl (Jackson, 1958) and Olsen (Olsen et al., 1954) methods, respectively.

Plant height (cm) was recorded using five randomly selected plants in each plot starting from the soil surface to the tip of the plant. Maturity date was recorded when at least fifty percent of the plant is matured while stand count, fruit length and fruit diameter were recorded at harvest. Uniform, unblemished, shinnies, absence of surface defects due to disease and insects, firmed fruits with normal fruit size based on visual observation were considered as marketable fruit while the rest were unmarketable fruits. In Each plot, all marketable and unmarketable fruits were harvested three times during the growth period when fruits become firmed and measured using triple balance. The sums of marketable and unmarketable fruits were considered as total fruit yield.

Data were subjected to analysis of variance using SAS statistical package (SAS Institute, 2002) to assess treatment effects. Whenever significant treatment differences were detected, means were separated using DMRT at 5% probability. In order to identify economically feasible recommendations partial budget analysis was done based on the manual developed by CIMMYT (1988). The partial budget analysis was based on data collected from Fogera district office of Trade and Transport, Cooperatives and from hot pepper farmers' field. At Fogera, the mean price of hot pepper, urea and DAP were 7.00 ETB kg^{-1} in the first scenario and 3.5 ETB kg ha^{-1} in the second scenario, 11.88 ETB kg^{-1} and 14.64 ETB kg^{-1} respectively. For sensitivity analysis, yields were adjusted downward by 10% from the exact yield while fertilizer cost was calculated by adding 10% ETB kg^{-1} increase from the current price of fertilizer. Minimum rate of return was taken at100%.

Results and Discussions

The result in 2011 indicated that there was statistically significant difference among the treatments in plant height, marketable yield and total yield (Table 2) but there was no significant difference in fruit length and fruit diameter (Table 2). The highest plant height was obtained from 46 kg N ha^{-1} and 20 kg P ha^{-1} followed by 69 kg N ha^{-1} and 30 kg P ha^{-1} (Table 2). But, there was no statistically significant difference among the other treatments in plant height (Table 2). During 2012, there was significant difference in fruit length, fruit diameter, plant height and yield among treatments (Table 3). The highest plant height was obtained from 138 kg N ha^{-1} and 20 kg P ha^{-1} followed by 92 kg N ha^{-1} and 30 kg P ha^{-1} and 138 kg N ha^{-1} and 40 kg P ha^{-1} (Table 3). The maximum fruit diameter was recorded at 115 kg N ha^{-1} and 20 kg P ha^{-1} (Table 3). In both years the maximum marketable (26460 kg ha^{-1} in 2011 and 27857 kg ha^{-1} in 2012$^{)}$ yield was obtained from 115 kg N and 20 kg P ha^{-1} (Table 3 and Table 4).

Table 2. Influence of N and P on hot pepper green pod at Rib irrigation scheme in 2011

Phosphorous P kg ha^{-1}	Nitrogen N kg ha^{-1}	Plant height cm^{-1}	Fruit length cm^{-1}	Fruit diameter cm^{-1}	Marketable Yield kg ha^{-1}	Total yield kg ha^{-1}
0	0	28.37ab	8.4367	1.28	17560f	17940f
20	46	32.67a	8.566	1.31	22360bc	22360b
20	69	30.57ab	8.2933	1.40	21890c	21890b
20	92	30.27ab	8.630	1.54	23447abc	24513ab
20	115	29.27ab	8.3933	1.46	26460a	26460a
20	138	27.20ab	8.770	1.62	23027abc	23463ab
30	46	31.53ab	9.196	1.45	24283abc	24283ab
30	69	32.07a	8.700	1.37	23600abc	23600ab
30	92	28.13ab	8.2167	1.52	23980abc	23980ab
30	115	25.47b	8.3367	1.57	25657ab	25657ab
30	138	28.83ab	8.510	1.57	23283abc	23283ab
40	46	29.77ab	8.760	1.49	22537bc	22537b
40	69	31.17ab	8.483	1.49	24717abc	24717ab
40	92	31.67a	8.210	1.60	22350bc	22350b
40	115	31.80a	8.573	1.44	23480abc	24230ab
40	138	27.33ab	8.190	1.53	23697abc	23697ab
CV(%)		12.35	7.77	13.21	7.25	8.21
Probability (P<0.05)		*	NS	NS	*	*

Table 3. Response of hot pepper to nitrogen and phosphorous at Rib irrigation scheme in 2012

Phosphorous P kg ha $^{-1}$	Nitrogen N kg ha $^{-1}$	Plant height (cm)	Fruit length (cm)	Fruit diameter (cm)	Marketable yield kg ha^{-1}	Total yield kg ha^{-1}
0	0	63.40^{h}	8.23^{c}	1.90^{e}	11984^{f}	12556^{e}
20	46	69.17^{fg}	10.10^{a}	2.50^{abcd}	17381de	18175^{bcd}
20	69	69.73^{defg}	8.33^{b}	2.49^{abcd}	16667de	17222^{cd}
20	92	73.53^{bcde}	9.63^{a}	2.53^{abc}	13412.70^{de}	14174.60^{d}
20	115	74.53^{abcd}	10.13^{a}	2.67^{a}	27857^{a}	27867^{a}
20	138	78.57^{a}	9.90^{a}	2.47^{abcd}	25119^{ab}	25129^{abc}
30	46	73.97^{abcde}	9.30^{ab}	2.37^{abcd}	18254^{bcde}	18929^{abcd}
30	69	71.70^{bcdef}	9.47^{ab}	2.23^{cd}	17619^{cde}	18071^{cd}
30	92	75.83^{ab}	9.20^{ab}	2.43^{abcd}	20714^{abcd}	21746^{abcd}
30	115	72.90^{bcdef}	9.07^{ab}	2.53^{abc}	17024de	17325^{cd}
30	138	73.17^{bcdef}	8.37^{b}	2.37^{abcd}	24841^{abc}	25421^{abc}
40	46	68.33^{fg}	9.63^{a}	2.17^{de}	15952de	16190^{cd}
40	69	66.20^{g}	9.37^{ab}	2.43^{abcd}	18095^{bcde}	18571^{abcd}
40	92	70.80^{cdefg}	9.10^{ab}	2.47^{abcd}	17619^{cde}	18135^{cd}
40	115	71.93^{bcdef}	9.10^{ab}	2.30^{bcd}	19524^{bcd}	27690^{ab}
40	138	75.67^{abc}	10.10^{a}	2.63^{ab}	20159^{bcd}	20476^{abcd}
CV (%)		4.12	7.59	8.44	22.72	28.20
Probability (P<0.05)		*	*	*	**	**

To observe whether there was significant difference among the treatments with the absence of the control treatment, separate analysis was done for the other treatments in the absence of the control and significant difference was observed among treatments (Table 4). The combined analysis over years also revealed that there was significant difference in marketable and total yield with the highest from 115 kg N and 20 kg P ha^{-1} even though maximum fruit length and fruit diameter were recorded from 115 kg N and 40 kg P ha^{-1} (Table 4).

Table 4. Combined analysis over years at Rib irrigation scheme for 2011 and 2012.

Phosphorous P kg ha $^{-1}$	Nitrogen N kg ha $^{-1}$	Plant height (cm)	Fruit length (cm)	Fruit diameter (cm)	Marketable yield kg ha^{-1}	Total yield kg ha^{-1}
20	46	50.92	9.42^{abc}	1.86b^{cd}	21353^{abcd}	21761^{abcd}
20	69	50.15	9.44^{abc}	1.80^{cd}	19277de	19678de
20	92	51.900	9.72^{ab}	2.07^{abc}	18737^{e}	18652^{e}
20	115	51.90	9.97^{ab}	2.087^{ab}	22769^{a}	23138^{a}
20	138	52.88	9.63^{abc}	1.92^{abcd}	20361^{abcde}	20508^{cde}
30	46	51.62	9.82^{ab}	1.88^{abcd}	22129^{ab}	22550^{ab}
30	69	53.01	9.61^{abc}	1.80^{cd}	21614^{abcd}	21923^{abcd}
30	92	51.98	9.70^{abc}	1.89^{abcd}	22136^{ab}	22810^{ab}
30	115	49.18	9.02^{bc}	1.95^{abcd}	21780^{abc}	22839^{ab}
30	138	51.00	8.75^{c}	1.93^{abcd}	21847^{abc}	22260^{ab}
40	46	49.05	9.79^{ab}	1.72^{d}	21869^{abc}	19768^{cde}
40	69	48.68	9.42^{abc}	1.94^{abcd}	19510^{cde}	22306^{ab}
40	92	51.23	9.76^{ab}	1.90^{abcd}	21735^{abc}	22080^{abcd}
40	115	51.87	10.11^{a}	2.16^{a}	22536^{ab}	23421^{a}
40	138	51.50	9.60^{abc}	1.95^{abcd}	21928^{ab}	22174^{abc}
CV		11.57	8.82	12.69	9.78	9.75
Probability		NS	*	*	**	**

Different studies showed that pepper responded to different rates of nitrogen and phosphorus. Amare *et al*. (2013), reported that 60 kg P ha^{-1} with 92 kg N ha^{-1} gave (10920 kg ha^{-1}) fresh marketable fruit yield at Bure. Similarly EARO (2004) gave blanket recommendation (200 kg P_2O_5 ha^{-1} and 100 kg N ha^{-1} (EARO, 2004) for hot pepper. Similar to the present study, Khan *et al*. (2010) recommended 150 kg N ha^{-1}) and 30 kg P ha^{-1} for Bangiladish. Phosphorus recommendations given by different authors at different place are higher than this finding; this may be due to the fact that the soil of the study site (Rib) has high available P. The recommendation for nitrogen was in conformity with the above findings. The high nitrogen demand by hot pepper in Rib irrigation area may be due to the low total nitrogen content of the soil (Table 1). Application of P fertilizer more than 20 kg ha^{-1} for hot pepper is unnecessary investment on P fertilizer. Similar trend was observed on total fruit yield in both years. However, the lowest marketable and total yields were obtained from the negative control (without fertilizer.)

The partial budget analysis showed that applying 115 kg N ha^{-1} with 20 kg P ha^{-1} had the highest net benefit (67753.22ETB ha^{-1}) and MRR of 2011.46 % followed by 46 kg N ha^{-1} with 30 kg ha^{-1} P gaining net benefit of 67019.65ETB ha^{-1} and MRR of 389.31% (Table 5). For one kg nitrogen and P fertilizer investment the farmer can get 20.11 ETB by using 115 kg ha^{-1} N with 20 kg ha^{-1} P fertilizers. In addition, application of 115 kg ha^{-1} N with 20 kg ha^{-1} P fertilizer gave 50.7% and 132.5 % yield advantage over the control in 2011 and 2012 respectively and application of these rates will boost the yield of hot pepper and increase the income of the farmers.

Table 5. Partial budget analysis using mean price of green hot pepper at 3.5 ETB kg^{-1}

P kg ha^{-1}	N kg ha^{-1}	Green hot pepper marketable yield per kg	adjusted green hot pepper	Total variable cost	Gross benefit	Net benefit	Marginal benefit	Marginal cost	MRR%
0	0	17557.32	15801.59	0.00	55305.56	55305.56			
20	46	21353.00	19217.70	2187.13	67261.95	65074.82	9769.26	2187.13	446.67
30	46	22129.00	19916.10	2686.70	69706.35	67019.65	1944.83	499.57	389.31
20	69	19277.00	17349.30	2781.13	60722.55	57941.42	D	94.43	
40	46	21869.00	19682.10	3186.26	68887.35	65701.09	7759.67	405.13	1915.35
30	69	21614.00	19452.60	3280.70	68084.10	64803.40	D	94.43	
20	92	18737.00	16863.30	3375.13	59021.55	55646.42	D	94.43	
40	69	19510.00	17559.00	3780.26	61456.50	57676.24	2029.82	405.13	501.03
30	92	22136.00	19922.40	3874.70	69728.40	65853.70	8177.47	94.43	8659.38
20	115	22769.00	20492.10	3969.13	71722.35	67753.22	1899.52	94.43	2011.46
40	92	21735.00	19561.50	4374.26	68465.25	64090.99	D	405.13	
30	115	21780.00	19602.00	4468.70	68607.00	64138.30	47.32	94.43	50.10
20	138	20361.00	18324.90	4563.13	64137.15	59574.02	D	94.43	
40	115	22536.00	20282.40	4968.26	70988.40	66020.14	6446.12	405.13	1591.12
30	138	21847.00	19662.30	5062.70	68818.05	63755.35	D	94.43	
40	138	21928.00	19735.20	5562.26	69073.20	63510.94	D	499.57	

D= Dominated, ETB= Ethiopian Birr

The sensitivity analysis indicated (Table 6) that under predicted worst economic condition 115 kg N ha^{-1} and 20 kg P ha^{-1} had the highest net benefit (67356.28ETB ha^{-1}) with MRR of 1813.26 %. Therefore, 115/20 kg N/P ha^{-1} is a valid fertilizer rate even under the worst price inflations that can be taken as economical fertilizer rates for green hot pepper production at Rib under irrigation (Table 6).

Table 6. Sensitivity analysis for the effect of nitrogen and phosphorus on the yield of green pod of hot pepper at Rib irrigation scheme.

P kg ha^{-1}	N kg ha^{-1}	Green hot pepper marketable yield kg ha^{-1}	10 % dawn ward adjusted green hot pepper kg ha^{-1}	Total variable cost	Gross benefit	Net benefit	Marginal benefit	Marginal cost	MRR%
0	0	17557	15801.5873	0	55305.5556	55305.56			
20	46	21353	19217.7	2405.56	67261.95	64856.38	9550.83	2405.57	397.03
30	46	22129	19916.1	2954.85	69706.35	66751.50	1895.12	549.28	345.01
20	69	19277	17349.3	3059.07	60722.55	57663.48	D	104.22	
40	46	21869	19682.1	3504.13	68887.35	65383.22	7719.73	445.07	1734.56
30	69	21614	19452.6	3608.35	68084.1	64475.75	D	104.22	
20	92	18737	16863.3	3712.57	59021.55	55308.99	D	104.22	
40	69	19510	17559	4157.63	61456.5	57298.87	1989.89	445.07	447.10
30	92	22136	19922.4	4261.85	69728.4	65466.55	8167.68	104.22	7837.16
20	115	22769	20492.1	4366.07	71722.35	67356.28	1889.73	104.22	1813.26
40	92	21735	19561.5	4811.13	68465.25	63654.12	D	445.07	
30	115	21780	19602	4915.35	68607	63691.65	37.53	104.22	36.01
20	138	20361	18324.9	5019.57	64137.15	59117.58	D	104.22	
40	115	22536	20282.4	5464.63	70988.4	65523.77	6406.18	445.07	1439.38
30	138	21847	19662.3	5568.85	68818.05	63249.20	D	104.22	
40	138	21928	19735.2	6118.13	69073.2	62955.07	D	549.28	

D = Dominated, ETB= Ethiopian Birr

Conclusion and recommendation

From the two years field experiment it is possible to conclude that nitrogen and phosphorus fertilizers are important to increase hot pepper yield. However, the amount of phosphorus required was low as compared to nitrogen due to the fluvial nature of the soil. This experiment was conducted on farmers field which was very difficult for water management that can be expressed in somehow its irregularity of the data in the two years. Even though it was very difficult to conduct such experiment on farmers' field, maximum effort was exerted to control variations due to management. Based on the partial budget analysis and biological yield results, it is possible to recommend 115 kg N with 20 kg P ha^{-1} as the first economically feasible fertilizer rate and 46 kg N with 30 kg P ha^{-1} as a second economically feasible fertilizer rate. Therefore, application of 115 kg N ha^{-1} and 20 kg P ha^{-1} followed by 46 kg N ha^{-1} and 30 kg P ha^{-1} for Rib and similar agro-ecologies under irrigation is feasible for hot pepper production.

Future fertilizer recommendation for Rib command area needs to be fine-tuned based on soil test and crop response based studies when the irrigation scheme construction is finalized in well organized irrigation research sites.

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Response of Snap Bean to Nitrogen and Phosphorous at Koga and Rib under Irrigation

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Abstract

A Field experiment was conducted for two years (2011 and 2012) to determine the optimum rate of nitrogen and phosphorus for snap bean green pod production at Rib and Koga schemes under irrigation. The experiment was composed of a factorially combination of three levels of nitrogen (46, 69, 92 kg N ha^{-1}) and five levels of phosphorus (10, 20, 30, 40 and 50 kg P ha^{-1}) and arranged in a randomized complete block design (RCBD) with three replications . Agronomic data were collected and subjected to analysis of variance using SAS software while LSD was used for mean separation whenever there was significant difference among/between the treatments. The result at Rib showed that nitrogen and phosphorous have significantly ($P<0.05$) affected pod diameter, marketable and total yields in 2011 whereas in 2012, there was significant difference in marketable and total pod yields against nitrogen rates and the interaction of N and P. Similarly, at Koga, nitrogen and phosphorus significantly affected marketable yield, total yield and other yield components. The partial budget analysis for Rib showed that 46 kg N ha^{-1}and 20 kg P ha^{-1} had the highest net benefit (146429.9 Eth. Birr ha^{-1}) with 6804% marginal rate of return (MRR) and for Koga 92 kg N ha^{-1} and 50 kg P ha^{-1} had the highest net benefit (95692.26 ETB ha^{-1}) with 1991 % marginal rate of return (MRR) .

Key Words: Snap bean, nitrogen, phosphorus, marketable yield, total yield

Introduction

Snap bean (*Phaseolus vulgaris* L.) is belonged to the family of Fabaceae. It is commonly called French bean, kidney bean, navy bean and green bean or string bean. It is an important short duration leguminous pod vegetable grown for its tender green pods (ARC, 2002). Although other types of beans can be grown (Lima, horticultural, edible soybeans, etc.), the greatest consumer demand is for those commonly called “green beans” or snap beans (Marr *et. al*., 1995). Rashid (1993) and ARC (2002) stated the nutritional value of such crops that the edible green pods supply protein, carbohydrate, fat, fiber, thiamin, riboflavin, Ca and Fe, and the seed contains significant amount of thiamin, niacin, folic acid as well as fiber. The crop commands high marketability both at home in Ethiopia (especially in urban areas) and abroad. It can suitably be grown at altitudes ranging from 1000-2000m a.s.l (ARC, 2002). A dry climate with irrigation is suitable for bean production as there will be no or little disease incidence in addition to avoiding water logged conditions (ARC, 2002). Even though they are nitrogen fixers, supplying bean plants with nitrogen is essential to obtain high yield. Sustained high yields can be expected with fertilization practices designed to supply crop nutrient requirements and protect the environment from excessive fertilization (Hochmuth & Hanlon, 2010). As Marr *et al.* (1995) stated beans require a regular supply of fertilizer for uniform growth, so one or two side dressings are necessary through the season, especially in wet seasons or in sandy soils. In addition to this, optimum combination of nitrogen and phosphorous may bring about considerable increase in the yield of bush bean due to their complementary effects (Nasrin and Jahan, 2010). Moreover, rationalizing the amounts of N application has a great economical impact for the farmer to minimize the expenses from chemical fertilizers as well as the environmental impact due to the excess of chemical fertilizers such as nitrogen fertilizers that may pollute underground water (Hochmuth and Hanlon, 2010). Over-fertilization will result in excessive foliage growth with little increase in yield and possible salt damage from fertilizer (Marr *et. al*., 1995).

In the production of vegetable crops like snap bean, good fertilizer usage is one of the important management practices, including proper seeding, pest control, adequate irrigation, and timely harvest. Because of the influence of soil type, climatic conditions, and other cultural practices, crop response to fertilizer may not always be accurately predicted. Soil test results, field experience, and knowledge of specific crop requirements help to determine the nutrients needed and the rate of application.

Fertilizer applications for beans should ensure adequate levels of all nutrients. Optimum fertilization is intended to result in top quality and yield, commensurate with maximum returns. However, most of the farmers in irrigated areas apply less or no fertilizer. The fertility status of the soil is depleted by continuous cropping if it goes without fertility restoring actions. Hence, the research was carried out to determine appropriate NP fertilizer rate that enhances the productivity of snap bean and feasible for farmers.

Materials and methods

Description of the study sites

The experiment was conducted at Koga and Rib irrigation schemes. The study site at Koga is situated at 11°25’20’’ latitude and 37°10’20” longitude at an altitude of 1960 m a.s.l. It is in Mecha district, West Gojjam admistritive zone. The soil is purely Nitisols with strongly acidic property and high exchangeable acidity and exchangeable Al^{3+} contents (Table 1). According to the classification of Clements and McGowen (1994), the soil has very low, low and medium organic matter, available phosphorus and total nitrogen content respectively (Table 1). The very low available phosphorus content could be due to the high acidity of the soil (Pam and Murphy, 2007). The EC value in soil to water ratio (1:5) is less than 2 ds/m^{-1}.

Table 1. Soil properties for Koga and Rib irrigation schemes

Koga							
pH (H_2O)	Exchangeable Al^{3+} (cmol$_c$ kg^{-1})	Exchange able acidity (cmol$_c$ kg^{-1})	EC (ds/m^{-1})	Total N (%)	Available P (ppm)	OM(%)	CEC (cmol$_c$ kg^{-1})
5.09-5.3	0.92-2.88	1.54-5.23	0.013-0.08	0.18-0.24	3.54-8.69	2.34-4.44	
Rib							
Na	Na	Na	Na	0.003-0.18	24.32-36.73	Na	33.00-36.25

Na = Not available

Rib study site is found in Fogera district and situated at 11^{0} 41’ to 12^{0} 02’ N latitude and 37^{0} 29’ to 37^{0} 59’ E longitude at an altitude of 1800 m a.s.l. The major soil type of the site is Fluvisols. The soil has high phosphorus and very low to low total nitrogen contents (Table 1). The CEC is high according to Pam and Murph (2007) (Table 1).

Snap bean variety Indam-2005 was used for the experiment under furrow irrigation system. The experimental design was factorial RCBD with three replications. The plot size was 3m X 3m and treatments were comprised of three levels of nitrogen (46, 69 and 92 kg ha^{-1}) and five levels of P_2O_5 (23, 46, 69, 92, and 115 Kg ha^{-1}). Absolute control (without input) was used for comparison purpose. Nitrogen was applied by spliting: Half at planting and the other half 30 days after emergence. The whole phoshporus was applied at planting. Spacing between rows and plants were 50 cm and 10 cm respectively. Data on plant height, green pod diameter, and green pod length, marketable pods, unmarketable pods and total yield were collected and analyzed by SAS 2002. Least Significant Difference (LSD) at 5% was used for mean separation. There were three harvesting times during the growth period and the data were collected in each consecutive harvesting time. Fleshy, tender, none shriveled pods, pods with normal length and green pods were considered as marketable while the rest are unmarketable. The sum of the marketable and unmarketable was taken as total yield.

In order to identify economical feasible recommendations partial budget and sensitivity analysis was done based on the CIMMYT economic analysis manual (CIMMYT, 1988). The price of snap been, urea and DAP were 10.00, 11.15 and 14.20 ETB kg^{-1}, respectively. To see whether the benefit is consistent in the worst price condition, Sensitivity analysis was done by increasing the current fertilizer cost by 10% to both urea and DAP.

Results and discussions

Rib study site

The results at Rib indicated that nitrogen and phosphorous significantly (P<0.01) affected pod diameter, marketable and total yields of snap been. The combined analysis over years showed that maximum yield was obtained by applying 46/20 kg N/P ha^{-1} fertilizer rates followed by 69/10 kg N/P ha^{-1} (Table 2). However, there was no statistically significant difference between 46/20 kg N/P ha^{-1} and 69/10 kg N/P ha^{-1} in marketable and total yield. The result was in agreement with the findings of Hochmuth *et.al.* (2009) in Hochmuth and Hanlon (2010) who reported none significant difference in marketable snap bean yield with increasing nitrogen rates. The longest pod length and maximum pod diameter were recorded fom 46/10 kg N/P ha^{-1} whereas the highest plant height was recorded from 46/30 kg N/P ha^{-1} (Table 2). There was no significant difference among fertilizer rates and 0/0 level on most of yield components at Rib except for pod length (Table 2). The relatively lower response of the crop to both nitrogen and phosphorous may be due to its can fix atmospheric nitrogen fixing capacity of the crop and the richness of the experimental soil in available phosphorus (Table 1).

Table 2. Effect of nitrogen and phosphorous on marketable and total yield of snap bean at Rib combined over years

N/P rate	Plant height	Pod diameter	Pod length	Marketable green pod kg ha^{-1}	Total green pod kg ha^{-1}
0/0	94.47^{ab}	0.85^{abc}	9.63^{bc}	8470.69^{c}	10075.69^{c}
46/10	92.76^{abcd}	0.87^{a}	10.73^{a}	12681^{ab}	12988^{ab}
46/20	93.98^{abc}	0.81^{abc}	9.53^{bcdd}	16513^{a}	16789^{a}
46/30	95.67^{a}	0.79^{abc}	9.33^{bcd}e	15182^{ab}	15485^{ab}
46/40	92.49^{abcd}	0.79^{abc}	9.00^{cdef}	11638^{b}	11978^{b}
46/50	89.73^{abcde}	0.73^{c}	8.87^{def}	12360^{b}	12638^{b}
69/10	95.42^{a}	0.89^{a}	9.00^{cdef}	15292^{ab}	15529^{ab}
69/20	88.27^{abcde}	0.84^{abc}	9.13^{bcdef}	11638^{b}	11924^{b}
69/30	95.82^{a}	0.86^{ab}	9.80^{b}	14288^{ab}	14567^{ab}
69/40	90.20^{abcde}	0.87^{a}	9.60^{bcd}	13986^{ab}	14331^{ab}
69/50	89.20^{abcde}	0.79^{abc}	9.60^{bcd}	15222^{ab}	15477^{ab}
92/10	89.36^{abcde}	0.82^{abc}	9.00^{cdef}	13861^{ab}	14145^{ab}
92/20	81.71^{e}	0.91^{a}	9.60^{bcd}	12057^{b}	12364^{b}
92/30	83.60^{cde}	0.73^{d}	8.50^{f}	13211^{ab}	13487^{ab}
92/40	83.87^{bcde}	0.85^{abc}	9.67^{bc}	12479^{b}	12771^{b}
92/50	82.20^{de}	0.87^{a}	8.67^{ef}	12568^{ab}	12838^{ab}
CV(%)	13.49	7.78	6.04	25.73	25.13
LSD(0.05)	10.71	0.13	0.76	4009.1	3997

The partial budget analysis for Rib showed that applying 46 kg N $ha^{-1}$and 20 kg P ha^{-1} had the highest net benefit (146429.9 ETB ha^{-1}) with MRR of 6803.60 (Table 3). Thus 46 kg ha^{-1} N and 20 kg ha^{-1} P are recommended for snap bean production at Rib irrigation scheme. Farmers and investors can benefit a lot from snap bean production through fertilizer application.

Table 3. Partial budget analysis for the effect of nitrogen fertilizer on the yield of snap bean at Rib

P2O5	N	Yield kg/ha	Ad (10% dawn ward)	Total variable cost	Gross benefit	Net benefit	MRR
0	0	8470.69	7623.62	0	124767	124767	
10	46	12681	11412.9	1687.565	114129	112441.4	
20	46	16513	14861.7	2187.13	148617	146429.9	6803.60
10	69	15292	13762.8	2281.565	137628	135346.4	
30	46	15182	13663.8	2686.696	136638	133951.3	
20	69	11638	10474.2	2781.13	104742	101960.9	
10	92	13861	12474.9	2875.565	124749	121873.4	21086.05
40	46	11638	10474.2	3186.261	104742	101555.7	
30	69	14288	12859.2	3280.696	128592	125311.3	25155.52
20	92	12057	10851.3	3375.13	108513	105137.9	
50	46	12360	11124	3685.826	111240	107554.2	777.71
40	69	13986	12587.4	3780.261	125874	122093.7	15396.41
30	92	13211	11889.9	3874.696	118899	115024.3	
50	69	15222	13699.8	4279.826	136998	132718.2	4367.45
40	92	12479	11231.1	4374.261	112311	107936.7	
50	92	12568	11311.2	4873.826	113112	108238.2	60.34

The sensitivity analysis (Table 4) indicated that application of 46 kg N ha^{-1} and 20 kg P ha^{-1} is feasible even at worst scenarios (146211.2ETB ha^{-1}) with MRR of 6176.00%. Therefore, 46/20 kg N/P ha^{-1} is recommended for snap bean production for Rib irrigation scheme.

Table 4. Sensitivity analysis for the effect of nitrogen fertilizer on the yield of snap bean at Rib irrigation scheme.

P_2O_5	N	Yield kg/ha	Adjusted (10% down wards)	Total variable cost	Gross benefit	Net benefit	MRR
0	0	8470.69	7623.62	0	124767	124767	D
23	46	12681	11412.9	1856.322	114129	112272.7	D
46	46	16513	14861.7	2405.843	148617	146211.2	6176.00
23	69	15292	13762.8	2509.722	137628	135118.3	D
69	46	15182	13663.8	2955.365	136638	133682.6	D
46	69	11638	10474.2	3059.243	104742	101682.8	D
23	92	13861	12474.9	3163.122	124749	121585.9	19160.05
92	46	11638	10474.2	3504.887	104742	101237.1	D
69	69	14288	12859.2	3608.765	128592	124983.2	22859.57
46	92	12057	10851.3	3712.643	108513	104800.4	D
115	46	12360	11124	4054.409	111240	107185.6	697.92
92	69	13986	12587.4	4158.287	125874	121715.7	13987.64
69	92	13211	11889.9	4262.165	118899	114636.8	D
115	69	15222	13699.8	4707.809	136998	132290.2	3961.32
92	92	12479	11231.1	4811.687	112311	107499.3	D
115	92	12568	11311.2	5361.209	113112	107750.8	45.7631

D = Dominated

Koga study site

The result at Koga site showed significant difference among the treatments for all of the parameters with the lowest result obtained from the control (Table 5). The highest pod diameter and plant height were recorded from the combinations of 46/10 kg N/P ha^{-1} while the highest pod length obtained from 46/50 kg N/P ha^{-1} (Table 5). The highest marketable yield was obtained from 92/50 kg N/P ha^{-1} (Table 5). The result is in line with Nasrin and Jahan (2010) who obtained higher green pod yield (18.61 t/ha) and greater seed yield from Bush Bean (*Phaseolus vulgaris* L.) by combining higher rate of nitrogen and intermediate dose of phosphorus in Bangladesh. The high demand of phosphorous for snap bean for high yield at Koga may be attributed to low phosphorus content of the soil due to phosphorus fixation resulted from its acidic nature (Table 1).

Table 5. Effect of nitrogen and phosphorous fertilizer on the yield of snap bean at Koga irrigation scheme

N/P rate	Plant height(cm)	Pod diameter (cm)	Pod length(cm)	Yields green pod(Kg/ha)	
				Marketable	Total
0/0	19.38b	0.99b	9.01d	3406.4f	4857.9e
46/10	47.88a	1.07a	9.34cd	7267.6e	7871.0d
46/20	52.21a	1.02abc	9.59abc	8351.9de	9425.6cd
46/30	50.82a	1.04ab	9.87ab	8564.4cde	9411.6cd
46/40	53.18a	1.05ab	9.80abc	8938.7bcd	9451.6cd
46/50	50.46a	1.04abc	9.96a	9874.1abcd	10702.3abc
69/10	50.55a	1.03abc	9.67abc	8571.9cde	9826.3bc
69/20	49.87a	1.04ab	9.46bcd	10800.2a	11804.9a
69/30	47.54	1.01bc	9.48bcd	8794.4cde	10409.4abc
69/40	52.05a	1.01bc	9.56abc	9596.2abcd	9822.2bc
69/50	51.46a	1.02abc	9.6abc	9858.3abcd	10790.8abc
92/10	53.50a	1.03abc	9.55abc	10048.2abc	11968.5a
92/20	49.67a	1.01bc	9.80ab	10588.3ab	11866.4a
92/30	49.67a	1.04abc	9.73abc	10990.3a	11628.9ab
92/40	48.58a	1.07a	9.89ab	10177.1abc	11050.8abc
92/50	49.42a	1.03abc	9.54abcd	11153.5a	11851.7a
CV (%)	19.39	3.93	4.10	15.83	15.89
LSD(0.05)	10.817	0.0466	0.45	1672.9	1858.8

The partial budget analysis (Table 6) showed that applying 92 kg N ha^{-1} and 50 kg P ha^{-1} had the highest net benefit (95692.26 ETB ha^{-1}) and MRR (1990.91 %) followed by 92 kg N ha^{-1} and 30 kg P ha^{-1} with net benefit of 95207.16 ETB ha^{-1} and MRR of 3444.95% (Table 6). Therefore, 92/50 and 92/30 kg N/P ha^{-1} are recommended as first and second options, respectively for Koga irrigation scheme. For both sites yield was increased using N and P and hence farmers should apply the recommended N P fertilizer rates.

Table 6. Partial budget analysis for the effect of nitrogen fertilizer on the yield of snap bean at Koga irrigation scheme.

N/P	Yield kg/ha	Adjusted yield (10% dawn wards)	Total variable cost	Gross benefit	Net benefit	MRR%
0/0	3406.4	3065.76	0	30657.6	30657.6	
46/10	7267.6	6540.84	1606.848	65408.4	63801.55	2062.67
69/10	8571.9	7714.71	2164.348	77147.1	74982.75	2005.6
92/10	10048.2	9043.38	2721.848	90433.8	87711.95	22832.65
46/20	8351.9	7516.71	2098.696	75167.1	73068.4	D
69/20	8564.4	7707.96	2656.196	77079.6	74423.4	D
92/20	10588.3	9529.47	3213.696	95294.7	92081	3167.28
46/30	10800.2	9720.18	2590.543	97201.8	94611.26	D
69/30	8794.4	7914.96	3148.043	79149.6	76001.56	D
92/30	10990.3	9891.27	3705.543	98912.7	95207.16	3444.95
46/40	8938.7	8044.83	3082.391	80448.3	77365.91	D
69/40	9596.2	8636.58	3639.891	86365.8	82725.91	D
92/40	10177.1	9159.39	4197.391	91593.9	87396.51	837.78
46/50	9874.1	8886.69	3574.239	88866.9	85292.66	D
69/50	9858.3	8872.47	4131.739	88724.7	84592.96	D
92/50	11153.5	10038.15	4689.239	100381.5	95692.26	1990.91

D=Dominated

The sensitivity analysis indicated (Table 7) that under predicted worst economic condition 92 kg N ha^{-1} and 50 kg P ha^{-1} had the highest net benefit (95223.34 ETB ha^{-1}) with MRR of 1800.82%. Based on the sensitivity analysis, the second highest net benefit (94836.6 ETB ha^{-1}) was recorded by applying 92 kg N and 30 kg P ha^{-1}. Therefore, 92/50 and 92/30 kg N/P ha^{-1} are recommended as first and second options economical fertilizer rates respectively for green snap bean production at Koga irrigation scheme.

Table 7. Sensitivity analysis for the effect of nitrogen fertilizer on the yield of snap bean at Koga irrigation scheme.

N/P	Yield kg/ha	Adjusted yield (10% dawn wards)	Total variable cost	Gross benefit	Net benefit	MRR
0/0	3406.4	3065.76	0	30657.6	30657.6	
46/10	7267.6	6540.84	1767.533	65408.4	63640.87	1866.06
69/10	8571.9	7714.71	2380.783	77147.1	74766.32	1814.18
92/10	10048.2	9043.38	2994.033	90433.8	87439.77	2066.60
46/20	8351.9	7516.71	2308.565	75167.1	72858.53	D
69/20	8564.4	7707.96	2921.815	77079.6	74157.78	D
92/20	10588.3	9529.47	3535.065	95294.7	91759.63	2870.26
46/30	10800.2	9720.18	2849.598	97201.8	94352.2	D
69/30	8794.4	7914.96	3462.848	79149.6	75686.75	D
92/30	10990.3	9891.27	4076.098	98912.7	94836.6	3122.68
46/40	8938.7	8044.83	3390.63	80448.3	77057.67	D
69/40	9596.2	8636.58	4003.88	86365.8	82361.92	D
92/40	10177.1	9159.39	4617.13	91593.9	86976.77	752.52
46/50	9874.1	8886.69	3931.663	88866.9	84935.24	D
69/50	9858.3	8872.47	4544.913	88724.7	84179.79	D
92/50	11153.5	10038.15	5158.163	100381.5	95223.34	1800.82

D = Dominated

Conclusion and recommendation

At Rib, application of 46 kg N ha^{-1} and 20 kg P ha^{-1} was economically feasible for green snap bean production. While at Koga irrigation scheme, application of 92 kg N ha^{-1} and 50 kg P ha^{-1} was recommended as the first option for green snap bean production and application of 92 kg N ha^{-1} and 30 kg P ha^{-1} is recommended as a second option. In addition, at Koga irrigation scheme, fertilizer rate study need to be done along with lime application for the soil in the command area is acidic. Moreover, at both locations, interaction of fertilizer especially N with water amount and frequency is a researchable gaps. Furthermore, since the crop is new to the area and has high demand on the urban market linking the farmers with market and introduction and demonstration of different recipes is highly demanding.

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II) Agricultural Water Management

Determination of supplementary irrigation requirement and schedule for Sorghum in Kobo-Girana Valley, Ethiopia

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Abstract

Supplemental irrigation is the application of a limited amount of water to the crop when rainfall fails to provide sufficient water for plant growth to increase and stabilize yields. The experiment was carried out for two cropping seasons (2011 and 2012) at Kobo irrigation research site, in Northeast Amhara to *determine the net Irrigation requirement) to be supplemented to moisture stressed areas to increase water value and crop productivity. Mean annual rainfall in the area is 630 mm, with considerable year-to-year variation and an average effective rain fall of 232.4mm in the growing season. The soil type is silt loam with average filed capacity and permanent wilting point of 27.57% and 12.3% on volume basis accordingly with PH value of 7.8.* Seven *treatments were tested with RCBD experimental design with three replications. Statistical analysis was applied using SAS soft ware to test the effects of treatments on grain yield, head weight, water productivity. The experimental analysis indicated that there was a significant difference in head weight, grain yield and water productivity. As observed in the experimental years the grain yield widely ranges from 5.397 ton/ha to 1.53 ton/ha. Supplementing the CROPWAT generated depth (100%) starting from development stage at optimal time of application gave the highest stalk biomass of 11 ton/ha and grain yield 5.397 ton/ha and it had a maximum yield advantage of 2.874 ton/ha compared with the controlled system in 2011 cropping season. In the second year (2012) supplementing the CROPWAT generated depth (100%) starting from development stage at optimal time of application with a seasonal water amount of 330.6mm had a yield advantage of 1.607ton/ha compared with supplementing of the CROPWAT generated depth (100%) during mid stage (supplementary of 226.5mm seasonal water) at 8 days interval. This research finding recommended that supplementary irrigation starting from development stage (20 days after sowing) is better during development and mid season stage at 8 days interval.*

Key words*:* Supplementary Irrigation, Irrigation requirement, Irrigation schedule, CROPWAT

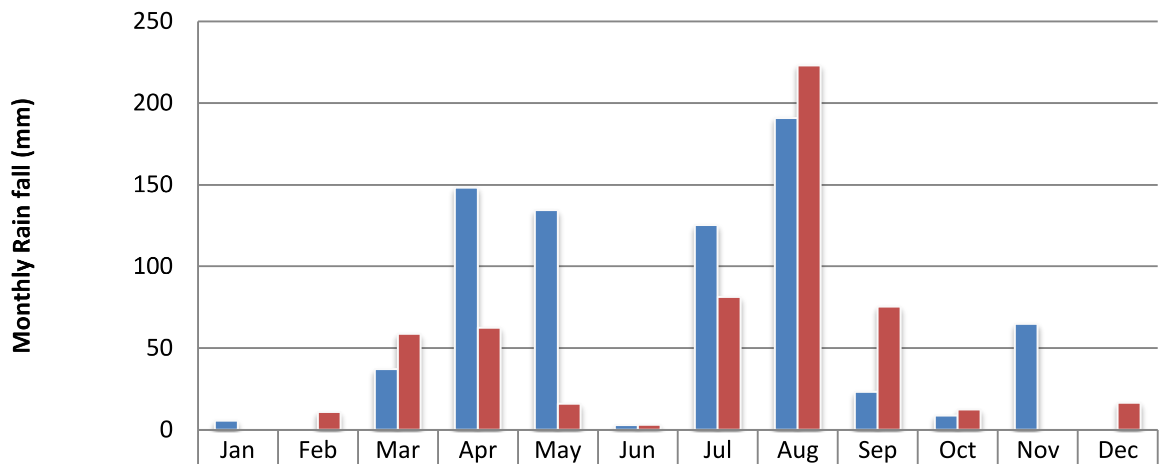
Introduction

Irrigation accounts for about 72% of global and 90% of developing-country water withdrawals. The Ethiopian economy is based on rain fed agriculture. Natural rainfall is the major source of water for agriculture. However, farmers' yield gain in rain fed regions in the developing countries are low largely due to low rainwater use efficiency because of inappropriate soil, water, nutrient and pest management options, lack of seeds of improved cultivars and poor crop establishment (Rockström *et al*.,2007,Wani *et al*., 2008). There are three primary ways to enhance rain fed agricultural production, namely: (i) to increase the effective rainfall use through improved water management; (ii) to increase crop yields in rain fed areas through agricultural research; and (iii) through reformed policies and increased investment in rain fed areas. This chapter focuses on the first way, in which supplemental irrigation (SI) plays a major role in increasing water use efficiency and yields of rain fed crops.

Rain fall pattern of kobo Girrana valley

Assessing seasonal or dekadal1 rainfall characteristics based on past records is essential to evaluate drought risk and to contribute to development of drought mitigation strategies such as supplementary irrigation. Rainfall variability has been reported to have significant effect on the country's economy and food production for the last three decades. There have been reports of rainfall variability and drought associated food shortages (Tilahun, 1999; Bewket and Conway, 2007). In most cases, what determines crop production in semiarid areas of Africa is the distribution rather than the total amount of rainfall, because dry spells strongly depress the yield (Barron et al., 2003; Segele and Lamb, 2005; Meze-Hausken, 2004).Water scarcity in North -Eastern Amhara, particularly in Kobo Girana Valley rain fed water scarcity is sever. Due to these; moisture stress is the major limiting factor for crop production which highly reduces the crop yield in the moisture stressed areas. Sorghum is an important food cereal crop used and the major production crop in rain fed agriculture in the Eastern Amhara particularly in Kobo Girana valley, where rainfall is not only low or not enough for production but also variable, it begins later and ceases earlier. It stops for certain days in the growing period as major contributor for yield reduction. As a result of such problems, farmers have been continuously affecting with sever grain yield shortage through their traditional agricultural practices.

This research was also conducted in such challenging climate variability; for the experimental year 2011 late onset and early cessation with relatively highest amount than 2012 experimental year were observed. In the second year rainfall distribution and variability is very high and observed with late onset and also long dry spell in the month of July and having highest rainfall record in August compared to the first experimental year (2011) as shown in figure-1.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Year 1 (2011)	5.6	0	37	148.2	134.2	2.8	125.2	190.9	23.2	8.7	64.8	0
Year 2 (2012)	0	10.8	58.7	62.6	15.9	3	81.2	222.9	75.4	12.5	0	16.6

Figure 1: Rain fall pattern of the experimental years (2011-2012)

Irrigation practices of kobo Girrana Valley

Amhara Regional State was emphasized on developing irrigation-based agriculture to attain food security at household and state levels which is very important that appropriate technologies are available for adoption by the farmers in the study area. Ground water exploration and extraction is the major irrigation water sources in the region. Kobo Girrana Valley Development Program (KGVDP) has already established about 5500 ha under irrigation and planned to reach about 17000 ha. One of the approaches taken as a counter measure to the unpredictability of rain and to overcoming such problems is using supplementary irrigation during the rain fed agriculture season in addition to the main season full irrigation developemnt. Supplemental irrigation (SI) is a highly efficient option to achieve this strategic goal by providing the crop with the needed amount of water at the required time (Oweis and Hachum, 2001). Supplemental irrigation is defined as “the addition of a limited amount of water to otherwise rain fed crops, when rainfall fails to provide essential moisture for normal plant growth, in order to improve and stabilize productivity". Unlike in full irrigation, the timing and amount of SI cannot be determined in advance, because the basic source of water to rain fed crops is rainfall, which is variable in amount and distribution and difficult to predict (Oweis *et al*., 1999). Alleviating soil moisture stress during the critical crop growth stages is the key to improved production. It was concluded by many authors that avoiding drought, through early flowering and maturity, was the main factor underlying higher seed yield under severe drought conditions.

In this area supplementary irrigation (SI) is necessary for the increment of sorghum grain yield and enhancement of food security. Therefore, the research was proposed to quantify and set both the required net Irrigation requirement (depth of water) to be supplemented in the moisture stress period and the time of water application (irrigation schedule) during the rain fed agriculture and to increase water value and crop productivity.

Materials and Methods

Description of the study area

The experiment was carried out over two cropping seasons (2011 to 2012) at Kobo agricultural irrigation main research station at Kobo Girana District, in North Eastern Amhara at 12.08^0 N latitude and 39.28^0 E longitude. The altitude of experimental area is 1470 m.a.s.l. The mean annual rainfall in the area is 630 mm, with considerable year-to-year variation. Such rain fall variation results in a range of conditions under which the use of SI is a useful option with which to improve and stabilize yields. There was an average effective rainfall of 232.4mm in the growing season. But this amount of rainfall didn't fulfill the crop water demand in the growing season. The soil type in the experimental site is Silty-Clay loam with average FC and PWP of 27.57% and 12.3% on volume basis accordingly. The site is characterized by average infiltration rate of 8 mm/hr and pH value of 7.8.

Methodology

Sorghum (Teshale Variety) with a growing period of 120 days was used as a test crop. The fertilizers used for the experiment were DAP 100 kg ha^{-1} (applied at planting) and urea 111 kg ha^{-1} (applied in two splits i.e. 36 kg at planting and 75 kg at knee height). The experiment was laid out in simple RCBD in three replications with experimental plot size of 3m by 6m. Totally six treatments were tested in the 1st year. While in the second year, one treatment (user adjustment) was added and hence seven treatments were examined. The treatments include**:** C-controlled (treatment under rain-fed condition no supplementary irrigation). Five supplementary irrigation levels (S1-S5) in different growing stages (Table1) were determined using CROPWAT 8 software program and **U-**daily user adjusted treatment (this treatment were included in the second year to adjust the rainfall event during irrigation and irrigation were also supplemented when the available soil moisture was below the allowable depletion without using model). Irrigation water was applied to the treatments using siphon tubes in furrow irrigation system, which was equipped with time duration to measure the amount of water applied in each furrow.

Table 1: The supplemental treatments in the experimental area

S.no	Treatments	Total crop water requirement (mm/season)	Effective rain fall (mm/season)	Seasonal irrigation requirements (mm/season)
1	Controlled (rain fed farming) **(C)**	232.4	232.4	0
2	Supplementing the CROPWAT generated depth (100%) starting from DSt **(S1)**	658.70	232.4	330.6
3	Supplementing the CROPWAT generated depth (100%) starting from DSt at 8 days interval **(S2)**	563	232.4	426.3
4	Supplementing the CROPWAT generated depth (100%) starting from MSt at 8 days interval **(S3)**	536	232.4	316.2
5	Supplementing the CROPWAT generated depth (100%) during DSt & MSt at 8 days interval **(S4)**	548	232.4	304.2
6	Supplementing the CROPWAT generated depth (100%) during MSt only at 8 days interval **(S5)**	458	232.4	226.5
7	User adjustment **(U)**	417.7	206	211.7

Water productivity, also known as water use efficiency, was determined as the ratio of crop yield per unit area, in terms of grain, to crop evapotranspiration (mm), and was expressed as kg of grain or biomass per m^3 of consumed (evapotranspired) water. Statistical analysis of the data included analysis of variance (ANOVA), using SAS software, to test the effects that season, SI had on grain yield, stalk biomass, and water productivity.

Results and Discussions

The results distinguish that year -to -year variations occurred in treatment effects (Table 2). Even though the actual rainfall amount occurred in the second year was less than the long term mean value, more amount existed at initial stage affects the growth performance and became stunted growth. Furthermore, the grain yield and yield components in the second year were highly affected by the occurrence of stalk borer disease at development stage.

Table 2: Analysis of variance

Source of variation	Degree of freedom	Mean square		
		Grain yield	Stalk biomass	Water productivity
Replication	2	0.7818	1.138	0.0271
Treatment	5	1.2255	3.664*	0.0958**
Year	1	59.6017**	126.875**	2.4701**
Treatment*year	5	0.4915	1.165	0.0196
Error	33	0.48	1.105	0.0196

** = Significant at (0.05) level of significance, ** = Significant at (0.01) level of significance*

The combined analysis of variance for both years showed that there was none significant interaction effect between treatments across years on grain yield, stalk biomass and water productivity (Table 3).

The experimental analysis indicated that there was significant difference in stalk biomass, grain yield and water productivity in the first year. Sorghum grain yield, biomass yield and water productivity were highly decreased in the second year, with the adverse effect of high rain in the initiation stage and disease infestation. However, grain yield, stalk biomass and water productivity showed statistically significant different. The grain yield widely ranges from 5.4 t ha^{-1} to 1.5 t ha^{-1} (Table 3).

Supplementing the CROPWAT generated depth (100%) starting from development stage at optimal time of application gave the highest stalk biomass (11 t ha^{-1}) and grain yield (5.4 t ha^{-1}) and it had a maximum yield advantage 2.9 t ha^{-1} compared to the control in 2011 cropping season (Table 3). Sorghum yield under rain fed condition (control treatment) consistently had lower yield in both years (Table 3). The production potential of the crop was extremely affected by rainfall amount and distribution conditions. Combined result of the two cropping season showed that stalk biomass and water productivity were statistically significant, but grain yield didn't.

In water productivity supplementing the CROPWAT generated depth (100%) during Mid stage only (mid stage supplementary of 226.5mm seasonal irrigation water) at 8 days interval had a maximum value of 1.67 kg m^{-3} which didn't significantly differ from 330.6mm/seasonal water application at both development and mid stage at eight days interval (Table 3). Supplementing the CROPWAT generated depth (100%) starting from development stage at optimal time of application with a seasonal water amount of 330.6mm had a yield advantage of 1.61 t ha^{-1} compared to supplementing with the CROPWAT generated depth (100%) during MSt (mid stage supplementary of 226.5mm seasonal water) at 8 days interval in 2011. Water productivity was about 0.96 kg of wheat grain per unit volume of water (m^3) of water under rain fed conditions and 1.36 kg of wheat grain m^{-3} under supplemental irrigation (Zhang and Oweis, 1999). Water productivity for sorghum grain yield in 2011 was in the range of 1.02 to 1.7 Kg m^{-3} with lower observation in the second year production season as shown in figure-2 and figure-3.

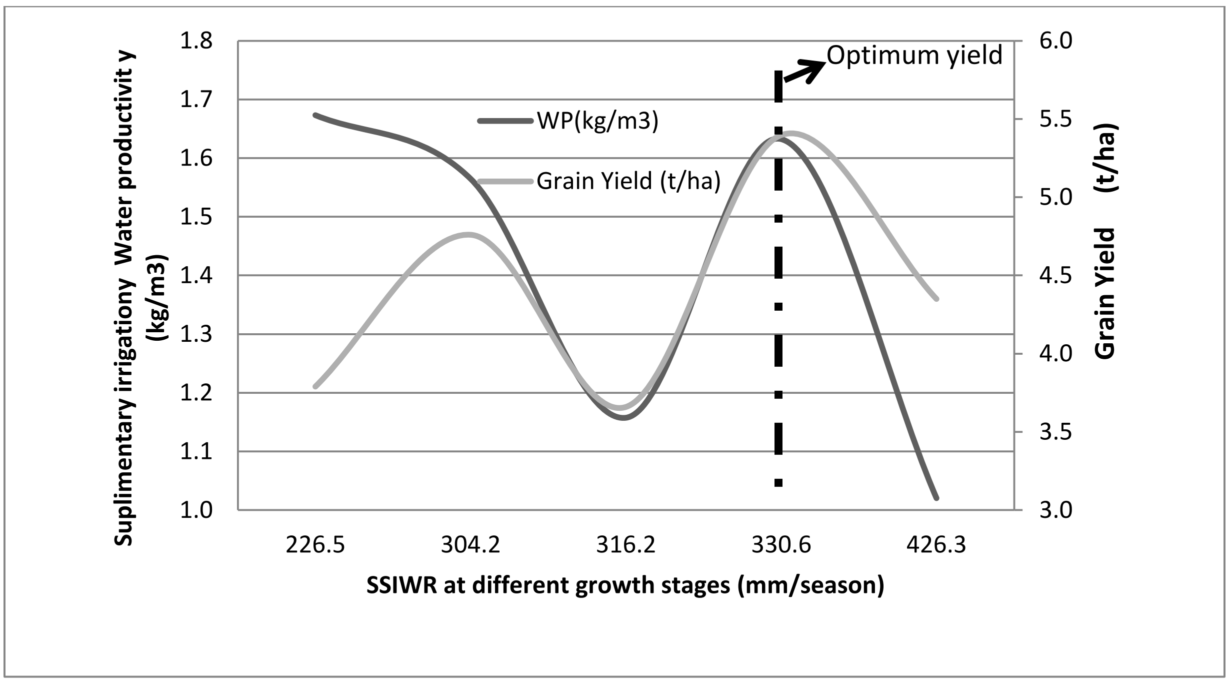


Figure 2: SSIWR at different growth stage in the first year (2011)

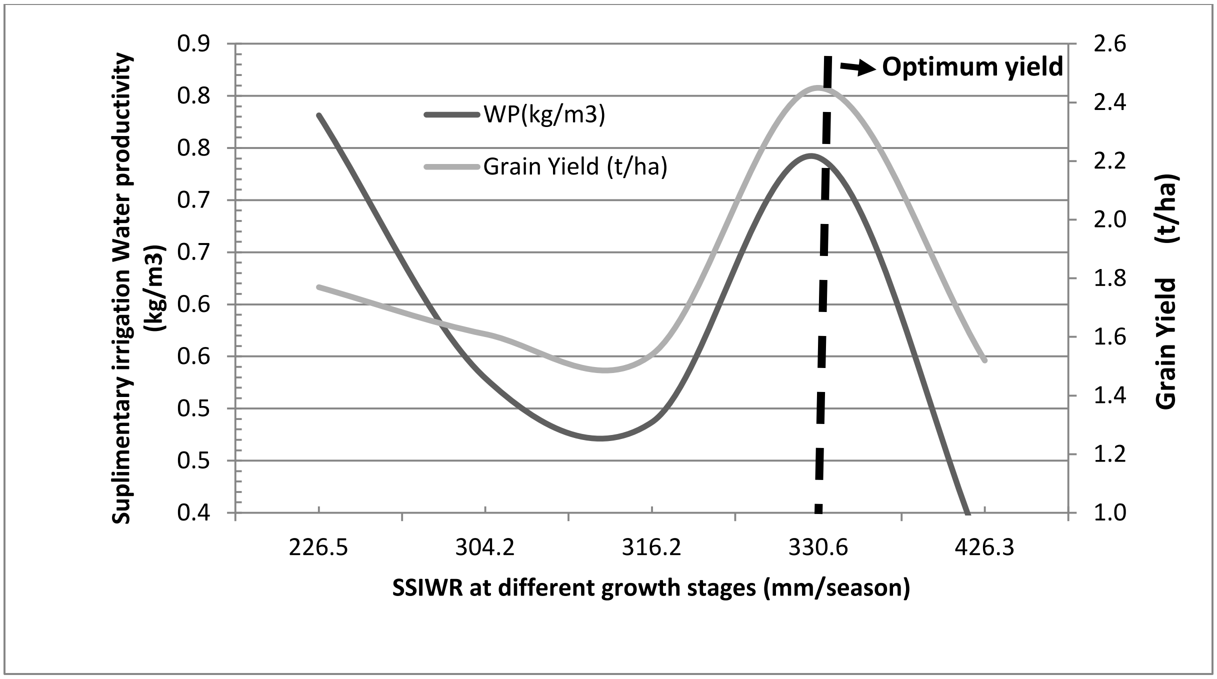


Figure 3: SSIWR at different growth stage in the second year (2012)

The above two figures (2 & 3) showed that for both experimental seasons water productivity versus and grain yield was coincided optimally at 330.6mm/season supplementary irrigation during development stage at none fixed interval giving the supplementary irrigation following different indicators like crop physiological appearance and soil moisture stress.

Table 3: Mean separation result of plant height, stalk biomass, grain yield and water productivity

S. no	Treatments (SSIWR in mm/season)	First year /2011/ Stalk biomass (t ha-1)	First year /2011/ Pure grain yield (t ha-1)	First year /2011/ water productivity (kg m-3)	Second year /2012/ Stalk biomass (t ha-1)	Second year /2012/ Pure grain yield (t ha-1)	Second year /2012/ water productivity (kg m-3)	combined Stalk biomass (t ha-1)	combined Pure grain yield (t ha-1)	combined water productivity (kg m-3)
1	C (0)	8.077b	2.523d	1.23b	4.873b	1.53b	0.78ab	6.49b	1.88	0.81a
2	S 1(330.6)	11a	5.397a	1.56ab	6.422ab	2.45a	0.74ab	8.35a	3.13	0.54b
3	S 2(426.3)	8.86b	4.35b	1.02c	6.400ab	1.52b	0.45c	8.34a	3.03	0.48b
4	S3(316.2)	9.2b	3.663c	1.16bc	7.790a	1.54b	0.49c	8.44a	2.82	0.52b
5	S4(304.2)	9.13b	4.763b	1.56ab	5.540b	1.61ab	0.53bc	7.24ab	2.8	0.49b
6	S5(226.5)	10.56a	3.79c	1.67a	5.243b	1.77ab	0.72ab	7.65ab	2.95	0.65ab
7	U(211.7)	-	-	-	6.022b	1.95ab	0.85a	-	-	-
	CV (%)	7.6	6.2	11.3	13.3	24.4	30.6	13	25	24.2
	LSD (0.05)	1.314**	0.458**	0.173**	1.467*	0.811*	0.2179*	1.716*	ns	0.239**
	Grand mean	9.47	4.08	0.84	6.04	1.77	0.378	7.75	2.77	0.58

*The same letters are not significantly different (P <0.05), ** significant (p<0.01) & * significant (p<0.05) according to a Duncan's multiple range test. Note: SSIWR= seasonal supplementary irrigation water requirement, GD= generated depth, DSt=development stage, LSt=late stage, OPT= optimum Time of application MSt=mid stage . Treatment : Controlled (rain fed farming)* ***(C),*** *Supplementing the CROPWAT generated depth (100%) starting from DSt* ***(S1)*** *without fixed interval**,** Supplementing the CROPWAT generated depth (100%) starting from DSt at 8 days interval* ***(S2),*** *Supplementing the CROPWAT generated depth (100%) starting from MSt at 8 days interval* ***(S3),*** *Supplementing the CROPWAT generated depth (100%) during DSt & MSt at 8 days interval* ***(S4),*** *Supplementing the CROPWAT generated depth (100%) during MSt only at 8 days interval* ***(S5),*** *User adjustment based on soil moisture sensor measurement to re-fill to field capacity and based on plant physiological responses****(U)***

Conclusion and Recommendation

Supplemental irrigation is a feasible option that can be used by farmers in the Kobo area to increase and stabilize their rain fed sorghum production. The application of supplemental irrigation can help the crop to escape the critical stages particularly terminal drought or moisture stress.

From our result, it can be concluded that semi-arid areas like Kobo Girrana Valley which have problems of rainfall distribution and occurrence (late onset and early offset) and having an access to irrigation can increase the yield advantage above 1t ha^{-1} with supplementary irrigation starting from crop development stages at none fixed interval following moisture deficiency indicators like crop physiological appearance and soil moisture stress with amount of 330mm seasonal irrigation water requirement for improved variety of sorghum (Teshale) from combined analysis of the two years the range of yield advantage over the control reaches up to 2.90 t ha^{-1}.

As an alternative if sorghum didn’t have moisture stress at development stage (early) and water is the limiting factor in the growing season, only by supplementing at development stage about 226.5mm at eight days interval can give a reasonable good grain, biomass yield and water productivity. However, this research finding highly recommended that supplementing rain fed for sorghum production starting from development stage (20 days after sowing) is better during development and mid season stage at 8 days interval. Although in rain fed areas, irrigation comes at a cost. Therefore, economic studies are highly recommended in order to evaluate its feasibility and to identify any constraints that might affect its implementation.

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Effect of Irrigation Scheduling and Chemical Fertilizer on Onion Yield at Megech

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Abstract

A field experiment was conducted to study the interaction effect of irrigation depth and fertilizer rate on onion yield at Megech, Dembia Woreda during 2011/12 and 2012/13 irrigation seasons. The experiment was arranged in a Randomized Completet Block Design (RCBD) with three replications. The ttreatments were combinations of two irrigation depths (ID) (31mm and 25mm) and three NP levels (50/46, 50/138, 100/138, kg N/P_2O_5 ha^{-1}*). All* P_2O_5 *was applied to each plot during transplanting and N fertilizer was applied in two splits; ½ at transplanting and ½ at 45 days after transplanting. Data on soil chemical properties, agronomic parameters and economics were collected and analyzed using SAS statistical software. Least Significant Difference (LSD (0.05)) was used for mean separation. The result revealed that the soil pH ranges between 6 and 7 confirming that the site best suits for onion production. The agronomic data also revealed that there was no significant interaction effect between irrigation depth and* N/P_2O_5*. The biological yield result indicated that 100/138 kg* N/P_2O_5 ha^{-1} *gave significantly higher onion total bulb yield. However, there is no significant difference between irrigation depths. The partial budget analysis indicated that application of 50/46 kg* N/P_2O_5 ha^{-1} *with 25 mm/7 days irrigation interval can benefit farmers more among other treatments. Therefore, 50/46 kg* N/P_2O_5 ha^{-1} *with 25 mm/7 days irrigation interval is recommended for Megech and similar areas.*

Key words: Irrigation, fertilizer, Onion, interaction, yield

Introduction

Onion (Allium cepa L.) is a high cash value crop with a very shallow root system, and in the world trade it ranks second in importance next to tomato among the vegetable. It needs frequent irrigation and fertilizer to maximize yield. It is used in every home almost daily. Its main uses lies in flavoring and seasoning many dishes. Onion has also an important role as a medical herb in many communities, and is claimed to minimize high blood pressure and other heart disease.

Onion production, which can easily be undertaken by unskilled people, may play an important role in poverty reduction programs and food security initiatives. It can also provide employment opportunities and a source of income. Horticultural crops are well adapted for small-scale production units and can provide relief for people at the individual household level while they also offer opportunities for trade and earnings of foreign currency.

In Amhara region onion production has been going on in different small and medium scheme irrigation sites. In Rib irrigation command areas the farmers have been practicing onion production in the last few decades. The local variety which is called shallot is also a common practice in Gonder Zuria Woreda. Recently this practice has been widely spreading in Dembia Woreda. Therefore, to maximize the production and productivity of onion, Gondar Agricultural research center (GARC) has done an experiment on fertilizer and water requirements of onion at Megech irrigation command area. However, fertilizer requirements may be affected by amount and frequency of irrigation water. On the other hand water use efficiency is highly dependent on plant nutrient and, supply. Therefore, any plant input factor that increases economic yield will improve the water use efficiency or vise-versa. Appropriate irrigation water application and method can improve nutrient use efficiency (*Ardell, et al., 2002)*. To investigate the relationship of fertilizer rate and water amount, interaction of water and fertilizer was studied for onion with the objectives of (i) determining optimum rate of N and P fertilizer combined with optimum amount of water (ii) evaluating the interaction effect of chemical fertilizer and water amount on the yield of onion.

Materials and methods

The experiment was conducted for two years (2011/12 and 2012/13) in Megech irrigation command area on farmers' fields. The experimental design was Randomized Complete Block Design in factorial arrangement with three replications. Three rates of the combination of N and P were and two water frequencies were used as a treatment. The fertilizer rates were 50/46 kg N/P_2O_5 ha^{-1} 50/138 kg N/P_2O_5 ha^{-1} and 100/138 kg N/P_2O_5 ha^{-1} the amount and frequency of water were 25mm and 31mm applied every 7 days. Adama red variety of onion was used for the experiments. Seedlings were prepared in a nursery and transplanted to the plots after 45 days. P_2O_5 and half of N fertilizer in the forms of DAP and Urea respectively were applied at transplanting. The remaining half of N fertilizer was applied 45 days after transplanting. All the experimental plots received equal amounts of water from time of transplanting to establishment. Therefore, treatments with irrigation amount started after the establishment of seedlings. The irrigation method was furrow and flow measurement was done using siphon. Other agronomic practices like plowing, harrowing, weeding, earthling up, pest control measures were done equally for each treatment.

Treatments

1. 50kg/ha N and 46kg/ha P_2O_5 combined with 31 mm amount and 7 days frequency
2. 50kg/ha N and 138kg/ha P_2O_5 combined with 31 amount and 7 days frequency
3. 100kg/ha N and 46kg/ha P_2O_5 combined with 31 mm amount and 7 days frequency
4. 50kg/ha N and 46kg/ha P_2O_5 combined with 25 mm amount and 7 days frequency
5. 50kg/ha N and 138kg/ha P_2O_5 combined with 25 amount and 7 days frequency
6. 100kg/ha N and 138kg/ha P_2O_5 combined with 25 mm amount and 7 days frequency

Data Collection and analysis

Initial composite soil sample (0- 20 cm depth) was taken before planting and analyzed for pH, available P, total N and CEC at Gondar Zonal Soil Testing Laboratory. The following soil analyzing methods were used to determine each soil chemical parameter:

- Soil pH in 1:2.5 soil to water suspension (Rayment and Higginson, 1992)

- Cation exchange capacity (CEC), by the ammonium acetate (pH 7) method (Schollenberger, 1927)
- Exchangeable basic cations (Ca, Mg, K, Na) content from the ammonium acetate leachate (Schollenberger, 1927)
- Total nitrogen, by the Kjeldhal method (Kjeldahl, 1883)
- Available phosphorus, by the Olsen method (Olsen *et al*, 1954)
- Organic carbon (OC), by the Walkley and Black method (Walkley and Black, 1934)
- Texture, by hydrometer method (Gee and Bauder, 1986)

Economic analysis was done using partial budget analysis method (CIMMYT, 1988). Partial budget analysis compares the impact of a new technological change on farm costs and returns. This approach is called partial because it does not include all production costs like land cost, it only includes those which vary between the farmer's current production practices and the introduced one (CIMMYT, 1988). Data such as: variable costs (N and P fertilizers and labour for different water depths which vary between treatments); onion yield per hectare resulted from each treatments and it was adjusted by 10% decrement for each treatment; farm price - prices of harvested onion which was 5.5 birr per kilogram; fixed costs which included land preparation, planting, weeding, seedling preparation and harvesting costs equally for each treatment.

Then the main components of PBA such as, total revenue, net income, change in variable cost, change in return, marginal cost of return (should be greater than 100%) was calculated and based on net income and marginal rate of return results decision on which fertilizer rate is more profitable for farmers was made, the higher the net benefit and the higher the MRR (which should be greater than 100%) is the higher the treatment is profitable and would be selected over the other treatments.

Agronomic data: bulb yield, stand count, bulb weight, bulb diameter were collected but only yield will be presented here, since the other yield components were not significantly affected by water depth and fertilizer application.

Results and discussions

Soil chemical properties of the study area

The laboratory analysis result revealed that the soil textural class of the experimental area is clay loam. Onion can grow on most soil types. Well drained, medium texture soils with pH 6-7 suits best for onion production (FAO, 2015). As shown in Table 1, the soil pH of the study area was under the best category for onion production. Since the irrigation method was controlled furrow, drainage and the texture condition was not a limitation for onion production. The total nitrogen (TN) content of the study site is medium (Landon, 1991 and Kamanu, *et al.*, 2012). According to the classification of Landon (1991) the organic matter content of the soil was low. Soil OM is vital to many soil chemical, physical, and biological properties and should be improved through different organic amendments. Increase in soil OM improves CEC, soil total N content and other soil properties such as water-holding capacity and microbiological activity (Horneck *et al.*, 2011). The soil of the study area had low available phosphorus content, medium Na^+ content, high exchangeable K^+ content, very high Mg^{2+}, Ca^{2+} and CEC contents (Landon, 1991). High content of exchangeable cations indicates that the soil of the area does not need application of fertilizer for these cations. On the other hand very high CEC value indicates that the nutrient retention capacity of the soils is very high and it is attributed to the high clay content of the soil (CUCE, 2007).

Table 1: Soil analysis results for the experimental site (Megech irrigation scheme)

Parameters	pH	Avail. P/PPM	OM	TN%	CEC	Ca^{++}	Mg^{++}	Na^+	K^+	Texture
	6.84	6.023	2.68	0.34	60.65	40.98	18.40	0.65	0.62	Clay loam

Effect of NP and irrigation amount on Onion Yield

Combined over years, the analysis of variance showed that the interaction effects of irrigation amount and N/P_2O_5 fertilizers didn’t significantly affect onion yield (Table 2). While the main effects of N/P_2O_5 fertilizers has significantly affected onion yield. For yield analysis total yield was considered, since total yield was the best predictor of treatment response because it is unaffected by potential bias decision on marketable and unmarketable yields.

Table 2. Analysis of variance for the effects of irrigation and N/P2O5 fertilizer on total onion yield

Source	DF	Mean Square
N/P_2O_5 fertilizer	2	40873278.33*
IRR_Depth	1	7137885.24^{ns}
Fertilizer*IRR_Depth	2	16277429.63^{ns}

** = significant difference, = no significant difference at 0.05 probability*

Higher onion bulb yield was obtained from 100/138 kg N/P_2O_5 ha^{-1} (Table 3). Similar result was reported by Aliyu *et al*. (2007) and Woldetsadik (2003), they reported that these fertilizers significantly affected onion yield and yield components. Since onion is a shallow rooted crop, it demands high nitrogen amount during the growing seasons (Ardell *et al*, 2008), when it demands high N, its P up take also increases. In other words, if the amount of N applied decreased, the plant P demand also decreased and resulted in delayed maturity, reduced quality and decreased disease resistance (Greenwood *et al*. 2001). Therefore N application is very important for P uptake, good growth and higher yield of onion.

Applying 31mm irrigation water at 7 days interval (31mm/7) gave relatively higher yield than the application of 25mm of irrigation water at 7 days interval (25mm/7) (Table 3). Though soil moisture condition was not monitored at the time of irrigation, the moisture difference between the two water depths application was not big. Hence, occurrence of approximately similar soil moisture conditions with applying these two treatments is expected. A drop in soil moisture was expected if it was applied below 25mm irrigation water. Enciso, *et al*., (2009) also reported none significant result 75% and 100% ETc water applications. They stated that even though numerically higher yield was observed with the 100% than with the 75% ETc treatments, there was no statistical difference. This is may probably be due to the fact that the treatments kept a water level at about the field capacity for most days of the season.

Table 3 The effect of irrigation amount and fertilizer on total onion yield (kg/ha)

Fertilizers	Yield (kg ha^{-1})
N/P_2O_5 kg/ha	
100/138	14631[a]
50/46	12889[ab]
50/138	10942[b]
LSD (0.05)	2596.5
Irrigation depth	
25mm/ 7	12375
31mm/ 7	13266
LSD (0.05)	2120
CV (%)	24

N.B: values with different letter states significant difference between the

Partial budget analysis

Partial budget analysis was done for combined result on the bulb yield of onion. The result showed that, 31mm/7 days water application with 100/138 kg N/P_2O_5 ha^{-1} fertilizers have the highest net benefit, but this would be considered profitable only if its rate of return is higher than 100%. But as Table 4 below shows its marginal rate of return (MRR) is 12.1 % which is much less than 100%. Other rates such as (50/138, 25); (100/138, 25); (50/46, 31); (50/138, 31) N and P_2O_5 kg ha^{-1} and irrigation water depths mm/7 days interval are marked as dominated because as their costs increased against 50/46 kg/ha N, P_2O_5 , 25mm/7 days interval, their net benefit did not increase, therefore all these rates are rejected. In this case the CIMMYT manual stated that when MRR for a new technology is less than 100%, that technology could not be beneficial for farmers (CIMMYT, 1988). So, it is possible to recommend the farmers practice or the lowest rate. Therefore, in this research since we could not select the one with its MRR less than 100% or the dominated one, 50/46 kg N/P_2O_5 ha^{-1} fertilizers with 25 mm/7 days interval irrigation water application is economically a better rate for farmers in the study area.

Table 4. Partial budget analysis for the effects of irrigation and N/P_2O_5 fertilizer on total onion yield (kg/ha)

N/P kg/ha, IWD mm/7 days	Mean yield kg/ha	Adjusted yield kg/ha	TR birr/ha	GFB birr/ha	VC birr/ha	NB birr/ha	DA	MC birr/ha	MNB birr/ha	MRR (%)
(50/46,25)	13117	11805.3	64929.2	54844.2	7817.2	47026.9				
(50/138,25)	11169	10052.1	55286.6	45201.6	9243.3	35958.3	D			
(100/138,25)	12841	11556.9	63563.0	53478.0	10643.3	42834.7	D			
(50/46, 31)	12661	11394.9	62672.0	52587.0	10750.0	41836.9	D			
(50/138,31)	10715	9643.5	53039.3	42954.3	12176.1	30778.2	D			
(100/138,31)	14421	12978.9	71384.0	61299.0	13576.1	47722.9		5758.9	695.9	12.1

NB: TR=total revenue, GFB=gross field benefit, VC= variable cost, NB= net benefit, DA= dominance analysis, MC= marginal cost, MNB= marginal net benefit, MRR=marginal rate of return

Conclusions

As the soil data analysis result of the study site showed, slightly acidic to neutral pH, high K, very high Ca, Mg and CEC the soil may be suitable for onion production with reasonable inputs such as Nitrogen, P and organic amendments for it had low organic matter, and available P contents. The onion bulb yield (biological yield) combined over years showed that N/P_2O_5 fertilizers irrespective of irrigation amount had significantly affected bulb yield. Therefore, applying 100/138kg N/P_2O_5 ha^{-1} gave the maximum biological onion bulb yield. However, the irrigation depth did not significantly affect the onion bulb yield may be due to the fact that the applied depths didn’t bring significant soil moisture difference. Unlike the biological result, the partial budget analysis result revealed that, maximum benefit can be obtained from application of 50/46 kg N/P_2O_5 ha^{-1} with 25mm/7days irrigation. Therefore, it is recommended that application of 50/46 kg N/P_2O_5 ha^{-1} fertilizers with the irrigation amount 25 mm at 7 days irrigation interval are recommended for onion production at Megech irrigation site.

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III) Soil and Water Conservation

Enhancing Farmers Participatory Decision Making for Improving Land and Water Management Practices at Enkulal Watershed

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Abstract

Many land-users in the highlands of Ethiopia do not make soil erosion a top priority problem until it reaches the stage of gully formation on their farmlands. Most soil conservation planning and implementation approaches therefore rely on empirical assessment methods by experts and give little consideration to sharing and enhancing farmers' local erosion knowledge. Therefore, supporting and facilitating the adoption and transfer of improved erosion control technologies and innovative land management practices through building and sharing farmers' local knowledge along with genuine participatory approaches is essential. The purpose of the study was to assess land and water management practices, improve the efficiency of soil conservation practices, and facilitate the knowledge transfer and adoption of improved measures through farmer-expert joint learning approach using farm ditches and gullies as a learning site. The farmer participatory problem identification and their involvement in collective decision-making process described here has provided positive impacts on the local knowledge and attitude of farmers. These were widely demonstrated by self-actions and change in practices. It has also brought an impact in generating innovative practices, minimizing sense of dependency, increasing knowledge of soil erosion and soil conservation, and understanding the consequences of ditch induced erosion for on-site and off-site long-term land degradation. In addition, the farmers have been empowered through the ownership of the erosion assessment, planning of conservation measures and practicing soil conservation improvements. Thus, the methodology enhances the participation of farmers in problem identification, planning and implementing efficient erosion control measures by themselves and orient them towards long term and sustainable erosion protection strategies by integrating farmer and expert knowledge, and using ditch erosion, crop residue, and gully erosion indicators as a tool for assessing and prioritizing severity of erosion.

Key words: Ditch erosion, Farmer-expert joint learning, improved soil conservation, Enkulal watershed

Introduction

In the highlands of Ethiopia, where intensive agriculture is practiced, land resources are being depleted at an alarming rate. Failure to balance soil and water conservation measures (SWC), with the use of effective technologies and farm management practices, against the current level of land degradation is a growing challenge to small-holder farmers who are striving to meet immediate economic objectives on one hand and sustainable environment on the other hand. Land degradation is the result of increased pressure on land use beyond its capability. Severe soil erosion in association with inappropriate farm management practices which is the main factor causing degradation that again leads to low efficiency of SWC (Mitiku *et al*., 2006).

Past soil and water conservation programs focused more on land degradation and less on the land user and used a top-down approach for information dissemination and SWC extension techniques. In the past, top down programs tended to focus primarily on symptoms of erosion through subsidized terracing than responding to the root causes of land resources degradation such as land use change and livelihood improvements. Soil conservation programs that aim to reduce land degradation problems, through treatment of causes, require a long term, bottom-up and interactive approach as well to supporting farmers who generally have detailed knowledge of their farm, know a wide range of potential interventions (although they can still learn new ideas from experiences elsewhere) and choose between these interventions on the basis of the resources and pressures on the farm household.

In recent years, it has become increasingly evident that the change in human dimension or socio-economic plays a key role in resources management. Problems are complex, uncertainties are high, prediction is possible to a limited extent only and integrated approaches to resources management are advocated. This implies that management is not a search for the optimal solution to one problem but an ongoing learning and negotiation process where a high priority is given to questions of communication, perspective sharing and development of adaptive group strategies for problem solving (Pahl-Wostl 2002a, 2002b). According to Bandura (1977) social learning refers to individual learning based on observation of others and their social interactions within a group, for example through imitation of role models. It assumes an iterative feedback between the learner and their environment, the learner changing the environment, and these changes affecting the learner.

Through such interactive exercises and iterative processes, the knowledge which is difficult to articulate can be explicit. So far, systematic methods to articulate local soil erosion knowledge and use it for sustainable technology development are not well understood and integrated in the formal soil conservation technology development. For the purpose of this study, in order to evaluate pattern of changes in attitude, skill and knowledge, we made use of local erosion indicators such as traditional ditches, crop stubble left in the farm, and protection of improved soil conservation practices as a learning object and the perception of participants before and after the learning process.

This paper provides information on the participatory learning processes for collective decision making to explore changes in soil conservation practices through farmer-expert joint learning approaches (JLA) taking case studies at Enkulal watershed, one of the operating micro-watershed in the Tana and Beles Integrated Water Resources Development Project. The centre of emphasis of the participatory decision making was to protect gully formation and development through the control of the causes like runoff from traditional ditches.

Objectives:

- To enhance bottom-up and farmer-expert joint decision making in order to assess, evaluate and improve the efficiency of land and water management practices using locally applicable indicators
- To identify limitations, strengths and improvement options for land and water management practices

Methodology

Description of study site

The study area, Enkulal watershed, is found in South Gondar Zone, Dera Woreda in Glawdios Kebele. The study site is located within Enkulal micro-watershed that drains about 398 ha area. It is located at $11^0$37’59’’ N and $37^0$47’48’’ and an altitude of 2300 m asl. Preliminary assessment of the watershed was undertaken in order to identify active land degradation problems. Finally, a catchment was purposely selected that drained by an active gully to use it as point of participatory decision making. About 22 households who own land within the drainage area of the gully were selected and involved in the subsequent participatory processes.

Enkulal watershed has a relatively mean high annual rainfall of 1577 mm and remains cloudy during most of the rainy season. Maximum observed daily rainfall is 89 mm (Bezawit, 2011). The study catchment is dominantly covered by crop followed by degraded patches of land used for grazing and small settlement area. Cereal cultivation is the dominant cultivation system and most of the cultivated fields are usually planted with barely, teff, wheat, fingermillet, maize, linseed, and lupin. Because of increasing land pressure, fallow periods are shortened and this results in decreasing yields due to decreasing fertility of the soil, increasing erodibility and ultimately total degradation.

Participatory and collective decision making strategies and procedures

In recent years, the role of human and social dimensions and integrated approaches to resource management are advocated through interactive learning among stakeholders (Pahl-Wostl, 2004; Sanginga et al., 2004; Palomo et al., 2011, Dile et al. 2013) under conditions when problems are complex, uncertainties are high, and predictions are only possible to a limited extent. This implies that adaptive participatory methods are not only enhance resource management but also drive the generation of social capital and social innovations. Thus, the participatory processes described below are built on the local contexts and help to explore and systematically articulate local knowledge.

The participatory process involved the following implementation procedures

Self confidence building measures**:** awareness and attitude change activities to motivate and increase the level of participation of farmer households during the process through informal group discussion and question and answer was conducted. This step was key to build the confidence and trust on the process and to encourage individual farmers activly involve in the collective decision making process.

Team/Group formation**:** since age, gender, and education of household members are the main determinants for the adoption of land and water management practices, based on these characteristics, among the participant farm households there were mix of 18 men and 4 women households. During field visits, two groups were formed: one group include land users who own land on the left side and group two who own land on right side of gully. All participant farmers either women or men household member are agreed to involve in every field visits arranged during exterme rainfall events, in key collective decision processes and in the monitoring and evaluation activities. Moreover, three member team was selected who were responsible to lead and manage the participation and decision processes and record minutes of the decision processes. The extension agents and/or researchers played a role of facilitation, motivation, and collection of evidences in the process.

Collection of baseline information : baseline information was collected on family size, productive labor force, crop type and productivity of each parcel of the participant farmers, number of livestock species per household, plot and terrace characterisitcs, number of ditches practiced per parcel, and dimension of gully.

***Practical oriented knowledge sharing and practicing*:** during the field visits, meetings, and monitoring and evaluation activities, participant farmers explored their practical experience and share their knowledge on selected issues such as gully formation and rehabilitation, traditional ditch management, improving efficiency of bunds, tillage management, and crop residue management. This process gradually facilitated a collective understanding of land management practices and the associated problems and constraints with its solutions. Eventually, through continous dialogue and discussions the land users gain environmental knoweldge that would help to protect the agricultural ecosystem sustainably.

***Monitoring and evaluation*:** annual monitoring were conducted on key performance indicators set in the bylaws such as terrace performance, ditch improvement, crop stubble management, control of free grazing, and collective action and change in practices.

***Arrange incentive mechanisms*:** different in kind incentive mechanisms were provided. Among these incentives improved crop varieties and improved lupine seed and improved fallow practices were included.

Results and Discussions

Initially, two meetings were conducted with participant farmers to brief objectives and procedures of the project activities, motivate and encourage farmers for their active involvement in the participatory decision making processes. Next to the awareness creation, a micro-catchment drained by an active gully was identified for a study site through discussion with the participant farmers. It was selected because gully damage is a common problem in the area. Once the micro-catchment was selected, the potential problems were also identified. Gully erosion, excessive traditional ditches per parcel, poor soil fertility, damage due to concentrated runoff drained from road, and lack of improved technologies were among the identified problems at the study site. As it was identified during group knowledge exploration process, concentrated runoff from traditional ditches drained to the border of two adjacent farms and runoff from road ditches are the major causes of gully formation.

Two groups of farmers were formed according to the position of their land holding relative to the gully (right and left sides) to assess problems, evaluate practices, do implementation and monitoring and evaluation activities in each farm plot every one or two weeks after heavy storms. This process enables farmers to share their knowledge of land management practices. They also exercised consensus based decision making through dialogue during the field visit. Of course this takes time and a continuous process to bring change and empower farmers to make decision by themselves.

The groups have leader and secretary who took responsibility to coordinate during field visit and discussions. They also recorded every discussions and decisions the group has made. Notebooks and pens were given for each group for recording the minutes.

Baseline Information on Household Characterisitcs, Farm Practices and Erosion Indicators

Household based labor, crop and livestock characteristics

Household labor, crop productivity per parcel and livestock holdings were collected as baseline for the purpose of analyzing the impact of the interventions at the end. Accordingly, the average family size and productive labor of the participant farmers was about 5 and 2.2 respectively. The total family size and productive labor of all households summed up to 91 and 38 respectively. The productivity of local crop varieties cultivated in the catchment range from 1-1.5 quintal per parcel or plot (Table 2). The total livestock number in the catchment was about 172 constituting 20 cows, 24 oxen, 35 other cattles, 45 sheep, 10 equines and 38 chicken (Table 3). This baseline information used to assess the balance of feed supply and feed requirement in the catchment and then plan for forage development to fill the deficit.

Table 2. Family size, productive labor and productivity of local crop varieites

	Family size	Productive family labor	Productivity in tons per parcel (0.05-0.26 ha)				
			Barley	Wheat	Teff	Maize	Other crops
Min	1.0	1.0	0.05	0.05	0.05	0.10	0.05
Max	8.0	6.0	0.30	0.30	0.25	0.10	0.20
Mean	5.1	2.2	0.13	0.15	0.13	0.10	0.13
Total	91.0	38.0					

Table 3. Individual household's and total number of livestock holding in the study catchment

	Cow	Ox	Other cattle	Sheep	Equines	Chicken
Min	1.0	1.0	1.0	1.0	1.0	1.0
Max	2.0	2.0	5.0	12.0	2.0	5.0
Mean	**1.4**	**1.6**	**2.2**	**3.8**	**1.4**	**2.7**
Total	**20.0**	**24.0**	**35.0**	**45.0**	**10.0**	**38.0**

Terrace/bund conditions

The catchment area had a total of 106 terraces. The respective minumum, maximum and average number of terraces per parcel were 2, 12 and 4. The length of terraces also varied from 11-38 m (average 18m). However, the terraces or bunds are not in a better condition. The runoff basin area of most terraces were filled up by sediment and the runoff from top areas overtopped the terraces. Parts of stone terraces were also damaged by livestock.

Ditch survey and erosion assessment

Initially in 2011, a total of 256 ditches were recorded in the study catchment. The density of the ditches and its dimension is dependent on the nature of the soil, slope of land and type of crop cultivated. Coarse textured soils were found to be drained with widely spaced ditches while clay soils were drained with closely spaced ditch systems. High density of ditches is commonly observed on teff covered fields planted on gentle and flat slopes. A minimum of 3 and a maximum of 52 ditches per individual farmer plot were recorded irrespective of the type of crop cover. The average initial depth and top width of ditches were 19 cm and 38 cm respectively (Table 4 and Fig. 1). The gradient of ditches was on average from 5 to 9 %. After the start of erosion the ditch channel is dynamic depending on the sediment concentration coming into the ditch. The ditch monitoring has revealed that depth of ditches was decreasing over rainy season due to splashing of the unconsolidated soil on the ridges and accumulation of sediment on furrow bed. It has been observed that the change in depth and width in two months period indicates accumulation of transported sediment along the channel. The results further showed that ditches, especially during erosive rains, encouraged runoff erosion the extent of which was further aggravated by increasing land and ditch slopes.

Ditches serve as a sediment transporting channel. The transport efficiency of the ditches was observed by measuring sediment accumulation area in the channel per unit length. It is the change in the cross section of the ditch. The sediment transport rate per unit length was increased from top to down end of the ditch and over the rainy season. In the middle of July, the sediment transport rate per ditch was 0.19, 1.33 and 1.52 cm^2m^{-1} at the top, middle and bottom of the ditch, respectively. The transport rate increased to 0.93, 3.39 and 4.32 cm^2m^{-1} in the middle of August. However, in September the transport efficiency was at decreasing rate most likely due to the decreasing of erosive rainfall events (Table 5). From a single farm ditch, on average, sediment is transported at a rate between 0.5 cm^2 and 4.0 cm^2 per meter of ditch. The average seasonal sediment transport rate was 1.27, 2.70 and 3.97 cm2/m per ditch at the upper, middle and lower part of the ditch (Table 5 and Fig. 2). Under heavy rain storms and combined with excessive ditch gradients, they serve as hot spots for accelerated erosion. Unless there is proper construction it provided high risk of erosion downstream in the form of rills and gullies, and leads to conflicts among adjacent land owners. The negative impacts of this practice are apparently observed in the field by forming gullies along adjacent farm boundaries, damage the terrace structures and serving as a sediment transporting channel where sediments accumulated at the outlets. Consequently, many land users who are practicing open farm ditches do not notice the risk of traditional open ditches to properly address erosion problems since they are constantly struggling only against the control of highly recognized and visible forms of erosion (Aklilu and de Graaf 2006). However, properly constructed drainage ditches can prevent erosion and gully on slopes by catching surface runoff before it reaches the critical stage. This indicated the importance of protecting and controlling ditch erosion without compromising the need to drain excess runoff.

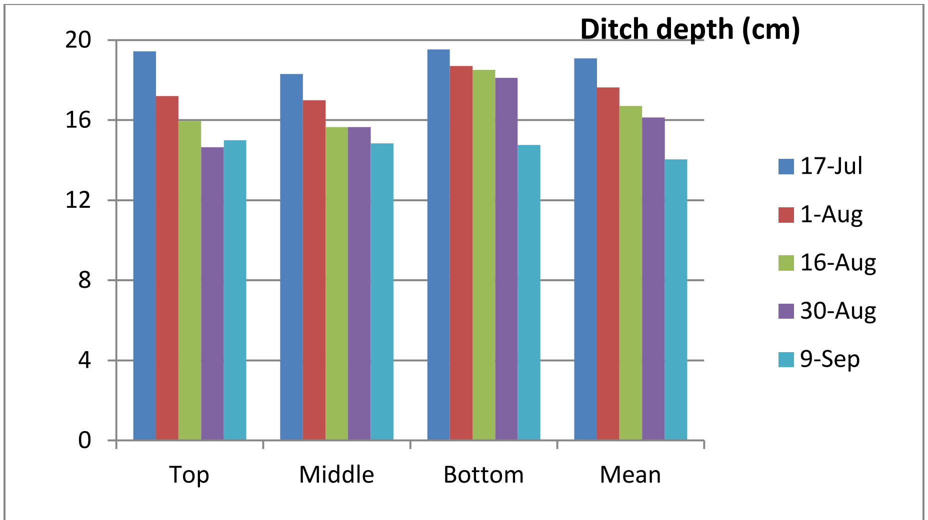
Photo 1: Erosion and sedimentation of farm drainage ditches

Table 4. Mean dimensions of drainage ditches at Enkulal micro-watershed, 2011

Date	Mean Depth, cm	Mean Width, cm	Mean cross-sectional area, cm2	Mean vol. per ditch, m3
17-Jul	19.09	38.28	735.2	**2.30**
1-Aug	17.63	36.35	649.9	**1.99**
16-Aug	16.70	36.38	617.4	**1.89**
30-Aug	16.13	35.88	616.0	**1.76**
9-Sep	14.03	36.63	530.0	**1.61**

Table 5. Mean sediment transport rate per ditch (cm^2/m), 2011

	Rate difference between ditch positions		
Date	[Middle-Top]	[Bottom-Middle]	[Bottom-Top]
17-Jul	0.19	1.33	1.52
1-Aug	0.26	3.31	3.57
16-Aug	0.93	3.39	4.32
30-Aug	1.77	3.82	5.59
9-Sep	3.00	0.59	3.58
Mean	**1.27**	**2.70**	**3.97**



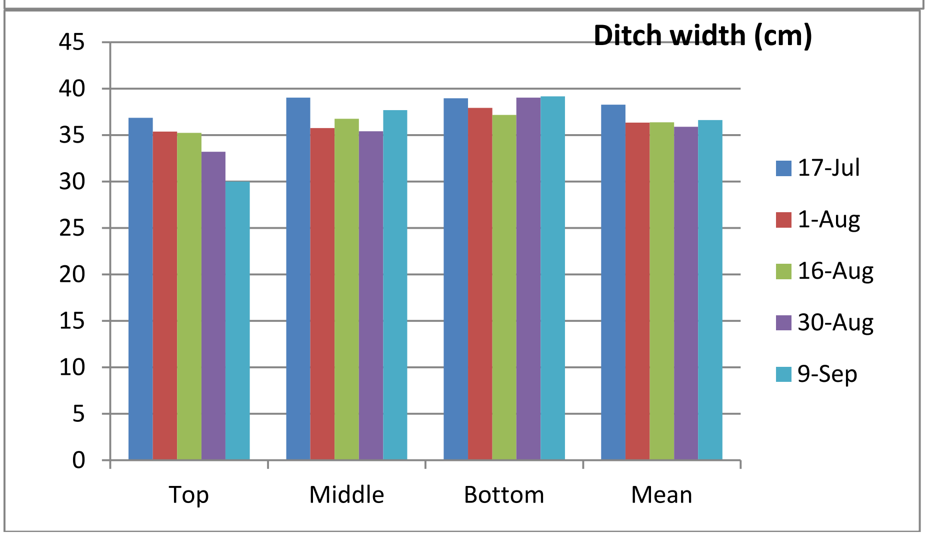


Figure 1. The change in depth and width at upper, middle and lower position along the length of ditch in 2011 rainy season

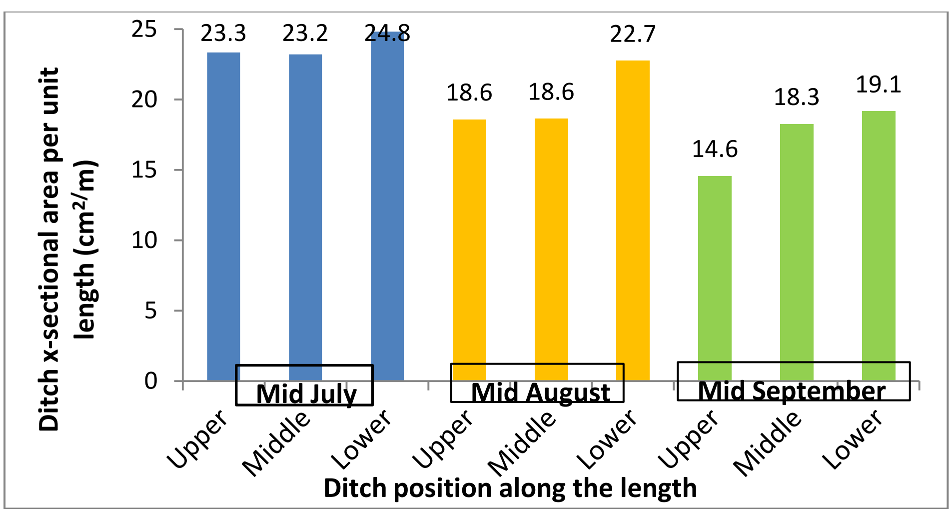


Figure 2. Ditch cross sectional area along the longitudinal section of ditches

Gully development

The gully was formed in the early 1990's (nearly 20 years of age) serving as a waterway for runoff discharged from adjacent farm ditches. The gully is still active and progressively developing. It has more than 378 m length. During the rainy season, bed erosion was more important whereas in the post rainy season collapse of gully side walls was active due to cracking problem. In the rainy season, the bed width was increased over the length of the gully (Fig. 3, 4 and 5). The depth increment has not shown clear trend. This is most likely due to the heavy sediment load that led to accumulation of sediment on spots where there is low gully bed gradient. Though the main cause of the gully erosion is runoff from road, the runoff discharged from farm ditches contributed to fast development of the gully and very dynamic too. The high longitudinal variation of the gully dimension and the dynamic changes (side head cuts) of the gully was as a result of the runoff drainage from farm ditches into the gully (Fig. 4 and photo 3).

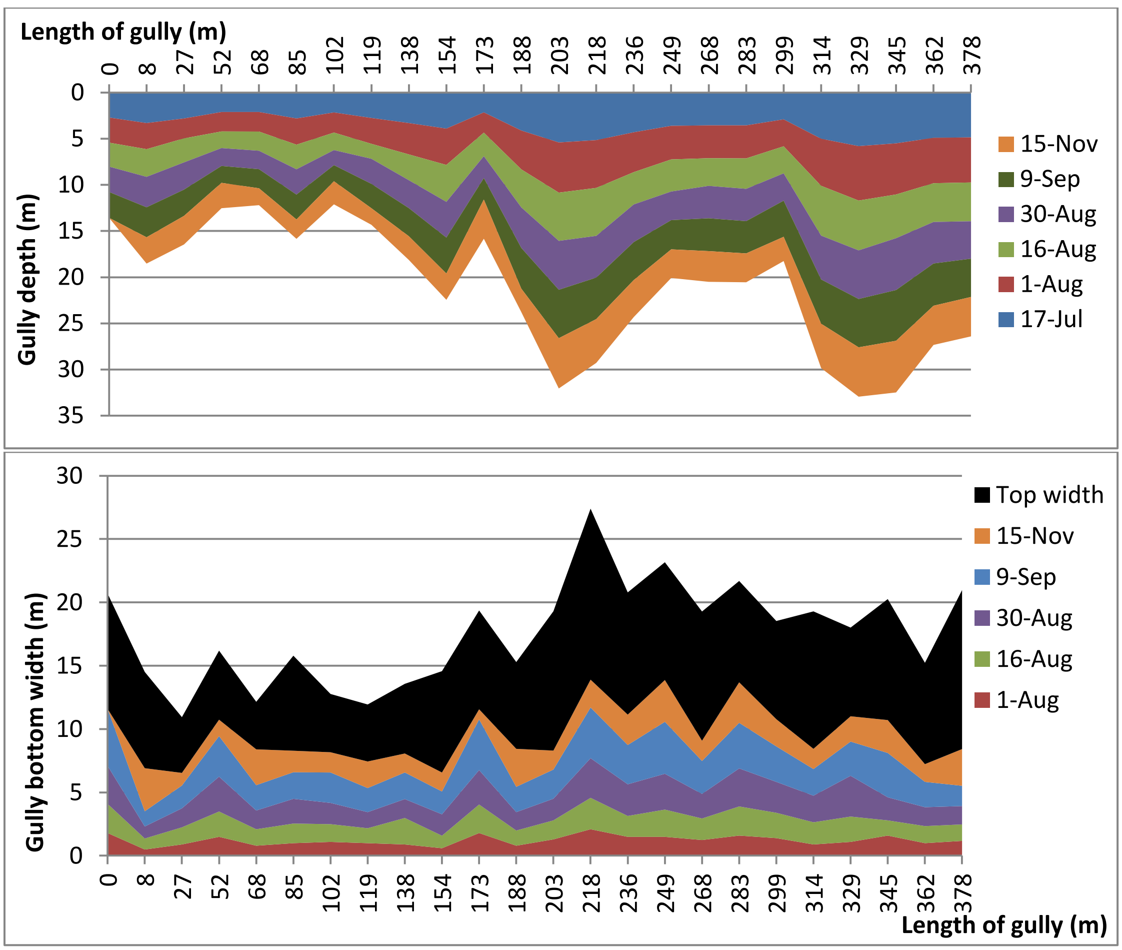


Figure 3. Cumulative development of depth (upper) and width (lower) of gully sections, 2011

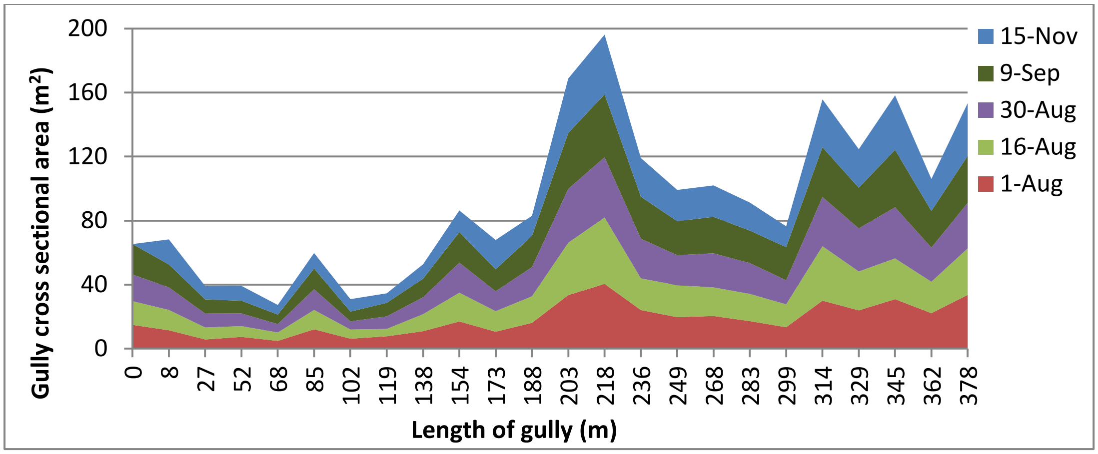
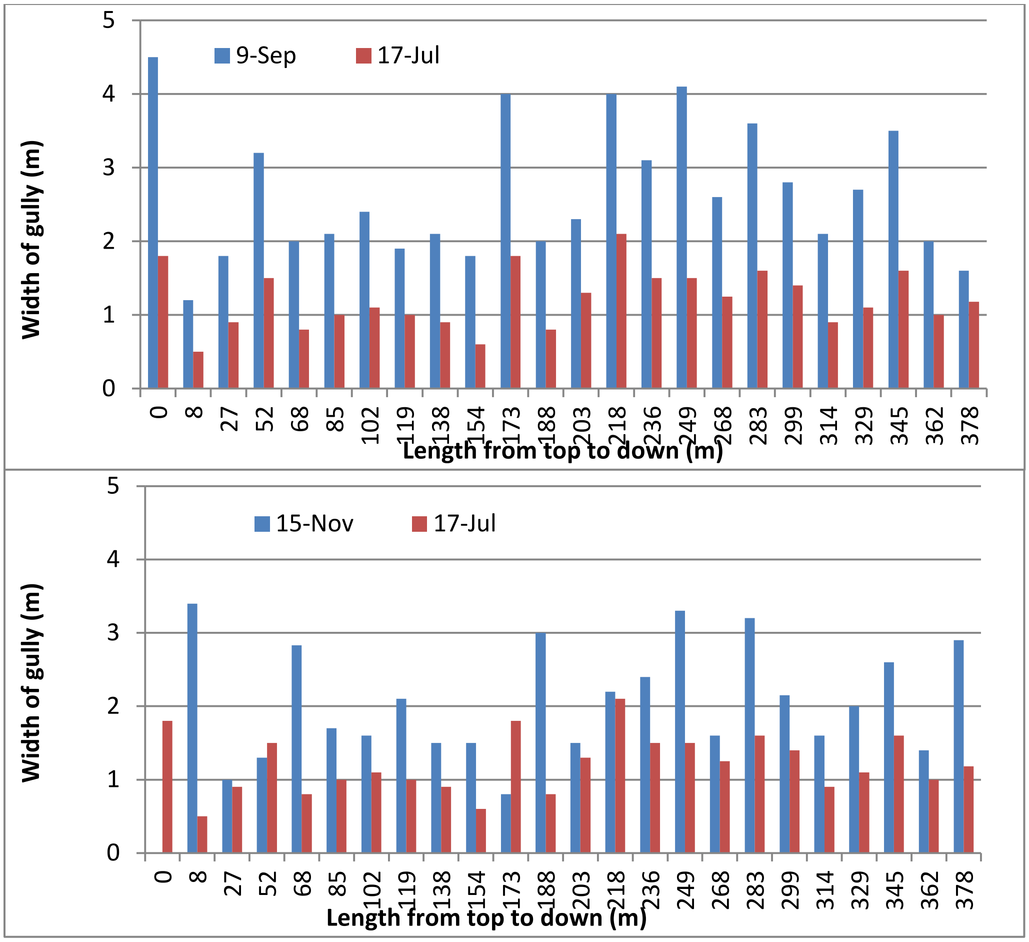


Figure 4. Cross-sectional gully development, 2011


Photo 2. Gully morphology due to runoff from farm drainage ditches


5
4
3
2
1
0
9-Sep
17-Jul
Width of gully (m)
0
8
27
52
68
85
102
119
138
154
173
188
203
218
236
249
268
283
299
314
329
345
362
378
Length from top to down (m)
15-Nov
17-Jul
Width of gully (m)
Length from top to down (m)

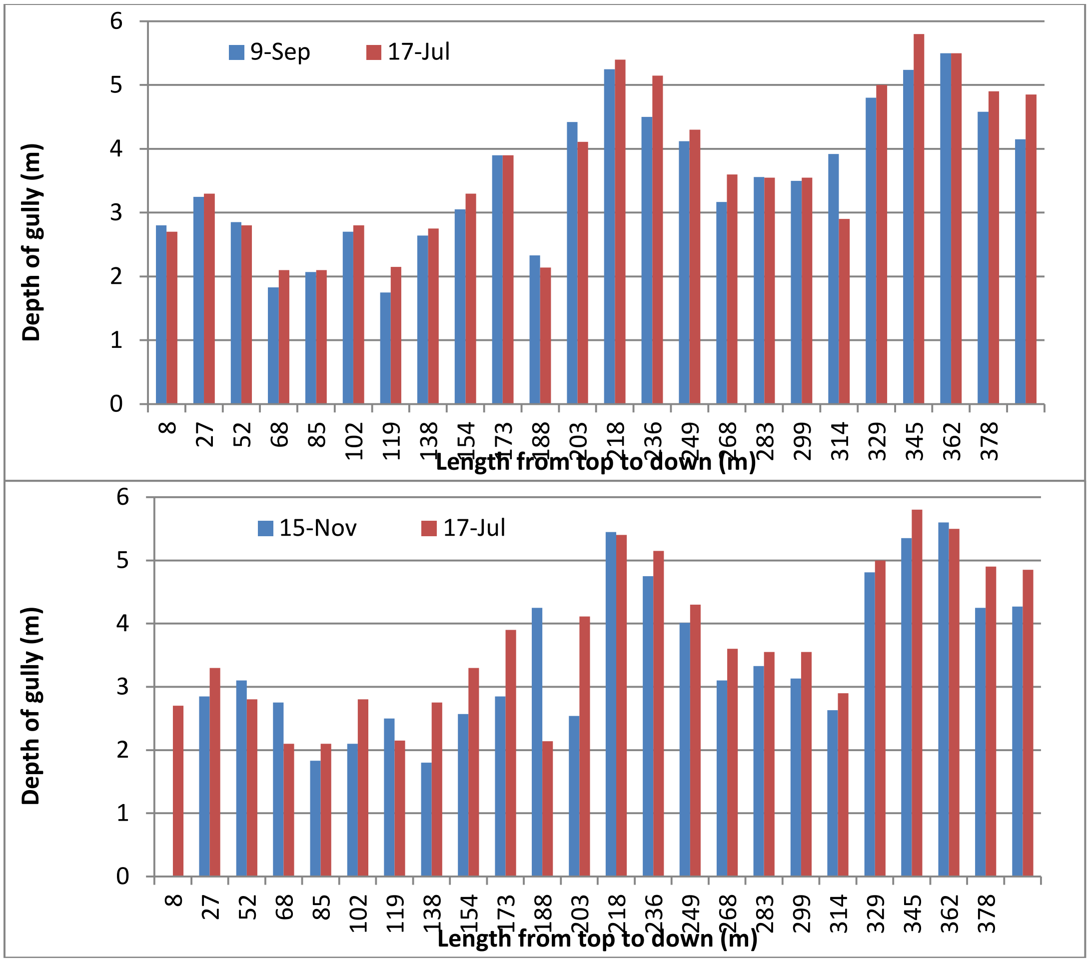


Figure 5. Comparson of periodical development of depth and width of gully, 2011

Assessment of Land Management Practices and Associated Problems

Weekly (sometimes every two weeks) field visits by all participant farmers resulted in the identification of key problems. The groups assessed and evaluated the efficiency of terraces, traditional ditches and crop residues against erosion reduction. They identified the shortcomings of terraces on each farmer plot, damage due to drainage ditches and removal of crop residues. The following were major problems identified and the respective solutions suggested after continous discussions.

Problem 1: Most of the terraces and bunds were damaged and poorly peformed. The most common causes for the damage were lack of adequate maintenance every year, ditches constructed across bunds, and tillage underneath the terrace.

Solution 1: All farmers agreed to maintain terraces or bunds on their plots during dry season. They agreed on the layout and design specifications with 50 cm width, 75 cm lower side height, 15 m maximum terrace spacing on gentle slopes, 20 cm distance of tillage operation on the lower side of terrace, sufficient gradient of bunds for adequate runoff disposal, and trenches on the upper side for traping silts as well to avoid waterlogging problem.

Problem 2: Erosion damage from traditional ditches were identified as associated problem of field drainage ditches.

Solution 2: Reduce the number of ditches per plot or parcel, reduce the ditch gradient so that it becomes non erosive, and avoid ditches that cross terraces/bunds are suggested solutions to control erosion from traditional ditches.

Photo 3: Runoff drainage ditches practiced by farmers

Problem 3: Land users often left none or minimum crop residue over the field. Even the remaining samll amount of crop residue left in the field was extensively open grazed during the dry season. The soil surface then expose to trampling and easily washed by water and wind erosion.

Solution 3: Currently, farmers left approximately 45 cm stubble of wheat and barley after harvest. Participant farmers then engaged in discussion and agreed to increase the hieght of stubble at least by 10 cm for wheat and barley,that increased to 55 cm after harvest. They also evaluated the order of importance of different crop residues for their contribution to the improvement of soil ferility (Table 6).

Table 6. Height of crop stubble of the different crops currently left on the surface after harvest and suggested height improvement agreed by participant farmers,

Crop	Planting season	Tillage frequency	Height of crop stubble left after harvest (cm)	Importance of residue to soil fertility (Rank)	Height of improved crop residue (cm)
Teff	Mid June-July 10 EC	4-5	5	8	10
Wheat	July 8-July 12 EC	5	45	7	50-55
Millet	Rain onset -June 12 EC	1-3	7	6	10-12
Noug	Rain onset -June 13 EC	1	68	5	75
Linseed	Rain onset- June 14 EC	1	7	3	10-12
Barley	June 1-June 15 EC	2-3	45	4	50-55
Potato	March - April	4-5	N/A	2	N/A
Lupin	Aug - Sept	No tillage	37	1	45-50

N/A – Not applicable

Implementation of Improved Practices

The following sections present results obtained through interactive knowledge exchange during regular field visits and discussions carried out by the participants and team of farmers organized for controlling the activities. The procedures have showed change in practices and perception of the participant farmers.

Agreed bylaws

To start with the implementation of proposed solutions that address the observed problems, bylaws and implementation modalities were discussed and arranged to control erosion and soil fertility depletion as well as to protect and monitor the implementation of improved land management practices. Specifications of terrace and ditch construction and height of crop residues left after harvest (Table 7) are determined and strictly implemented during the construction period. Each of the participant farmers had taken the responsibility to respect and implement the agreed bylaws**.** Three member task force elected among the participant farmers was the main controlling body of the agreed bylaws with the support given by the DAs in the Kebele.

Table 7. Agreed specifications of improved terraces, ditches and crop residues

Implemented Activities	Specifications
Terrace construction	
• Max. Spacing (m)	15
• Height (cm)	75
• Top width (cm)	50
• Bottom width (cm)	Variable
• Tillage away from terrace (cm)	20
Ditch construction	
• Ditch count	Decided on field condition
• Ditch length (m)	Maximum 25 m
• Ditch gradient (%)	< 6 %
• Crossing of terraces	Prohibited
Height of crop residues left after harvest (cm)	
• Teff	10
• Wheat and barley	50-55
• Millet and linseed	10-12
• Lupine	45-50
• Niger seed	75

Micro-catchment treatment with terrace/bund construction

Since January 1 2012, the farmers started to implement improved terraces including maintenance of the existing bunds, construct new terraces on plots where there was wide spacing between existing terraces, and construction of waterways beginning from top part of the catchment. A total of 1684 person days (865 male and 819 female) were mobilized for 34 working days. The daily work norm per person was decided by the Kebele. Based on this norm, the development group leaders distributed the total work load to individual work force. The work load per person per 3 effective working hours was 5 m of bund construction. Women and men had given equal work load but implement together with appropriate division of work. Using the total mobilized labor a total of 6290 m (ca. Volume 2562.5 m^3) graded soil bunds (sum of 1300 m stone faced soil bund and 4990 m soil bunds), nearly 180 m narrow waterways, more than 100m cut-off drains and some check dams were constructed. The average dimension of the trench of soil bunds was 43-45 cm depth and 50-52 cm width (ca. volume 1411.5 m^3). The embankment was constructed with top width of 30-35 cm, bottom width of 80-100 cm, and distance between embankment and trench was 30-35 cm (ca. 1151 m^3). All the newly constructed and maintained bunds were covered with susbania and treelucern forage legume species which covers half of the catchment area.

Photo 4. Bunds and waterways constructed in 2011/12

Plantation of shrub cuttings in the gully

The side wall of the gully was planted with cuttings of "*Mogn Enchet*" brought from Chilga woreda. This shrub is new for the area and frequent follow up about its biological characteristics was made for its survival and adaptation. It has a very high biomass and stay green throughout the year. It is very fast propagating shrub species. It can be used not only for gully rehabilitation but also for compost making as it has huge biomass and green throughout the year. More than 1215 cuttings of `*Mogn enchet*` were planted on July 7, 2003 EC (July 14, 2011). Until 9th of September the rate of survival was increasing. After September of the same season, the side walls of gullies started to crack and slide down and resulted in fall of the planted cuttings. Accordingly, the survival rate was decreasing to about 752 plants (average of 62 %) (Fig. 6). Survival was nil on very steep slopes and on highly fragile gully sections which implies the importance of gully shaping on such critical sections.

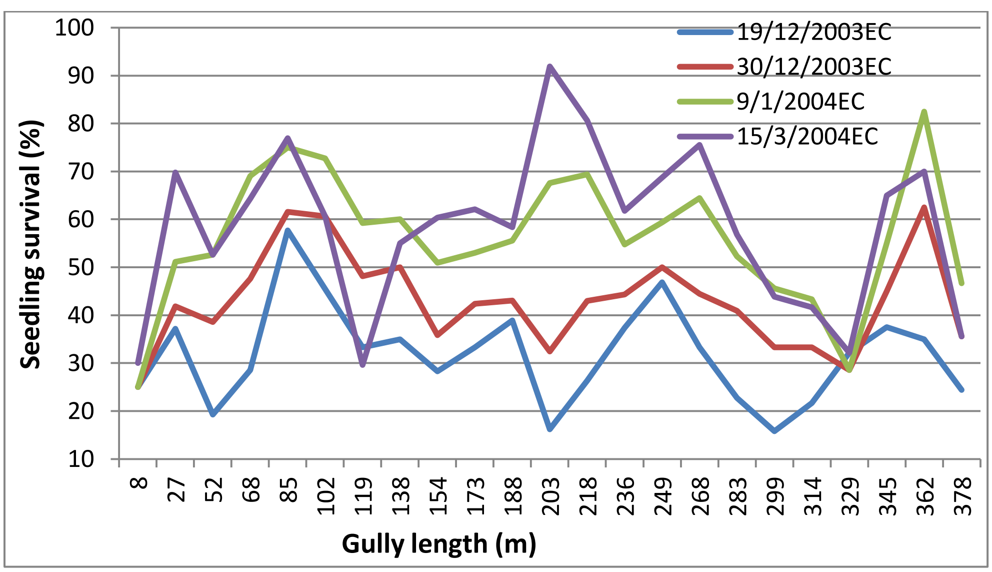


Figure 6. Survival rate of planted cuttings over the season, 2011

Monitoring and Evaluation of Improved Practices

The progress and performance of improved practices as well as the participatory processes were periodically monitored in order to evaluate the effectiveness of knowledge transfer, continuity of the change in improved practices and the collective decision making process. The following sections explain the results of the monitoring activities.

Improvements on ditch practice

Inventory of number of ditches per parcel, ditch gradient and length were monitored every season to evaluate whether the farmers respect the agreed bylaws. After one rainy season, i.e. in 2012 most of the farmers respect the ditch specification and reduced significant number of ditches per parcel (Fig. 7). The baseline data collected in 2011 indicates that the total number of ditches was about 256 (average of 10.7 ditches per parcel) of which 77% contributed from teff fields. After one rainy season in 2012, the total number of ditches was reduced to about 74 (average of 2.4 ditches per parcel). About 53 ditches (72%) recorded from plots covered with teff crop. However, the number of ditches again increased to 263 in 2013, of which 95% of the ditches were constructed on teff plots. More than 52%, 23% and 58% of the parcels were planted with teff in 2011, 2012 and 2013 respectively. Therefore, the reason for increased number of ditches is often associated with increase in the area coverage of teff. But most of the farmers who experience to construct many ditches significantly reduce the number of ditches. This of course needs continuous follow up and discussion with farmers why some farmers still construct ditches within the terraced fields. Except on few plots, significant number of farmers improved ditch gradient below 6%. None of the farmers construct ditches crossing bunds.

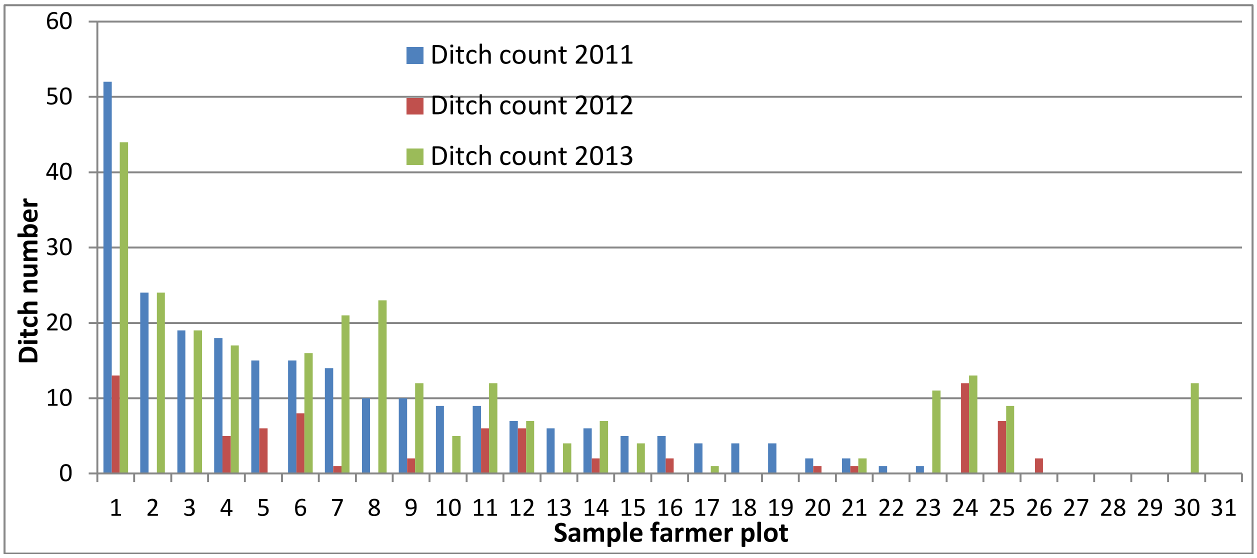


Figure 7. Comparison of number of ditches recorded in 2011, 2012 and 2013

Protecting terraces from damage

All the newly constructed terraces were found in good condition both in terms of stabilized embankment and the drainage ditches. Out of total parcels monitored, 45.5% (total of 42 terraces) are found in better condition. However, 51% (total of 61 terraces) of the parcels did not respect the agreed tillage distance, 20cm away from the upper and lower side of terraces (27% till upper side and 24% till both sides). The trenches/ditches of newly constructed and maintained terraces have still sufficient capacity to drain excess runoff, not completely filled with sediment. Maintenance of terraces for the previously constructed terraces and waterways were carried out by individual farmers instead of using collective action.

Improved crop residue management

Farmers were agreed to harvest wheat and barley 10 cm more than the usual harvesting height. In 2012, only one farmer planted wheat. Data on harvest height and biomass was collected from two sample plots: control plot harvested with usual height and experimental plot harvested with agreed height. Crop residue harvest samples from equal unknown plot area were taken from both plots. Measurement of three sub-samples of harvest indicated that approximately 7-14.5 cm average height (equivalent to 8.5 g biomass) and 21-30 cm average height of crop residue (equivalent to 16.6 g biomass) were found for control and experimental plot respectively. It implies that additional 8 g biomass was left over the field which in turn contribute to at least organic matter increase to the soil.

Controlling free grazing

All the newly constructed terraces were planted with legume species. However, the farmers did not able to regulate free grazing. Almost all planted forage species are eaten and damaged by livestock including the Napier and other species planted inside the gully. This was a serious issue not only for the study site but also for the whole terraces in the cultivated areas of the watershed.

Collective monitoring and follow up of the elected task force

The main objective of the study was to increase farmers' capacity towards self evaluation and for collective decision and actions and ultimately empowered themselves. Although they got a lot of experience and exchange of knowledge among each other during the process in the two year period, they now tend to decrease their motivation and discussion in group about common implementation activities like controlling free grazing and gully maintenance. In 2013, some farmers were also increased the number of ditches per plot compared to the number of ditches recorded in the second year, 2012. Indeed, at individual level, some farmers changed their usual practices like harvesting crops at height above the usual harvesting height for some crops like wheat in order to increase soil organic matter or reduce soil depletion.

Views of selected farmers on the farmer participatory decision making processes

Twelve randomly selected participant farmers were interviewed by an independent interviewer about their view on the farmer-expert joint learning process and their attitudinal changes on the soil erosion processes and soil conservation practices. The views of some of the participants were extracted and presented as follows:

1. *"Initially, I do not trust and accept the way of learning because I felt it is what we knew. Now we learned good lessons and new practices. I learned how much the ditches damage or wash away our soil"* said by ***Fentie Mandie (male)***

2. *"I learned that our tillage operation has damaged the terraces and should be made somehow away from upper and lower side of the terraces"* said by ***Dires Tebabal (male)***

3. *"Previously many are not interested to construct terraces on their land, this time we have learned its importance. I learned to avoid diverting runoff from ditches to adjacent land. We managed to protect communal lands and pathways together. I was happy that both men and women have made equal contribution"* said by ***Birkie Zewdie (Female)***

4. *"The participatory process gave me an opportunity to know and capable to control rills, loss of seeds and fertilizer by erosion, negotiate and mange conflicts raised among adjacent farm owners, aware of damage due to livestock trampling. I learned a lot that helps to apply on my own land. But i expected mills, water wells, more improved seeds and training" said by* ***Lakew Mesel (male)***

5. *"The group visit and dialogue helps individuals to share common responsibility. I understood that seeing is believing. I learned lupine improves soil fertility. Now, I give attention to my plot and the soil" said by* ***Aragaw Muche (male)***

6. *"In the beginning, I was not actively participating. But after some time I learned that improved terrace construction is interesting because our land is protected from erosion. However, I fear that there is no land left for our animals use for pasture" said by* ***Manhal Ewnetu (female)***

7. *"In the beginning I was reluctant to participate. Now I learned how to protect my land from damage and learn how to make decisions in common. Taking lessons from our discussion I will protect terraces from animal damage and now I feel responsibility to protect" said by* ***Marie Yimam (female)***

Incentive Mechanisms

For the purpose of motivating farmers to actively participate in the continuous implementation and monitoring activities, improved sweet lupine seeds (approximately 0.5 kg) were distributed to the participant farmers and recommended to plant on bunds, along the ridges of ditches and open lands for purpose of improving land and feed sources. In addition, about 5kg lupine seeds were provided for seed multiplication at FTC sites. They were also advised to select one or two sheep and feed them and further disseminate seeds to other farmers. Improved crop varieties were also offered. Teff (Kuncho variety) and potato (Belete variety) were distributed to 15 farmers and 1 farmer respectively. Technical support was also provided on compost preparation, and construction of terrace and waterways.

Conclusion and Recommendations

If land degradation processes and problems are to be understood and effective land management practices planned, local contexts that govern decision making need to be considered. As context is so diverse from place to place and time to time, local understanding can provide insights into the contextual issues. Therefore, in order to sustain appropriate land management practices, farmers must involve and acquire capacity to respond to these local changing situations. Drawing on this concept, the participatory learning and collective decision making process can be conceptualized as the interaction and integration of biophysical dimensions with the human dimensions. This interaction determines the limits within which sustainable land management practices are physically possible, viable, and socially acceptable.

It is evident that in the process of participation and interactive exercises among farmers with the facilitation of experts, participant farmers build capacity, understood and aware of less visible and seasonal/ short-term erosion indicators which can be used as early warning erosion indicators and as monitoring tools. Use of combination of erosion indicators, for example ditch erosion and low harvest height of crop residues in this case study, is a useful means of gaining an overall impression of the land degradation situation and limitations of soil conservation technologies, as well as the adaptation conditions of sustainable technologies.

In many instances, participants developed awareness that they gained a more holistic understanding of the negative impact of their land management practices and specific erosion processes. They also realized the importance of working together (interactive knowledge) towards a common goal. In fact, it was observed that building common understanding for action and more effective knowledge systems for sustainability takes time and patience, and need continuous engagement. Unless care has to be taken on the continuous motivation and facilitation, the changes gained at one time may be reverting back. A good example observed in this study was the extreme reduction of farm drainage ditches during the initial learning stage and increasing again when the engagement of facilitators reduced.

The participatory learning approach applied in the current study supported to monitor and quantify evidences on the positive and negative effects of existing land management practices, build capacity of farmers through knowledge sharing procedures, and improve practices and collective actions and decision making. It helps to motivate and engage those innovative farmers to practice the knowledge and skill gained during the interactive learning, gradually others will follow them. This approach eventually builds self-confidence, enhances capacity of the farmers, and reduces the burden of development agents. It is therefore recommended to test and apply this approach, i.e., the land user participatory learning approach/method for collective decision making, in other watersheds where community mobilization based soil and water conservation works.

Acknowledgment

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Evaluation of in-situ moisture conservation techniques on sorghum (*sorghum bicolor L.*) Production at dry low lands of Wag Himra, Ethiopia

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Abstract

The dry land areas of Ethiopia accounts for more than 66.6% of the total land mass. In this semi-arid region, the amount of rainfall is usually inadequate, erratic in distribution, short in duration and variable. Consequently, moisture availability is the most limiting factor for rain fed crop production. In response to solve moisture deficit problems for sorghum production, a field experiments was conducted to evaluate different in situ rain water harvesting techniques on growth and yields of sorghum at low lands of Wag-Himira. Tie ridge, contour soil bund, trapezoidal soil bund, zai-pit with manure evaluated against the conventional tillage were evaluated for two years. In situ rain water harvesting techniques have shown a significant (p<0.05) effect on both grain and biomass yields. Moreover, tie ridge provided the highest and significant(p<0.05) grain and biomass yield advantage over other in situ rain water harvesting structures at Zequala in 2009 cropping season. However, in 2010, the in-situ moisture harvesting techniques did not show significant (P<0.05) yield advantage over the farmers conventional practice at Zequala due to occurrence of early rainfall, while significant (p<0.05) yield advantage over the conventional practices was obtained at Abergelle. The findings indicated that tie ridge and contour soil bund increased grain and biomass yields in dry lands areas of Wag Himra. Considering partial budget analysis tie ridge gave net benefits of about 10365 Birr/ha which is acceptable. Therefore, tie ridge is recommended as a best insitu moisture harvesting technique for Wag-Himra area and similar agro-ecologies.

Key words: Dry land areas, in situ rain water harvesting, moisture availability, sorghum

Introduction

The dry land areas of Ethiopia accounts for more than 66.6% of the total land mass ranging from arid with <45 days of LGP to sub moist zone with LGP of 60-120 days (Kidane *et al*., 2001). The semi-arid areas are characterized by low annual rainfall concentrated to one or two short rainy seasons. The average annual rainfall varies from 400 to 600 mm in the semi-arid zone, and ranges between 200 and 1000 mm from the dry semi-arid to the dry sub humid zone (Rockstrom, 2000). The length of the growing period ranges from 75 to 120 and 121–179 days in the semi-arid zone and dry sub-humid zone respectively. Potential evaporation levels are high, ranging from 5 to 8 mm/day (FAO, 1986) giving a cumulative evapo-transpiration of 600–900 mm over the growing period. The amount of rainfall is usually inadequate, erratic in distribution, short in duration and variable. Consequently, moisture availability is the most limiting factor for rain fed crop production in the dry lowland areas. Rain fed agriculture has failed to provide the food requirement for the rapidly increasing population of the country. Although the reason for this are complex, the primary constraint in the semi arid areas is lack of suitable technology for soil and water management and crop production under relatively low and erratic rain fall situation (Reddy and Kidane, 1993). In regions where crops production are entirely rain fed, reduction of 50% in the seasonal rain fall may result in total crop failure, however, the available rainfall can be concentrated on small area, and reasonable yield still will be received. (Critchley, 1991).
Dry land crop production is critically dependent on the amount of water availability during the crop-growing season. It is believed that substantial increase of crop yield can be achieved through proper water conservation and management practice. Efficient use of available water by plants has also an impact on other crop management practices such as the use of fertilizer application in dry areas which is low compared to the area with optimum soil moisture conditions.

As land pressure increase, more and more marginal areas are used for agriculture. Much of this land is located in the arid and semi arid belts where the rainfall is irregular and much of the rain is quickly lost as surface run off. Recent droughts have clearly indicate the risk to human beings and livestock, which caused mainly by the failure or shortage of rainfall.

Therefore, the objective of this study was to evaluate and select effective and feasible in situ soil moisture harvesting technologies for moisture stress areas of Wag Himra.

Materials and Methods

Description of the study area

The field experiments was conducted in semi-arid areas of Zequala and Abergelle Woredas in Wag Himra Administrative zone, located about 65 and 55 km away from the capital of the administrative zone, Sekota town, respectively. Figure 1 shows the location of the trail sites in reference to Amhara region and Wag Himra Administrative zone. The study sites were characterized with gentle slope, uniform or even topography, and the soils suitable for agriculture were selected; clay loam and silt loam soils for Zequala and Abergelle trial sites, respectively.

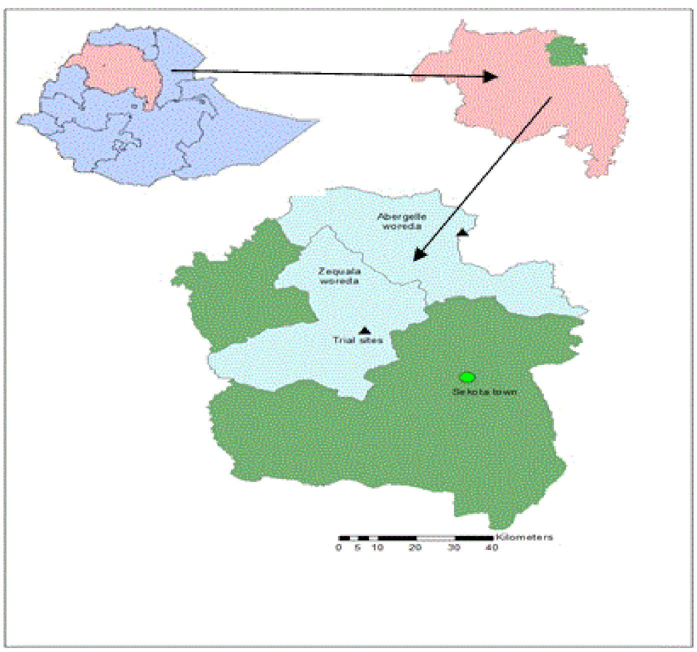

Figure 1. Location map of the trial sites

The rainfall distribution of the study areas is characterized by short, erratic and variable across different growing season. Based on the 10 years metrological data collected from the nearby metrological stations, the annual rainfall of Zequala ranges from 180 to 650 mm, with annual average rainfall of the area about 370 mm. Similarly, it ranged from 150 mm to 560 mm for

Abergelle with annual average rainfall of about 310 mm. Besides to this, the rainfall in these areas mostly starts lately around end of July and ceases then earlier around end of August. The rainfall usually stops during a critical (flowering) stage of major crops, and the availability of low moisture content in the soil during this stage is a limitation factor for crop production in the study areas.

The treatments were control (without any moisture harvesting techniques), contour soil bund, trapezoidal soil bund, zai pits with manure and tie ridges. The treatments were arranged in RCBD with three replications. The construction of the techniques described by Critchley (1991) was used for the study with some modification to fit the experimental sites. The dimension area for one treatment was 17 m*7 m and the distance between plots and blocks were 1 m and 1.5 m, respectively. Diversion ditch was constructed to divert inflow of runoff from the up slope.

Description and design specification in-situ moisture rainwater harvesting structures

1. **Contour soil bund**: is used to hold flowing surface run off, through the area in to surrounding space of two adjacent bunds. The bunds were constructed at a horizontal spacing of 3.5m with 35 cm minimum height of a bund. Moreover, the base width of the bund was fixed at 75 cm with a 6m distance between ties in the bund.

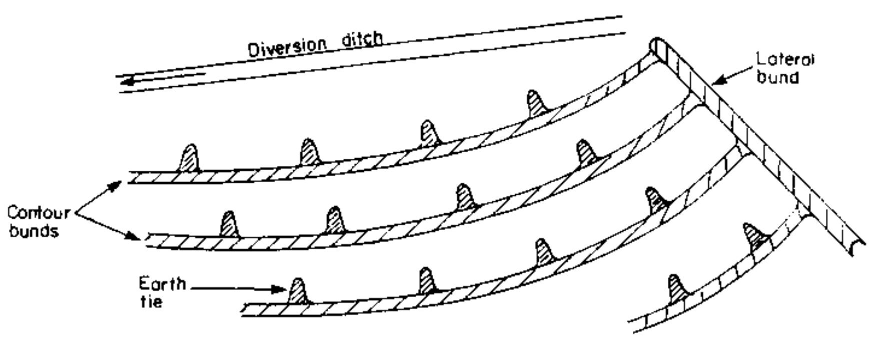

Figure 2. Field Layout and cross sectional view of contour soil bund

1. **Trapezoidal soil bund:** is used to enclose and to impound run off, which is harvested from rainfall in the area. Crops were planted with the enclosed area and external area to fill the plot size. The trapezoidal bund was constructed with a base length of 3m, angle between a base and side bund of 135°, with a minimum and maximum bund height of 0.2

and 0.6 m, respectively. The bund had a 1:1 side slope with 1.8 m and 0.6 m top and base width, respectively.

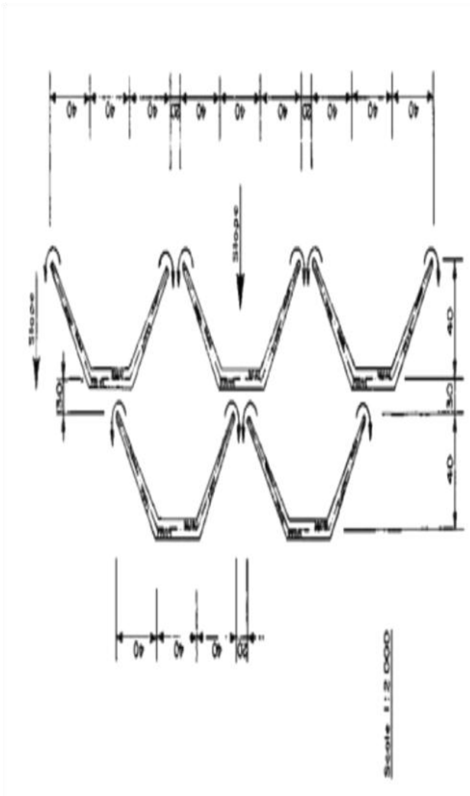

Figure 3. Field layout and typical dimensions of trapezoidal bund

2. **Zai- pit with manure**: the pits concentrate local run off coming from the nearby area. The pits had a dimension of 30 cm in diameter and constructed at a spacing of 1m and 50 cm between pit lines and between pits centre to centre distance, respectively.

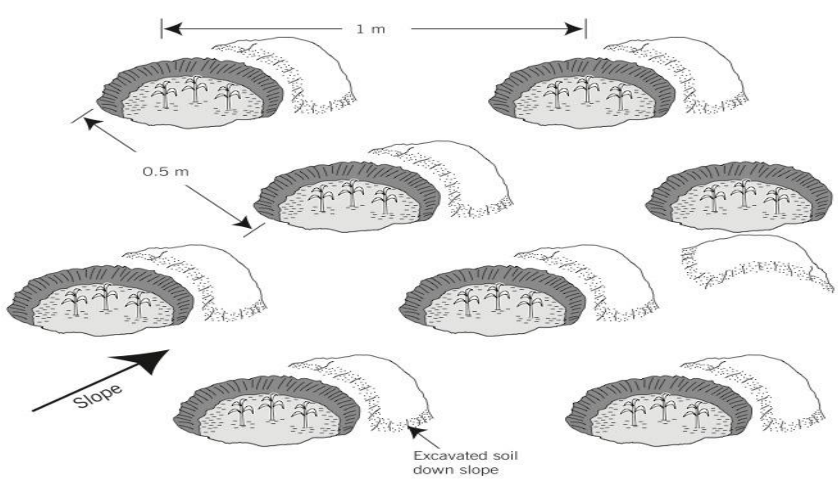

Figure 4. Field layout and cross sectional view of contour soil bund

3. **Tie-ridge:** ridges follow the contour at spacing 75 cm. Runoff was collected from the uncultivated strip between ridges or in the furrow tie at 2-3 m interval. The ridge was constructed with 30 cm height, and sorghum was planted on the ridges.

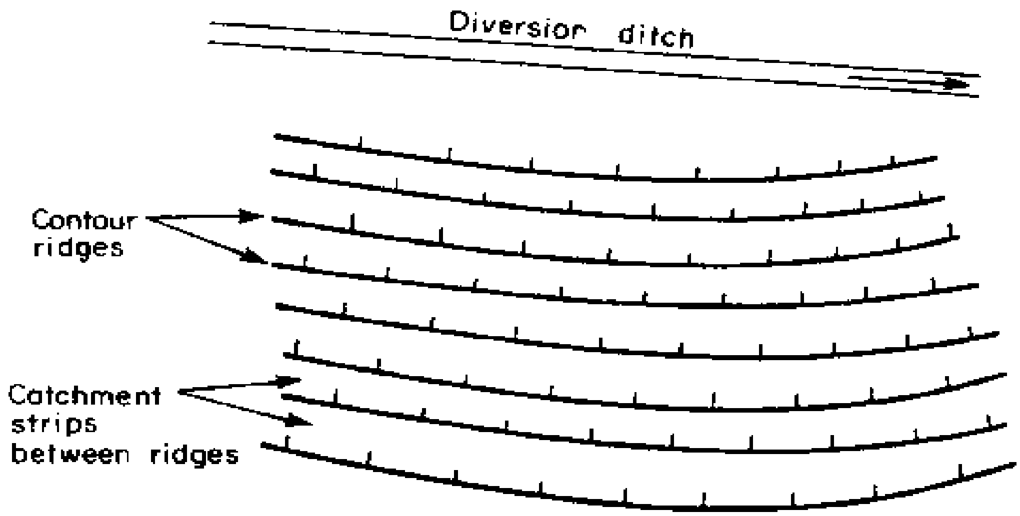

Figure 5. Field Layout and cross sectional view of contour soil bund

Agronomic Practices

Sorghum (*Sorghum bicolor*) was used as a test crop which is dominantly growing and staple food in the area. It has area coverage of around 15,200 ha in the zone, and took up 22.3 % of the grain production (CSA, 2009). Improved sorghum varieties Amsale and Abshir were used during the first and second year, respectively as an indicator crop to test the efficiency of the techniques. 100 DAP Kg and 50 Kg urea were used and applied to each treatment equally except zai pit which was applied with compost. All DAP was applied during planting and urea was applied in split half at planting and half after 35 days after planting. The fields were ploughed three times and sowing was done in the first week of July in both locations. Weeds were monitored and removed by hand three times.

Data collection and analysis

Data on grain yield and fresh stalk biomass were taken from all plants except two border rows in the plot. Plants height was measured by taking 10 randomly selected sorghum plants from each plot. Analysis of variance (ANOVA) was conducted in dependently for the two years and locations using SAS statistical software system for windows V8. For the purpose of cost benefit analysis, the grain and biomass yield of sorghum were adjusted down by 10% to minimize the plot management effect or to reflect actual farm level performance. We considered 5 Ethiopian Birr (ETB) as an average market price of one Kg of sorghum grain and 0.05 ETB for biomass at Sekota. Using the current prices in the season, the price of 100Kg UREA and DAP was taken 1165 and 875 ETB, respectively. The cost of labor was done by the standard work norm developed by World Food Program (WFP). Accordingly, 20 ETB was taken for one person per day.

Results and discussions

As presented in Appendix Table 1, in 2009, the analysis of variance showed that sorghum performance using in-situ moisture harvesting structures was significantly different ($p<0.05$) from framers' conventional practice. Tie ridge gave the highest and highly significant grain yield and biomass of 2301.81 and 7647 kg ha^{-1} respectively compared with other in-situ moisture harvesting structures. The farmers conventional practice (control plot) gave the least fresh biomass (2400 kg/ha) and no grain yield. Contour soil bund and trapezoidal soil bund were not statistically significantly different to each other in grain yield of sorghum. Moreover, contour soil bund didn’t show statistically significant biomass yield difference compared with zai pits with manure and trapezoidal bund on fresh biomass. However, zai pits with manure have significant yield advantage over the contour soil bund (about 690 kg/ha) and trapezoidal bund (about 490 kg/ha). Tie ridge has 155.4%, 108.8% and 44.8% yield advantage over contour soil bund, trapezoidal bund and zai pits with manure, respectively. The high level of yield difference between in-situ moisture harvesting techniques (200-1400 kg/ha) revealed that the interaction of the different structural designs and configuration or layouts of the techniques with the soil physical properties and the amount of rain fall during a growing period for that particular cropping season. During this cropping season, the amount of rainfall falling in the study area was too low, about 260 mm per annum, which was below the minimum seasonal water demand of sorghum, which ranges from 450 to 650 mm (FAO, 1986). However, the major benefit of in-situ moisture practices is to store water with the soil which will later be used by the crop during a stress time at critical growing stages. In addition to this, as described in the previous section, the experiment was conducted in clay loam soil which has a higher water holding capacity which has also a significant contribution for increasing the water available to the plants during a stress period. The advantages of moisture conservation practices on both grain and biomass yield on clay loam textured soil during a low rainfall season was therefore clearly seen in this experiment.

The result is in line with the findings of Kidane *et al.* (2001), who reported substantial yield increment ranging from 50% to 100% compared with the traditional practices for the crops (sorghum, maize, wheat and Mung been) grown using tie ridges and planted on flat seedbed at dry land areas. This finding is also in accordance with the results of Heluf (2003) and Mudalagiriyappa *et al*. (2012). Likewise, Tekle (2014), reported that grain yield of pearl millet was significantly influenced by moisture conservation practices. This might be due to the hypothesis that the conservation of moisture has been known to help in photosynthesis, fertilization of flowers, seed setting, protein synthesis and nitrogen metabolism thus improving the crop yields (Sakthivel *et al*., 2003).

In 2010, the response of the in-situ moisture harvesting structures in terms of sorghum grain yield and biomass at Zequala experimental site was different from the response obtained in 2009 (Appendix Table 2) due to the occurrence of high rainfall during the growing period, especially at germination period. Higher amount of rainfall was observed during this cropping season, amounting to 650 mm, which was the optimum and ideal water amount required for sorghum production. The farmers' conventional practice has therefore shown statistically significant grain and biomass yield difference with zai pits with manure and tie ridge. On the other hand, the grain and biomass yield response of contour soil bund and trapezoidal were not significantly different from farmers' conventional practices. Both contour and trapezoidal bunds have produced about 580 and 440 kg ha^{-1} more grain yield than zai pit, and 740 and 600 kg ha^{-1} than tie-ridges, respectively. The occurrence of high rainfall during germination resulted in yield response of treatments contrary to the response obtained in 2009. However, plant height did not show significant difference among the moisture harvesting structures which implies the influence of the early rainfall was not directly on plant height reduction rather on the stalk biomass per plant and grain weight per head.

During 2010, even though there was no significant difference among the structures, tie ridge provided relatively lower yield compared to the control. The crop under in-situ moisture harvesting structures showed deficiency symptoms to nitrogen i.e. yellowing of older leaves from the mid rib to the margin and stunned growth which in turn resulted in low grain and biomass yields. This might be attributed to the high rainfall during germination which in turn resulted in water logging which caused yield reduction. In addition, the soil of the study area had high clay content and low infiltration rate (5 - 6.35 mm/hr), and was vulnerable to water logging during this cropping season thus resulted in low yield. The result clearly showed that the tie ridge and zai pit were significantly affected by water logging problem.

Water logging is considered to be one of the major problems in crop production, affecting an estimated 12% of the global cultivated area (Li 1997). Previous studies had also reported negative effects of water- logging on crop yields. For example, increasing durations of water logging decreased maize yield (Yang and Chen 1998; Li *et al*. 2001). Similarly, Bhan (1977); Dickin and Wright (2008), observed in their studies that water- logging decreased crop yield. Water-logging significantly affects plant morphology, decreasing cell permeability (Patwardhan *et al*., 1988). The most unpleasant consequence of the water logging is hypoxia i.e. shortage of oxygen or anoxia i.e. total lack of oxygen in the soil medium which causes the reduced growth, inhibits the metabolic processes and finally reduces the yield of the wheat. The field experiment conducted at Zequala during the two cropping seasons revealed that in-situ moisture conservation structures have shown variable responses under low and high rainfall occurrence during the early stage of the growing season. This implies that the structures have different adaptation conditions.

Appendix Table 3 presents grain and biomass yield of sorghum in 2010 cropping season at Abergelle. The performance of sorghum was less by half than the performance obtained at Zequala due to location, soil type and difference in rain fall distribution of the area. Contour soil bund gave highly significant grain and biomass yields compared with other in-situ moisture harvesting structures. Tie- ridge, zai pits and trapezoidal bund have no significant difference to each other, but they have shown significant yield and biomass increment over the control. The amount of rainfall recorded during the 2010 cropping season at Abergelle was moderate, about 450 mm. However, as the experiment was conducted in silt loam soil which has a relatively high infiltration rate (10 - 12.7mm/hr), the grain and biomass yields of the crop were not affected by water logging.

Partial budget analysis is indicated in Appendix Table 5. At Zequala (2009) and Abergelle (2010) the partial budget analysis revealed that tie ridge gave the highest net benefit of 10364.71

ETB/ha and 1077.39 ETB/ha, respectively) with an acceptable marginal rate of return (MRR). The partial budget analysis for Zequala in 2010 showed that the net benefits of the new technologies were low, but the cost increase due to high rainfall during the early growing stage.

Conclusion and recommendation

The two years on farm evaluation experiment results indicated that among the evaluated in situ moisture harvesting structures tie ridge with spacing of 75 cm was effective and soil bund with 3.5 m horizontal spacing for gentle slopes were found to be suitable in the in the dry of Wag-Himra areas (study areas) and similar agro ecologies. The tie ridge also gave the highest net benefit in both locations with acceptable marginal rate of return (MRR). The results of the experiment also indicated that the efficiency of the moisture conservation practices varied based on the rainfall distribution and soil types. During a low rainfall season, the construction of in-situ moisture practices has paramount advantage with a significant yield increment especially in soils with high clay content. However, during a high rainfall season, there was a reverse response that there was a reduction of both grain and biomass yield of sorghum due to water logging.

To improve the efficiency of in-situ moisture harvesting structures, it needs on time sowing, safe disposal of excess water from the field whenever it occurs and maintenance of structures and altering the furrow and ridge based on the rain fall distribution. As a recommendation, further research need to be done regarding the tying time of the tie ridge and on safe disposal of excess water.

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Appendices:

Appendix Table 1: Mean grain yield and biomass of sorghum in year2009 at Zequala

Treatment	Grain yield(kg/ha)	Biomass yield (kg/ha)
Control	0.00d	2400.5d
Contur soil bund	901.2c	4530.5bc
Trapizoidal soil bund	1102.5c	5045.0b
Zai pit with manure	1589.3b	3884.7c
Tie-ridge	2301.8a	7647.8a
Mean	1356.91	4701.7
CV(%)	15.22	11.43
LSD (0.05)	388.92	1011.5

Appendix Table2: Plant heights, grain and biomass of sorghum in year2010 at Zequala

Treatment	Plant height (meter)	Grain yield (kg/ha)	Biomass yield (kg/ha)
Control	1.43a	1749.1a	5414.6ab
Contur soil bund	1.31a	1599.9a	4761.3bc
Trapizoidal soil bund	1.46a	1462.0a	5991.3a
Zai pit with manure	1.36a	1019.2b	3699.2c
Tie-ridge	1.43a	860.3b	3968.5c
Mean	1.40	1338.2	4767.0
CV(%)	6.26	11.82	11.97
LSD (0.05)	0.16	297.87	1074

Appendix Table3: Plant heights, grain and biomass of sorghum in 2010 at Abergelle

Treatment	Plant height (meter)	Grain yield (kg/ha)	Biomass yield (kg/ha)
Control	1.20a	302.43c	1855.6c
Contour soil bund	1.36a	1082.85a	5218.5a
Trapizoidal soil bund	1.26a	454.06b	2818.2bc
Zai pit with manure	1.12a	537.00b	3609.2b
Tie-ridge	1.24a	567.23b	3511.2b
Mean	1.24	588.71	3402.6
CV (%)	6.64	11.27	15.31
LSD (0.05)	0.155	124.97	980.9

Appendix Table 4: Computation of costs

Cost that varies	Treatment	Calculation	Total
Labor cost for constructing structure	Control		-
	Contour soil bund	250Pd/ha*20birr/pd	5000
	Trapezoidal bund	300pd/ha*20birrr/Pd	6000
	Zai pit with compost	29629pit/50pit/PD*20 birr/PD	11851
	Tie ridge	20PD*20birr	400
Fertilizer cost(DAP and urea)	Control	1Dap*1165+ 0.5urea*875	1602.5
	Contour soil bund	1Dap*1165+ 0.5urea*875	1602.5
	Trapezoidal bund	1Dap*1165+ 0.5urea*875	1602.5
	Zai pit with compost	-	-
	Tie ridge	1Dap*1165+ 0.5urea*875	1602.5
Compost cost	Zai peat with manure	10PD preparation*20 birr + 10PD for transportation*20 birr	400
Labor cost for maintaining structure	Control	-	
	Contour soil bund	60PD/ha*20birr/day	1200
	Trapezoidal bund	75pd/ha*20birr/pd/day	1500
	Zai pit with compost	125pd/ha*20birr/pd/day	2500
	Tie ridge	20pd/ha*20birr/pd/day	400

Appendix Table 5: Partial budget analysis

	Treatments				
	Control	Contour soil bund	Trapezoidal bund	Zai pit with compost	Tie ridge
Average grain yield 2009 at Zequala(kg/ha)	-	901.20	1102.50	1589.30	2301.81
Average grain yield 2010 at Zequala (kg/ha)	1749.10	1599.90	1462.00	1019.20	860.30
Average grain yield 2010 at Abergelle (kg/ha)	302.43	1082.85	454.06	537.00	567.23
Adjusted grain yield 2009 at Zequala(kg/ha)	-	811.08	992.25	1430.37	2071.63
Adjusted grain yield 2010 at Zequala (kg/ha)	1574.19	1439.91	1315.8	917.28	774.27
Adjusted grain yield 2010 at Abergelle (kg/ha)	272.187	974.565	408.65	483.30	510.51
Average biomass yield 2009 at Zequala(kg/ha)	2400.50	4530.50	5045.00	3884.70	7647.80
Average biomass yield 2010 at Zequala (kg/ha)	3665.50	3161.4	4529.30	2680.00	3108.20
Average biomass yield 2010 at Abergelle (kg/ha)	1553.17	4135.65	2364.14	3072.20	2943.97
Adjusted biomass yield 2009 at Zequala(kg/ha)	2160.45	4077.45	4540.5	3496.23	6883.02
Adjusted biomass yield 2010 at Zequala (kg/ha)	3298.95	2845.26	4076.37	2412.00	2797.38
Adjusted biomass yield 2010 at Abergelle (kg/ha)	1397.85	3722.08	2127.73	2764.98	2649.57
Gross field benefit (ETB/ha)2009 at Zequala	756.16	5482.51	6550.43	8375.53	12767.21
Gross field benefit (ETB/ha)2010 at Zequala	9025.58	8195.39	8005.73	5430.60	4850.43
Gross field benefit (ETB /ha)2010 at Abergelle	1850.18	6175.55	2787.98	3384.24	3479.89
Labor cost(ETB/ha) for construction and maintenance 1st year		6200	7500	14351	800
Labor cost(ETB/ha) for construction and maintenance 2nd year		1200	1500	14351	800
Fertilizer cost 1st and 2nd year (ETB/ha)	1602.5	1602.5	1602.5	-	1602.5
Compost cost 1st and 2nd year (EB/ha)	-	-	-	400	-
Total Cost that varies 1st year at Zequala and Abergelle (ETB/ha)	1602.5	7802.5	9102.5	14751	2402.5
Total Cost that varies 2nd year (ETB/ha)	1602.5	2802.5	3102.5	14751	2402.5
Net benefit for 2009 at Zequala (ETB/ha)	-846.34	-2319.99	-2552.07	-6375.47	10364.71
Net benefit for 2010 at Zequala (ETB/ha)	7423.08	5392.89	4903.23	-9320.4	2447.93
Net benefit for 2010 at Abergelle (ETB/ha)	247.68	-1626.95	-6314.52	-11366.8	1077.39
MRR in Zequala 2009	-	D	D	D	14.01
MRR in Abergelle 2010	-	D	D	D	1.04