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Response of Potassium Fertilizer on Bread Wheat (Triticum aestivum l.) in Acidic Soil of Tsegede Highland, Northern Ethiopia

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Abstract

A field experiment was carried out on acidic soils of Tsegede, Northern Ethiopia where wheat production is severely constrained by soil acidity to evaluate wheat crop response to potassium. Four potassium levels (0, 25, 50, and 75) kg ha-1 in the form of potassium Sulphate (K2SO4) were applied considered as treatments along with recommended NP(46N and 20P) fertilizers and lime(5.4 t ha-1 at Endamariam and 4.1 t ha-1 at Endaslasie) were arranged in randomized complete block design with two replications at two farmers field. Initial soil analysis was made following standard procedures. The soil reaction (pH) is classified as strong acid and The Exchangeable aluminum and Exchangeable Acid also revealed as toxic for plant growth at both Endaslassie and Endamariam. However the total percentage of organic matter and total Nitrogen were high at both sites while very low in available phosphorus. Endamariam and Endaslassie have Medium to low exchangeable cations (Calcium and potassium), respectively while Exchangeable Magnesium was medium at both locations. The ANOVA result indicated that total biomass and grain yield of wheat showed significant ($P \leq 0.05$) response to the potassium fertilizer application, and Plant height also affected by the application of potassium fertilizer at only Endamariam, However Days to 50 % Maturity, panicle length and harvest index were not significant affected by application of potassium fertilizers at both locations. The soils that received 25, 50 and 75 kg ha-1 potassium gave additional grain yield increment by about 30.6, 31.0, and 41.1 % at Endamariam and 27.7, 27.6, and 36.7 % at Endaslassie over the control (treatment with only recommended lime and recommended NP) respectively, while the total biomass yield improved by 25.21, 25.66, and 35.39 % at Endamariam and 23.0, 22.8, and 31.9 % at Endaslassie respectively. However there is no significant difference among each treatments having potassium fertilizer on all yield and yield components at both locations. This significant wheat yield response to the applications of Potassium over the control implies that deficiency of K in the acidic soils of the area is a constraint that limits wheat crop production. Hence, a combined application of 25 kgha-1 Potassium fertilize along with recommended lime and N&P fertilizers are recommended to achieve sustainable wheat crop production on acidic soils of the Tsegede highlands and similar localitiesce.

Introduction

Wheat is one of the major cereal crops produced worldwide and Ethiopia is one of the largest wheat producing countries in the Sub-Saharan Africa (Asfaw *et al.*, 2012). However, Ethiopian wheat yields have been consistently well below the East African and world average yields, indicating low productivity of the crop (Schneider and Anderson, 2010).

Soil chemical degradation such as soil acidity, salinity and sodicity, Low levels of fertilizers, pesticides and improved seeds, moisture stress, are some of the major crop production constraints in Ethiopia (Alemayehu S. *et al*, 2011) . Acid soil problem is a major limitation to crop production on highly weathered and leached soils in the tropical and temperate regions of the world (Uexküll and Mutert, 1995). And it is often developed in regions where excessive rainfall coupled with unfavorable temperature and precipitation is high enough to leach appreciable amounts of exchangeable basic ions like potassium (K), calcium (Ca), magnesium (Mg), and sodium (Na) from the surface of soil. Its effects on crop growth are those related to the deficiency of major nutrients and the toxicity of aluminum (Al), manganese (Mn) and hydrogen (H) ions in the soil (Mesfin, A., 2007, Achalu C.*et al,2012*). About 30% of the highly weathered soils of Ethiopia have been reported to be acidic (Tekalign *et al*., 1988).

Replenishing soil fertility is the primary biophysical requirement for increasing food production in sub-Saharan Africa countries (Sanchez, 2010). However there has been a long established understanding, that Ethiopian soils are rich in potassium and believed to contain enough or sufficient quantity of the K nutrient thus there is no need for the application of this nutrient (Murphy, 1968; Asgelil *et al*., 2007; Deressa *et al*., 2013). As a result the role of potash fertilizer in crop production is ignored for many years in the history of Ethiopian Agriculture (Fassil, 2008). Nevertheless, some reports indicated that elements like K, S, Ca, Mg and micro-nutrients particularly Cu, Zn, Mn, and Mo are becoming depleted as a result of the Continuous application of nitrogen (N) and phosphorus (P) fertilizers without due consideration of these nutrients (Bereket *et al*., 2011) and potassium deficiency symptoms are being observed on major crops in different areas of the country;(Abiye *et al*., 2004; Asgelil *et al*., 2007; Deressa *et al*., 2013). Fassil and Charles (2003) also revealed that 76% of the investigated soils were deficient in K at six locations in Tigray regional state.

As potassium (K) is the third most essential nutrient element next to N and P for plant nutrition and It plays significant roles in the physiological processes of protein formation(Rehm and Schmitt, 2002; Lakudzala, 2013) and Potassium fertilization is frequently associated with improved crop quality as well as better handling and storage properties. Plants deficient in potassium are stunted and develop poor root systems. Thus, due to this low level of K in the soils negative effects on crop yield and quality are observed in some parts of Ethiopia (Abiye *et al*., 2004; Pound and Jonfa, 2005). In the prevailing conditions when the release is not enough to fulfill the requirement of crops, the small available quantity has to be supplemented with commercial fertilizers. Emerging research evidences based on the responses of potato and wheat proved that it is indeed becoming a limiting nutrient in some of the Ethiopian soils (Haile and Mamo, 2013).

The same is true for Tsegede highlands, Around 20,000 hectares of the area are severely affected by soil acidity, and 15% of this land area is totally out of crop production (TARI, 2008; Abrha *et al*, 2013). In Tsegede highlands there are reports that shows acidic cations are toxic and basic cation such as calcium, magnesium and potassium are deficient and the initial soils indicate that low to medium level of potassium in the study sites. Though some researches which are focused on acid severity characterization, lime rates, acid tolerant varieties for cereals and feeds are conducted, the appropriate rate of potassium fertilizer on cereal crops in general and in that of wheat crop in particular is not yet known.

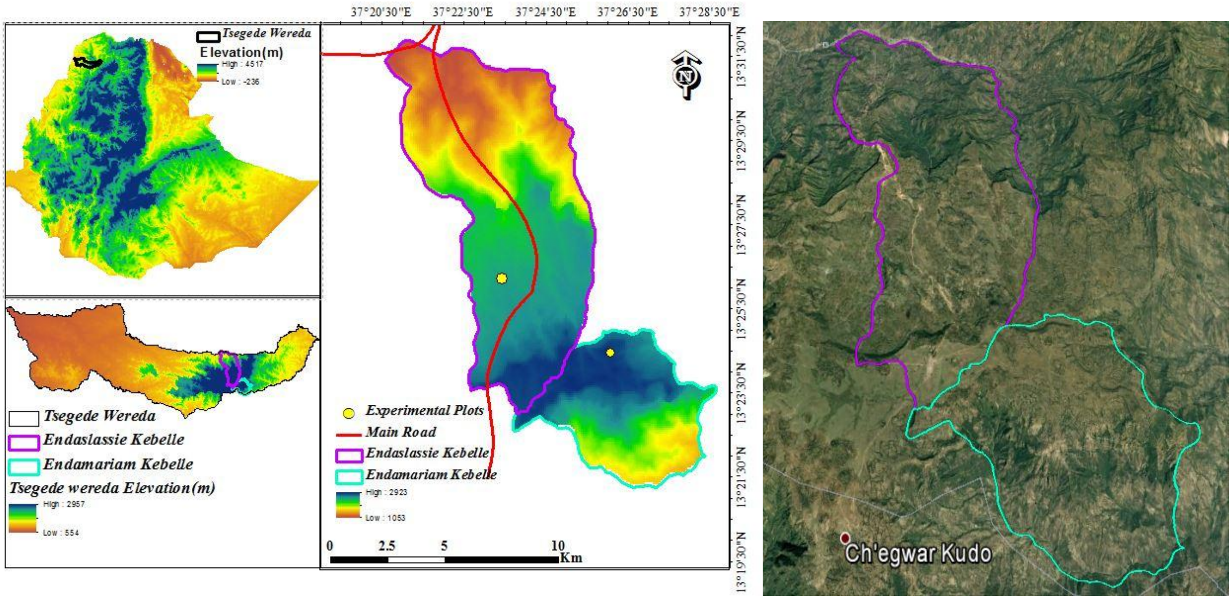
Hence, the study was conducted with the objective of evaluating the the effect of potassium fertilizer on the yield and yield components of Wheat crop grown on the acid soils of the area.

Materials and Methods

Area Description

The experiment was conducted on the highlands of Tsegede District which is located in the western Zone of Tigray Region, northern Ethiopia, located at 13^0 14′ 21″ and 13^0 44′ 46″ north and 36^0 27′ 44″ and 37^0 45′ 05″ longitudes with an altitude of 1050 to 2948 meters above sea level.

Figure 1 Location Map of the Study Area



The mean annual rainfall of the area is about 2316 mm that usually starts at about the end of March and ends in early November with the peak in August. The mean annual temperature of the area is 13.2^0C and ranges from 7.8 to 18.6 0C. The study site was at Endamariam and Endasslassie kebelles, with area coverage of 34 and 37.56 km^2 respectively. It consists of high and rugged mountains, flat topped plateaux, deep gorges and rolling plains. The dominant soil types in the Tsegede highlands are mainly Humic Cambisols (FAO/UNESCO, 1981). Wheat (*Triticum spp*.), Barley (*Hordeum vulgare*), Teff (*Eragrostis tef*), fingermillet (*Eleusine coracanaa*), Faba bean (*Vicia faba*), Field pea (*Pisum sativum*), Noog (*Guizotia abyssinica*), and Linseed (*Linum usitatissimum*) are Crops which grown mostly in the highlands of the District.

Site Selection, Soil Sampling and Analysis

This was conducted during 2011/2012 across two acid affected locations each has two replication. A composite soil sample was taken by inserting the auger up to a depth of 20 cm. All the subsample of a single composite sample were collected in a bucket and thoroughly mixed. Finally, about 1 kg of soil was taken using quartering method from the bulk composite soil sample to a polyethylene bag with the necessary label on it and this soil sample was air-dried, milled and sieved to pass through 2mm diameter mesh sieve and laboratory analysis were made for texture, pH, organic carbon, total N, available P, exchangeable acidity, k, Al, Na, Ca, Mg and CEC following their respective standard procedures.

Experimental design and procedures

An experiment was conducted to reveal the response of wheat to K fertilization applied with lime and recommended NP. Four K fertilizer levels (0, 25, 50 and 75) kg ha-^{1} K applied in the form of potassium Sulphate (K_2SO4) was considered as treatments. The Design was RCBD with two replications and Plot size of 5m*5m. Uniform rates of N (64 kg N ha^{-1} from urea), P (20 kg P ha-^{1} from triple supper phosphate) and Recommended Sheba lime($CaCO_3$) with 8.1 t ha^{-1} at Endamariam and 6.2 t ha^{-1} at Endaslasie were applied on each experimental plot regardless of the treatments. applied in the form of gypsum (25 kg ha-^{1} CaSO4.2H2O). Urea fertilizer was applied in split application. Improved bread wheat variety; Galama (HAR-604) was used as a test crop and All management practices were done. The Treatments were 0, 25, 50 and 75 kg/ha of K at both locations. Land preparation and plowing, weeding, pesticide application and other agronomic management were carried out as per the recommendation for wheat.

Data collection, plant sampling and analysis

Plant height was determined by measuring the length of the plants from the ground level to the top of the spike just before physiological maturity. At physiological maturity, the plants were harvested close to the ground level by hand; air dried in an open dry environment and total biomass was determined by weighing the total biomass (straw and grain) using sensitive balance. Grain yield per plot was determined after carefully separating the grain from the straw.

Data Analysis

Analysis of variance was subjecting to the statistical software program SAS 2004, version 9.0 to carry out for yield and yield parameters of the crop to determine its response to the applied K. For statistically significant different parameters, the means were separated using the least significant difference (LSD). For profitability of Wheat production using different fertilizer sources, marginal rate of return (MRR) was calculated as the change in net revenue (NR) divided by the change in total variable cost (TVC) of the successive net revenue and total variable cost levels (CIMMYT, 1988).

Results and Discussion

Initial Soil Physiochemical Characteristics of Experimental Sites

The soil reaction (pH) is classified as strong acid at both locations as per the pH rating category suggested by Yuste and Gostincar (1999). The Exchangeable aluminum and Exchangeable Acid also revealed as toxic for plant growth (FAO, 1979) at both Endaslassie and Endamariam. The total percentage of organic matter and total Nitrogen were high at both sites as prescribed by Tekalign (1991) while very low in available phosphorus according to the availability index suggested by Beegle and Oravec (1990). According to FAO, 2006 the soil result indicated that Endamariam and Endaslassie have medium to high Cation Exchange capacity (CEC) respectively. However Medium to low exchangeable cations(Calcium and potassium) were recorded at Endaslassie and Endamariam respectively while Exchangeable Magnesium was medium at both locations (table 1).

Table 1 Initial Surface (0-20 cm) Physical and Chemical Property of the Experimental Fields

Location (Elevation)	**Texture**	**pH**	**OM (%)**	**TN (%)**	**Av. P (mg kg^{-1})**	**EA (cmol+ kg^{-1})**	**CEC (cmol+ kg^{-1})**	**Exchangeable cations (cmol+ kg^{-1})**				**Sheba($CaCO_3$) (t ha^{-1})**
								Al	K	Ca	Mg	
Endaslasie (2332m)	Sandy loam	4.79	6.83	0.34	3.15	4.17	25.38	3.09	0.42	6.43	1.52	6.2
Endamariam (2882m)	Sandy loam	4.66	6.51	0.29	2.24	5.42	22.52	4.87	0.19	3.05	1.18	8.1

Note: OM= Organic Matter; CEC= Cation Exchange Capacity; TN= Total Nitrogen and Av. P= Available Phosphorus

Wheat Yield Response to Potassium

The one way ANOVA result showed that total biomass and grain yield were significantly ($P < 0.05$) affected by potassium fertilizer at both locations (Endamariam and Endaslassie), and Plant height also affected by the application of potassium fertilizer at only Endamariam, However Days to 50 % Maturity, panicle length and harvest index were not significant affected by application of potassium fertilizers at both locations (Table 2 and 3).

Table 2 One Ways Analysis Of Variance For Some Considered Wheat Yield Parameters Response to the Application of K Fertilizer in the Forms of Potassium Sulfate (Endamariam)

K (kg/ha)	**D50%M**	**PH(cm)**	**PL(cm)**	**B.yld(kg/ha)**	**G.yld(kg/ha)**	HI
0	122.250	72.09 [b]	7.3450	4776.2 [b]	1962.3 [b]	0.4075
25	120.000	80.86 [a]	7.5625	5980.1 [a]	2562.0 [a]	0.4275
50	121.250	83.02 a	7.4050	6001.7 [a]	2570.5 [a]	0.4275
75	118.000	82.88 [a]	7.7175	6466.4 [a]	2767.8 [a]	0.4275
P_Value	0.5518	0.038	0.2233	0.0198	0.0429	0.4967
mean	120.37	79.71	7.51	5806.1	2465.6	0.4225
LSD(0.05)	6.58	8.113	0.39	1012.8	558.76	0.034
CV	3.55	6.61	3.44	11.32	14.71	5.16

Mean values across columns followed by the same letter(s) are not significantly different at P > 0.05

NB- D50%M-Days to 50% maturity, PH(cm)-Plant height in centimeter, PL- Panicle length, B.yld-Biomass yield, HI-Harvest index, G.yld (kg/ha)-Grain yield in kilogram per hectare

Table 3 One Ways Analysis of Variance for Some Considered Wheat Yield Parameters Response to the Application of K Fertilizer in the Forms of Potassium Sulfate (Endaslassie)

K (kg/ha)	**D50%M**	**PH(cm)**	**PL(cm)**	**B.yld(kg/ha)**	**G.yld(kg/ha)**	HI
0	121.25	73.110	7.5400	5286.8 [b]	2181.5 [b]	0.4100
25	119.25	79.340	7.6100	6500.2 [a]	2785.3 [a]	0.4275
50	118.00	81.523	7.7675	6490.2 [a]	2782.5 [a]	0.4275
75	116.00	81.380	7.8700	6972.0 [a]	2983.0 [a]	0.4275
P_Value	0.405	0.1472	0.1798	0.0104	0.0415	0.596
mean	118.63	78.84	7.697	6312.28	2683.06	0.423
LSD(0.05)	6.619	8.29	0.332	913.94	553.14	0.033
CV	3.62	6.83	2.80	9.39	13.38	5.12

Mean values across columns followed by the same letter(s) are not significantly different at P > 0.05

NB- D50%M-Days to 50% maturity, PH(cm)-Plant height in centimeter, PL- Panicle length, B.yld-Biomass yield, HI-Harvest index, G.yld(kg/ha)-Grain yield in kilogram per hectare

Wheat Grain and Biomass Yield

Application of different rates of Potassium fertilizer results significant difference in grain and biomass yield (Table 4). The soils that received 25, 50 and 75 kg ha^{-1} potassium gave additional grain yield increment by about 30.6, 31.0, and 41.1 % at Endamariam and 27.7, 27.6, and 36.7 % at Endaslassie over the control (only recommended lime and recommended NP) respectively, while the total biomass yield improved by 25.21, 25.66, and 35.39 % at Endamariam and 23.0, 22.8, and 31.9 % at Endaslassie respectively (Table 4).

However there is no significant difference among treatments having potassium fertilizer on all yield and yield components at both locations.

This significant wheat yield response to the applications of different Potassium levels over the control implies that deficiency of K in the acidic soils of the area is a constraint that limits wheat crop production. Similar report by Singh and wanjari, 2012, Adhikary and Karki, 2006, Application of potassium could increase wheat yield significantly, and a study by Wassie and Shiferaw, 2011 also suggesting that Application of Potassium is very critical in acidic areas of Chencha, Southern Ethiopia.

Table 4 Effect of Different K Fertilizer Rates on Grain and Total Biomass Yield of Wheat

K (kg/ha)	Endamariam		Endaslassie	
	B.yld(kg/ha)	**G.yld(kg/ha)**	**B.yld(kg/ha)**	**G.yld(kg/ha)**
0	4776.2 [b]	1962.3 [b]	5286.8 [b]	2181.5 [b]
25	5980.1 [a]	2562.0 [a]	6500.2 [a]	2785.3 [a]
50	6001.7 [a]	2570.5 [a]	6490.2 [a]	2782.5 [a]
75	6466.4 [a]	2767.8 [a]	6972.0 [a]	2983.0 [a]
P_Value	0.0198	0.0429	0.0104	0.0415
mean	5806.1	2465.6	6312.28	2683.06
LSD(0.05)	1012.8	558.76	913.94	553.14
CV	11.32	14.71	9.39	13.38

Mean values across columns followed by the same letter(s) are not significantly different at $P > 0.05$

Wheat plant height

The analysis of variance showed that recorded plant height was significantly affected by the treatments only at Endamariam. Wheat crops grown in the soils applied with 25, 50, 75 kg ha^{-1} K Plant height was considerably ($P \leq 0.05$) increased by 12.2, 15.2, and 14.97 over the treatments with only recommended lime and NP fertilizers(control) respectively (Table 2). The highest plant height was recorded in the soils received 50 kg ha^{-1} K fertilizer though it has not significant difference with the other potassium levels. This might be due to the effect of potassium fertilization in which readily soluble minerals helps to the vegetative growth of the crop up to the potassium level of 25 kg/ha. A study conducted by Abdenna D. *et al*., 2013 also revealed that fertilizing the soils with potassium and calcium is a necessity to increased production and productivity of acidic soils at East Wollega, Ethiopia.

Partial Budget Analysis

The marginal rate of return at the potassium application rates of 25, 50, and 75 kg ha^{-1} are all greater than 100%. As the MRR for these rates are greater than 100%, investing extra money is economical. Though Application of potassium at 75 kg ha^{-1} rate was economically profitable statistically they have no yield difference with the potassium at 25 kg ha^{-1}.Thus application of this 25 kg ha-^{1} potassium for wheat at Tsegede highlands preferable.

Table 4 Partial Budget Analysis for Potassium Fertilizer

Fertilizer Levels (kg ha^{-1})	Fertilizer Cost (Birr)	Transport and labor cost (Birr)	Total variable cost (TVC) (Birr)	Grain yield (kg ha^{-1})	Total revenue (TR) (Grain yield*9 (Birr)	Net revenue (TR-TVC)	Marginal rate of return (MRR) (ratio)	MRR (%)
0	0.0	0.0	0	1962	17658	17658	-	-
25	294.8	34	328.8	2562	23058	22729	15.42	1542
50	589.7	64	653.7	2571	23139	22485	-0.75^{D}	-75^{D}
75	884.5	98	982.5	2768	24912	23930	4.39	439

Conclusion and Recommendation

In the study area where the soil is very strong acid and toxic for plant growth with climate is humid, receiving excessive rainfall, with likely possible depletion of potassium, potassium fertilizer applied in the form of potassium sulfate had significant variation in most of the considered wheat yield parameters (total biomass yield, grain yield, and plant height). Though Application of potassium at 75 kg ha^{-1} rate was economically profitable statistically they have no yield difference with the potassium at 25 kg ha^{-1}.Thus application of this 25 kg ha-^{1} potassium in combination with lime along with Recommended NP could maximize wheat crop yield grown in the acidic soils of the Tsegede highlands as well as areas with similar clime and soil conditions. In addition to this uncontrolled land encroachment in the low land areas can minimize as a result of making productive of these farmlands. This should be demonstrated and scale ups to the farmers in the area and it would help for dissemination through the extension System so as to make the results usable in the future. However plant uptake and related issues didn't studied here.

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