Revised Research Article

Optimum K fertilizer level for growth and yield of Wheat (*Triticum aestivum*) in Cambisols of northern Ethiopia

Abstract

A field experiment was conducted in summer to evaluate the response of wheat to different potassium fertilizer rates on Cambisols of Tigray, Northern Ethiopia. The experiments were laid out in Randomized Complete Block Design replicated three times with 4 levels of potassium (0, 30, 60, 90, K_2O kg/ha). Data on yield and yield components of wheat were collected and regression, as well as variance analyses, were done. Results depicted that wheat plant height, spike length, harvest index and 1000 seed weight were all not significantly influenced by K fertilizer rates. However, biological and grain yield of wheat was significantly influenced by potassium levels. Hence, the highest biological yield (straw + grain) and grain yield of wheat were obtained at the rate of 90 K_2O kg/ha. Besides, the highest N and K uptakes by wheat were found at 60 K_2O kg/ha. Similarly, the highest apparent K recovery and agronomic use efficiency were found at 30 K_2O kg/ha. Hence, it can be concluded that potassium fertilization is important and the levels in the blended formula did not meet the wheat requirement in the soil reference group. Thus, this study recommends application of potassium.

Key words: Potassium, Blended fertilizer; Cambisols; Wheat; Uptake

1. Introduction

Wheat cultivation is a major farming practice in Ethiopia. However, soil degradation and nutrient depletion have gradually increased and become a serious threat to agricultural productivity in the country (Kebede and Yamoah, 2009). In line with this, low production of wheat has been shown in various parts of the country as a result of limited nutrient supply (Gebreselassie, 2002).

Increasing soil productivity is absolutely necessary to feed the increasing population in Ethiopia. In addressing this issue balanced fertilization with an optimum application rate is necessary to improve soil fertility and thus increasing the productivity of crops including wheat.

Among others, potassium fertilization has been improved growth and yield of wheat crops in various parts of the world. Several researchers conducted in Bangladesh, Saudi Arabia, Iran and India such as by Saha et al (2010), Alderfasi and Refay (2010), Malek-Mohammadi et al (2013), and Khan et al (2014) respectively indicated that growth and yield of wheat were increased by application of potassium fertilizer at different levels. On the other hand, fertilizer demonstrations is carried out in Ethiopia by the FAO and the then Ministry of Agriculture through the Freedom from Hunger Campaign conducted in the sixties and early seventies showed that the response to potash fertilization was inconsistent; thus, only urea and DAP were recommended for implementation (Tekalign Mamo, personal communication September 6, 2015). As a result potash fertilization was not practiced for the last many years due to the view that potassium was not deficient in Ethiopian soils. However, recent research findings such as by Abegaz (2008), Deressa et al (2013), EthioSIS (2014), and Wassie (2009) have indicated that potassium was deficient in various areas of the country. In line with this, as one part of nutrient management strategy potassium fertilization has been started in 2014 in the form of blended fertilizers (between 7 and 12 kg per 100kg in the form of K_2O) in different regions of the country. Despite the various efforts made in including K as fertilizer through the introduction of K containing blended fertilizers in Ethiopia, the optimum level and its effect on growth, yield and nutrient uptake of wheat on specific soil type in the various parts of the country was not studied yet. Besides, there is no adequate evidence which justifies whether the recommended rates of K in the blending formula (between 7 and 12 kg/ha in the form of K_2O) meets the crop demand or not. Thus, this study was designed to investigate potassium fertilization and its optimum level of growth, yield and nutrient uptake of wheat in Cambisol of northern Ethiopia.

2. Materials and methods

2.1. Study area

The study was conducted in Enderta district, which is located in south eastern zone of Tigray region, northern Ethiopia.Before this experiment the field was covered by barley and tef respectively for previous two consecutive growing seasons. The district is bounded by Hintalo Wajerat in the south, Seharti -Samre and Degua-Tembien in the west, Kilte-Awulaelo in the north and Afar region in the east. Geographically, the district is located between 13˚12'55" -13˚38'38" N latitudes and 39˚16'43" - 39˚48'08" longitudes. The average elevation of the area is about 2200 m above sea level (Gebre et al, 2015). The Wereda falls in SM2-5b Agroecology, characterized by dry climatic conditions and erratic rainfall. Based on meteorological data collected from the nearest meteorological station on the study site, annual rainfall of the latest six years ranges between 258 and 756 mm. The growing season of 2015 had received a relatively lower rainfall compared to the long term average, since it was affected by El-Nino.. The mean annual temperature ranges between 11.5 and 24.4 ˚C. The most common soils of the study district are: Cambisol, Calcisols, Vertisols, Kastanozems, Leptosol, Luvisols, Phaozems, Regosols and Fluvisols (Gebre et al, 2015).

2.2. Experimental design and procedures

The experiment had 4 levels of potassium (0, 30, 60 and 90 K_2O kg/ha) applied as potassium chloride (KCl) on top of recommended blended fertilizers. These treatments were laid following Randomized Complete Block Design (RCBD) with three replications. The plot size was 3 m by 3 m with spacing of 1 m between blocks and 0.5 m between plots. On top of the blended fertilizer which contains 15.2% N, 48.8% nitrogen was added to satisfy N wheat requirements (64N kg/ha.) in the area. The blended fertilizer was applied at planting, while the nitrogen and K fertilizers were applied twice during the crop growth stage that is 1/3 of the full dose at planting and the other 2/3 at tillering stage.

The initial experimental field soils were analyzed for texture, pH, organic matter, cation exchange capacity (CEC), total nitrogen, available phosphorus and exchangeable K. The methods used for soil physical and chemical analysis were: Soil pH (Rhoades, 1982), Organic carbon % (Walkely and Black method 1934), soil texture by hydrometer (Bouyoucos, 1962), available Phosphorus (Olsen et al, 1954), total nitrogen by Kjeldhal method (Bremner and Mulvaney, 1982), Neutral Ammonium acetate method (Landon, 1991) for cation exchange capacity and Exchangeable K^+. After maturity, wheat crop samples were collected and partitioned into grain and straw parts. The grain and straw samples were analyzed for nitrogen and potassium. Plant total nitrogen was analyzed using Kjeldhal method (Bremner and Mulvaney, 1982) whereas potassium using dry ashing method (Chapman, 1965). In this experiment, picaflour (Kakaba) bread wheat variety was used as a test crop. Data on plant height, spike length, biological yield, grain yield and 1000 seed weight were collected.

The nutrient uptake by straw or grain was calculated by multiplying each nutrient concentration (%) by respective straw or grain yield in kg/ha. Moreover, apparent recovery and K agronomic use efficiency were calculated with the formulas proposed by Fageria and Baligar (2003).

$$\text{Apparent K recovery (kg/kg)} = \left(\frac{\text{Un} - \text{Uo}}{\text{n}}\right) \text{...} \textbf{ Eq. (1)}$$

Where; Un stands for nutrient uptake at 'n' rate of fertilizer and Uo stands for nutrient uptake at control (no fertilizer) and 'n' stands for fertilizer applied.

$$\text{Agronomic K use efficiency(kg/kg)} = \left(\frac{\text{Gn} - \text{Go}}{\text{n}}\right) \text{.....................................} \textbf{ Eq. (2)}$$

Where Gn and Go stand for grain yield of fertilized plots at 'n' rates of fertilizer and grain yield of unfertilized plots, respectively, and 'n' stands for nutrient applied

2.3. Data analysis

Analyses of variance (ANOVA) were carried out using Statistical Analysis Software (SAS) version 9. Whenever treatment effects were significant, mean separations were made using the least significant difference (LSD) test at the 5 % level of probability. Moreover, regression analyses were also done.

3. Results and discussion

3.1. Soil properties before planting

The physical and chemical properties of the experimental fields before planting are indicated in Table1.

Table 1: Soil physio- chemical properties of the site before sowing

Parameters	Value
pH_{water}(1:2.5)	7.55
Organic Carbon (%)	0.64
Total N (%)	0.06

P-Olsen(mg/kg)	2.88
Exchangeable K(Cmol/kg)	0.29
CEC (Cmol+/Kg)	23.6
% Sand	55
% Silt	25
% Clay	20
Textural class	Sandy Loam

The site is sandy loam in texture, slightly alkaline in soil pH, low in organic Carbon% and totalnitrogen (Tadesse, 1991), medium in the CEC (Landon, 1991) and Exchangeable K (Jones, 2002) and low in available P (Olsen et al, 1954). The continuous cultivation without using an organic source of fertilizer may have contributed to the low level of organic carbon and total nitrogen.

3.2. Plant height and spike length

Data presented in figure 1 and table 2 showed that K fertilization had a promoting effect on plant height and spike length. Results showed that average plant height and spike length had increased with K application rates even though the trend was not consistent. The tallest plant height and spike length were obtained in the treatment which received 60 K_2O kg/ha and it is not statistically different from the other treatments. However, the shortest plant height was measured at control treatments. These findings agreed with the research findings of Khan et al. (2007) and Tahir et al. (2008).

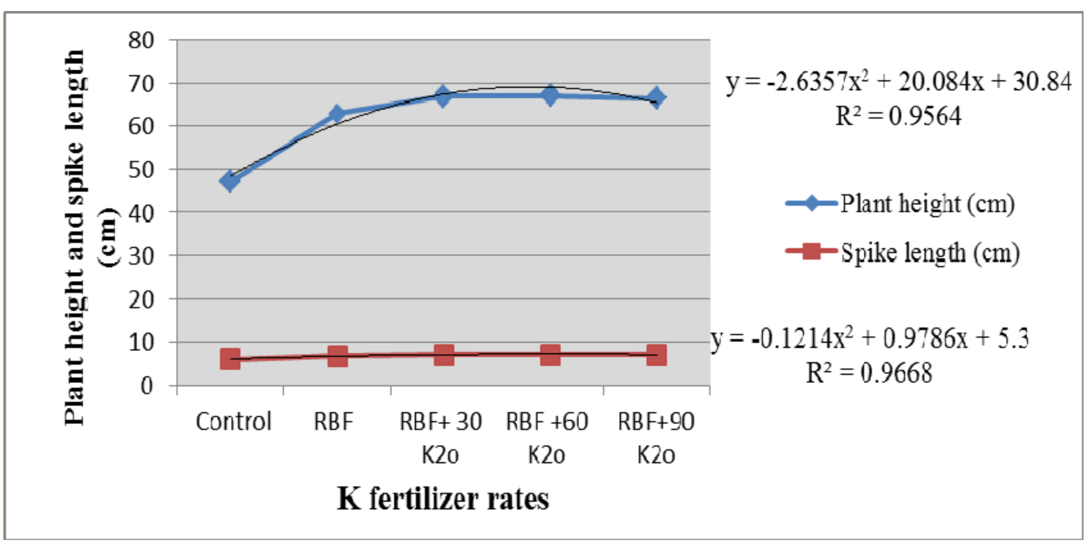

Figure1.Regression analyses of plant height and spike length

3.3. Biological yield (Total above ground biomass) and Grain yield

In both regression analyses and analysis of variances showed that application of K fertilizer rates significantly increased the biological and grain yield of wheat in the study site. In line with this, the highest biological and grain yield of wheat was obtained from treatment that received 90 K_2O kg/ha. Moreover, the lowest biological and grain yields were recorded from the control treatment and it was significantly lower ($P<0.05$) as compared with other treatments. The differences in mean biological yield obtained from 0 and 30 K_2O kg/ha in one hand and 30 and 60 K_2O kg/ha on the other hand were not significant. Besides, the application of 60 K_2O kg/ha was significantly ($p\leq0.05$) increased grain yield of wheat over application of 30 K_2O kg/ha on the study site. However, the difference in wheat grain yield between the application of 60 and 90 K_2O kg/ha was not significant ($p>0.05$). In this study, treatments which received 90 K_2O kg/ha increased grain yield by 40.2% and 40.74% over treatments which received 30 and 0 K_2O kg/ha. The results are in agreement with the research findings of Wassie and Tekalign (2013), and Maurya et al. (2014) who reported that application of potassium levels had significant effect on the biological and grain yield of wheat.

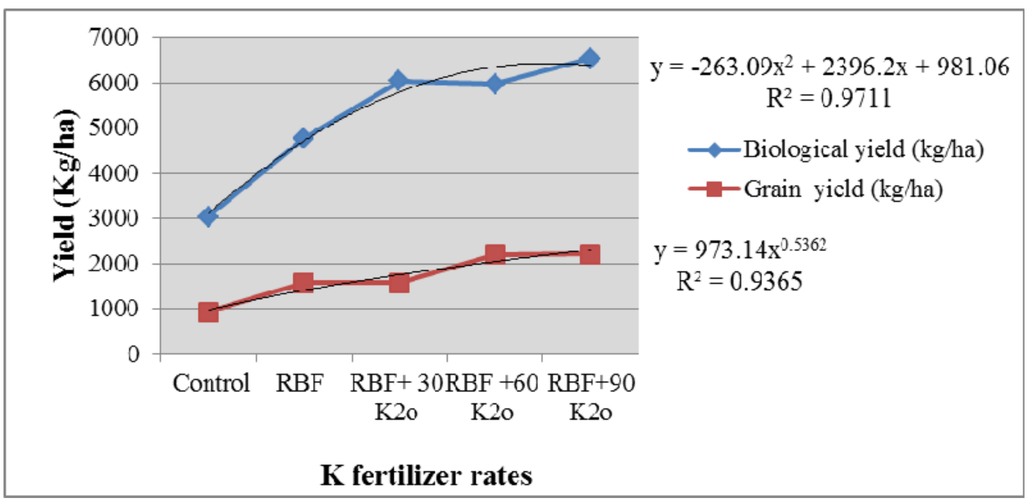

Figure2. Regression analyses of biological yield and grain yield

3.4. Harvest index and 1000 seed weight

The result showed that harvest index and 1000 seed weight were not significantly affected by the applications of K rates. However, the highest harvest index and 1000 seed weight were recorded at a rate of 60 K_2O kg/ha. The non-significant harvest index result was indicating approximately equal positive effects of potassium on seed and biological yield. The non-significant result found on the 1000 seed weight was agreed with the research findings of

Morshedi and Farahbakhsh (2010) who reported that application of K at any level had no significant effect on 1000 seed weight of wheat.

Table 2: Effect of potassium fertilizer rates on wheat plant height, spike length, biological yield, grain yield, harvest index and 1000 seed weight.

Treatment	Plant height (cm)	Spike length (cm)	Biological yield (kg/ha)	Grain yield (kg/ha)	Harvest index	1000 seed weight (g)
Control	47.1	6.1	3048.1 [c]	935.3 [c]	0.31	26.5
RBF	63.0	6.9	4772.2 [b]	1574.7 [b]	0.35	26.1
RBF+ 30 K_2okg/ha	66.9	7.1	6044.4 [ba]	1580.7 [b]	0.26	22.9
RBF +60 K_2okg/ha	67.1	7.2	5981.5 [ba]	2203.6 [a]	0.37	28.6
RBF+90 K_2okg/ha	66.4	7.2	6531.5 [a]	2216.2 [a]	0.34	27
Lsd(0.05)	ns	ns	1507	551.85	ns	ns
CV	12.2	6.4	15.2	17.2	15.3	14.2

Means followed by the same letter along columns are not significantly different. RBF: recomended blended fertilizer (NPKSZN), Lsd: least significant difference CV: Coeficient of variance, ns: non-significant.

3.5. Nutrient uptakes, apparent recoveries and agronomic use efficiency

3.5.1. K uptake by wheat grain and straw

The result indicated that K uptake by grain and straw were influenced by different K treatment combinations. K uptake by grain and straw of wheat had shown a linear increasing trend with increasing K rates though there were some inconsistent results. The highest K uptake by grain and straw was found at 60 K_2O kg/ha. The lowest grain and straw K uptake were obtained from the control treatment in the studied soil reference group. This result is in agreement with the research findings of Wani et al. (2014) in Kashmir, India.

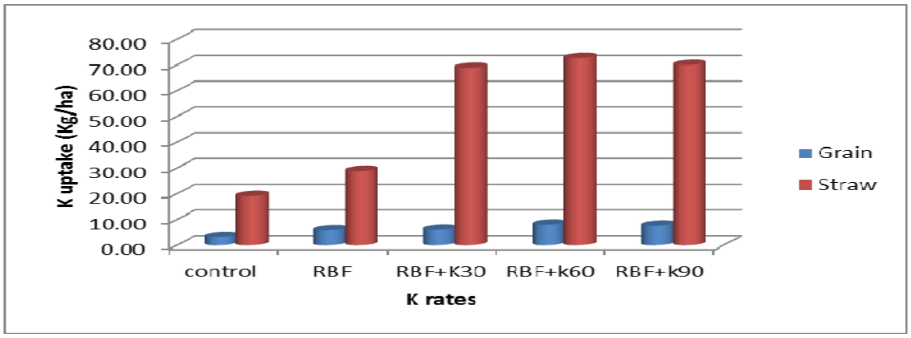

Fig.3. Effect of K rates on K uptake by wheat grain and straw

3.5.2. N uptake by wheat grain and straw

Potassium fertilization had promoted N uptake by grain and straw. Nitrogen uptake by grain and straw of wheat was influenced by various K treatment combinations as indicated in Figures 4. Grain and straw uptake of nitrogen by wheat increased linearly up to 60 and the lowest N uptake by grain and straw was found in control. This result is consistent with the research findings of Ashok et al. (2009).

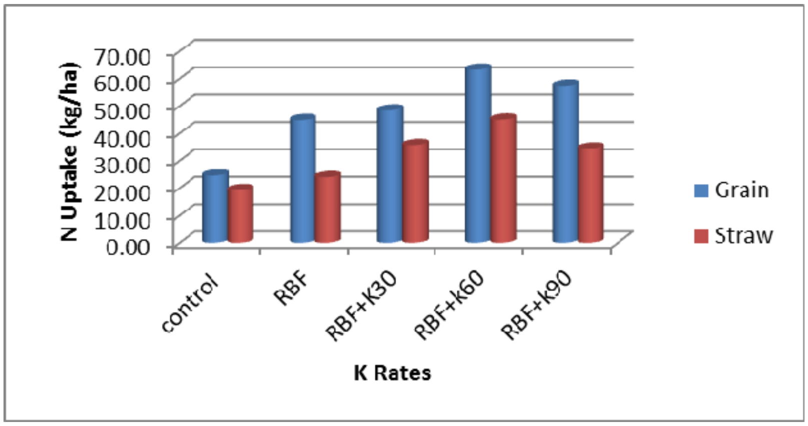

Fig.4. Effect of K rates on N uptake by wheat grain and straw

3.5.3. Apparent Recovery and Agronomic Use Efficiency of K

The potassium application rate had influenced apparent K recovery and agronomic K use efficiency in the study site. Both apparent recovery and K use efficiency had shown decreasing trend with increasing K rates even though the apparent recovery was not consistent. As a result, the highest agronomic K use efficiency and apparent recovery were obtained at the lowest application rate (30 K_2O kg /ha).

Table 3: Effect of potassium level on apparent recovery and agronomic use efficiency

Level of K (kg/ha)	ARK (kg/kg)	AUE K (kg/kg)
30	1.88	21.51
60	0.41	21.14
90	0.61	14.23

ARK=Apparent recovery of potassium; AUEK= Agronomic use efficiency of potassium

4. Conclusions

Potassium fertilization has been started in the country in the form of blended a blanket recommendation in 2014 to improve the productivity of cereals including wheat. However, there were no comprehensive works on its rates and whether the level in the blended formula meets the growth and yield requirement of the crop or not. Thus, the result of this experiment indicated that nutrient uptake, K recovery, K agronomic use efficiency, biological and grain yield of wheat were significantly responded from the additional K levels. Hence, the level of potassium in the blended formula did not meet the growth and yield requirement of wheat on Cambisols of the studied district. In line with this, the highest biological and grain yields of wheat were obtained at 90 K_2O kg/ha. However, the highest K and N uptake by grain and straw were found at 60 K_2O kg/ha rates. Besides, the highest apparent K recovery and agronomic use efficiency were found at 30 K_2O kg/ha. Therefore, straight application of potassium is recommended rather than incorporating in the blend.

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