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Potassium Fertilization and Application Time for Wheat Yield Improvement in Cambisols of Enderta Districts, South Eastern, Tigray

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors HBG and DB designed the study, wrote the protocol, conduct laboratory analyses, analyzed and interpreted the data and wrote the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Recently the government of Ethiopia has introduced potassium as fertilizer through the introduction of various K containing blended fertilizers. However, the optimum application rate and time of application on specific crop and soil type has not been studied yet. So, a field experiment was conducted to determine the optimum rate of potassium and its application time for wheat yield and yield components in Cambisols of Enderta district South Eastern zone of Tigray. The experiment was laid out in Randomized Complete Block Design with 4 levels of potassium (0, 40, 60 and 80 of K_2O kg/ha) with and without split application including control in three replications. Results depicted that except harvest index all the yield and yield components of wheat were influenced by potassium fertilization. Moreover, split application of K significantly affected the yield and yield components of wheat as compared to single application of full dose of K. In line with this, the highest grain and straw yields of wheat were obtained at 80 kg/ha K_2O levels and statistically similar with the split

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application levels of 40 and 60 kg/ha K_2O. This implies that the 40 kg/ha K_2O at split application is economically feasible (optimum) level of K for wheat production in the Cambisols of the area studied. The highest agronomic efficiency and partial factor productivity were also obtained at the level of 40 kg/ha K_2O in split forms. Hence, potassium fertilization is important and should be applied in split methods rather than at full single dose at planting for increasing wheat yield and improving agronomic efficiency and partial factor productivity in the Cambisols of Enderta districts.

Keywords: Application time; Enderta; potassium; wheat.

1. INTRODUCTION

Wheat (*Triticum aestivum*) is an important cereal crop in Ethiopia in feeding the growing population. Even though Ethiopia's wheat output has increased somewhat in recent years, the nation must still import wheat each year due to a surplus of demand over supply. Therefore, in order to obtain a bigger yield of higher quality wheat, it is necessary to increase essential production components.

"Nutrient depletion and imbalance are among the major attributes that contribute to declining soil productivity in Ethiopian" [1]. "Potassium is among the macro nutrient which is taken up by plants in large amount for producing promising yields. Potassium controls many biochemical and physiological processes in plants such as enzyme activation, photosynthesis, protein synthesis, osmoregulation, energy transfer, stomata regulation, cation-anion balance, and stress resistance" [2,3,4]. "Moreover, K fertilization decreases insect infestation and disease incidence in various plants species" [5,6].

Researches conducted on potassium fertilization in various parts of the world [7,8,9,10] have shown the promoting effects on yield and yield components as well as drought, and disease resistance of crops. Besides, potassium application time had influenced the growth and yield of crops as compared to single basal application [11,12]. In line to this, [13] indicated that split application of K resulted considerable increase in the productive efficiency of N and K as well as a larger rise in grain yield, protein content, and wet gluten content in wheat grains compared to basal applications of K. It has also been shown that applying K in split doses during the growth phase is advantageous since it reduces leaching loss of K while increasing the fertilizer's rate of utilization [14].

The role of Potassium fertilizer on crop production in Ethiopia was not prioritized for many years [15] due to the view that Ethiopian soils are rich in potassium. On the contrary, Ethiopian agriculture is a highly exploitative type in which plant nutrients including potassium is extracted from the soil where by very little or no crop residues are returned back to the soil. Additionally, the levels of K in Ethiopian soils were found to be below the ideal threshold for sufficient crop production [15, 16]. In line to this, soil with Ca: K > 50:1 and Mg: K >15:1 are likely to respond to potassium fertilization [1].Similarly, the Soil Fertility Atlas of Tigray region indicated a potassium deficiency in various parts of the region including Enderta [17].

Based on the recent findings the government of Ethiopia has introduced potassium as a fertilizer through introduction of various K containing blended fertilizers as part of the nutrient management strategy. However, the optimum application rate and time of application on specific crop and soil type has not been studied. Therefore, this experiment was aimed at investigating the effects of K level and time of application on yield and yield components of wheat on Cambisols of Enderta district.

2. MATERIALS AND METHODS

2.1 Study Area

The experiment was conducted in 2014/15 growing season on Cambisols of Enderta district, south eastern Tigray. The growing season of 2015 had received a relatively lower rainfall (142.13mm) compared to the long term average (405.76mm), since the area was among those affected by El-Nino.

"Geographically, the district is located between 13°12′55″ and 13°38′38″ N latitude and 39°16′43″ and 39°48′08 E longitudes. The average elevation of the district is about 2,200 m above sea level" [18].

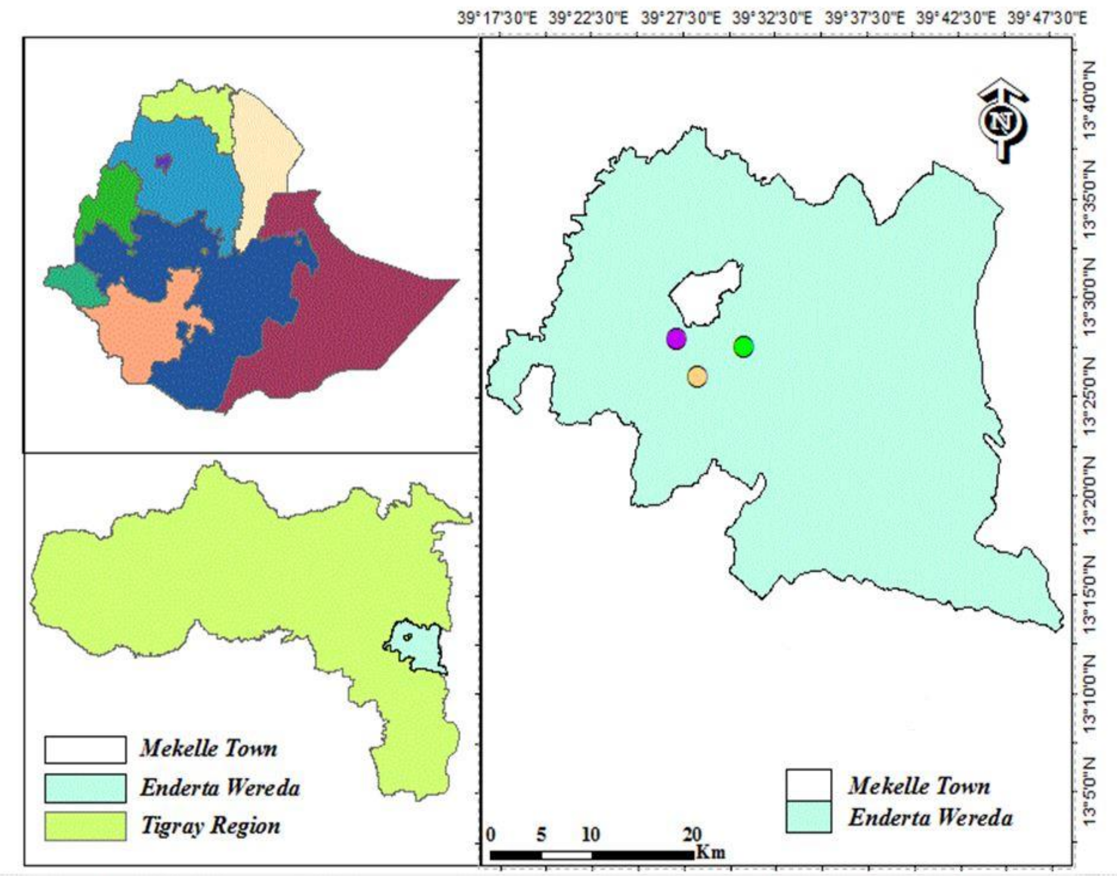

Fig. 1. Location map of the study area

2.2 Experimental Design and Procedures

The treatment consisted of with and without split application of K including control (0, 40, 60, 80, 20+20, 30+30, and 40+40 kg/ha of K_2O). These treatments were laid out in Randomized Complete Block Design (RCBD) with three replications. The total plot size was 11m*24m (264m^2) with spacing of 1 m between blocks and 0.5 m between plots and with net harvested plot of 3 by 3 m plots (9m^2) based on recommendations set by Mekelle soil research center. Optimum nitrogen (64N kg/ha) was added to satisfy N wheat requirements in the area. The nitrogen fertilizer was applied twice during the crop growth stage that is 1/3 of the full dose at planting and the other 2/3 at the full tillering stage. Besides, the potassium split was applied ½ at planting and ½ at the full tillering stage. Source of the fertilizers for N and K were Urea and potassium chloride respectively. The seed rate of wheat was 150kg/ha and it was sown using manual row maker. In the trial, pica flour (Kakaba) bread wheat variety was used as a test crop.

Table 1. A treatment set up of the experiment (kg/ha of K_2O)

T1	Control
T2	40 full dose @ planting
T3	60 full dose @ planting
T4	80 full dose @ planting
T5	40 in split (20@ planting and 20 @ tillering)
T6	60 in split (30@ planting and 30 @ tillering)
T7	80 in split (40@ planting and 40 @ tillering)

The initial soil of the experimental field was 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 [19], Organic carbon % [20], soil texture by hydrometer [21], available Phosphorus [22], total nitrogen by Kjeldhal method [23], Neutral Ammonium acetate method [24] for cation exchange capacity and Exchangeable K+. Field monitoring and data recording were made during the wheat growth in the field. Data on plant height, spike length, grain and straw yield, and 1,000 seed weight were collected.

Agronomic efficiency (AE) and partial factor productivity (PFP) were calculated using the formula developed by [25].The AE indicates the economic production obtained per unit of nutrient applied, while the PFP is the quantity of grain obtained per nutrient applied. They were calculated using the following equations:

$$\mathrm{AE} = (\mathrm{Gt} - \mathrm{Gr})/\mathrm{Na} \quad (1)$$

and

$$\mathrm{PFP} = \mathrm{Nn}/\mathrm{Na} \quad (2)$$

Where Gt = grain yield obtained from fertilized plots; Gr = grain yield obtained from unfertilized (control) plots; Nn = the total grain yield obtained from each treatment; and Na = the quantity of nutrients 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.

3. RESULTS AND DISCUSSION

3.1 Soil Properties of the Surface Soil Before Planting

Table 2. Properties of soil surface layer of the experimental site at starting of the experiment

Parameters	Value
pH	7.53
EC(ds/m)	0.07
OC (%)	0.63
T.N(%)	0.06
Av.P (ppm)	2.89
Ex.K(ppm)	112
CEC (meq/100g soil)	23.62
Sand (%)	55
Silt (%)	25
Clay (%)	20
Tex-class	Sandy loam

The physical and chemical properties of the soil in the experimental site are indicated in Table 2. The is sandy loam in texture, slightly alkaline in soil pH, low in organic Carbon% and total nitrogen [26], medium in the CEC [24] and Exchangeable K [27], and low in available P [22]. The continuous cultivation without using an organic source of fertilizer may result low level of organic carbon and total nitrogen under the experimental soil.

3.2 Effect of K Level and Time of Application on Wheat Yield and Yield Components

3.2.1 Plant height and spike length

Results in Table 3 depicted that, the average plant height was increased with increasing K application levels even though they are not statistically significant at full dose of K application at planting except control. On the contrary, time of application of K significantly affected plant height as compared to full dose at planting. In line with this, the tallest plant (75.2 cm) was measured on plots that received 60 kg/ha of K_2O in split application even though it is statistically similar with the treatments which received 40 and 80 kg/ha K_2O in split applications. But, the shortest plant height was measured at the control. Likewise, an increasing trend in spike length with increasing K levels and time of application was observed even though it statistically similar except control. These findings are in accordance with the research findings of [28] who reported that spike length of wheat was not significantly affected by any of the K levels.

3.2.2 Number of seeds/spike, Grain yield and straw yield

As it is depicted in Fig. 2 and Table 3 the K rates significantly affected number of seeds/spike, grain and straw yields of wheat. The number of seeds/spike, grain and straw yields of wheat were increased with the increased application of K rates. Moreover, split application of K significantly affected the yield and yield components of wheat as compared with the full dose application of K at planting itself. In line to this, the more number of seeds/spike of wheat was obtained at 60 kg/ha K_2O while, the highest grain and straw yields of wheat were obtained at 80 kg/ha K_2O levels and is statistically similar with the split application of 40 and 60 kg/ha K_2O.This implies that the 40 kg/ha K_2O by split application considered as economically feasible (optimum) level of K for wheat production in the Cambisols of the area studied.

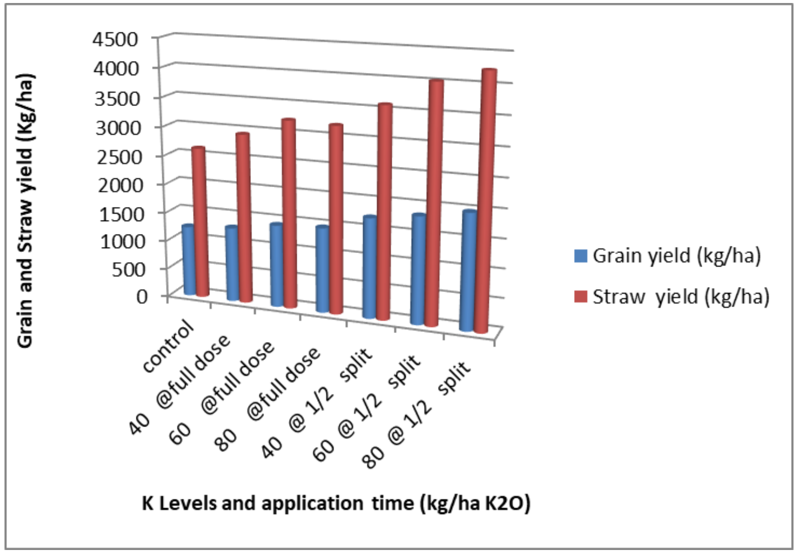

Fig. 2. Effect of potassium level and time of application on grain and straw yield of wheat in Cambisols of Enderta

Table 3. Effect of K level and time of application on yield and yield components of wheat on Cambisols of Enderta

Treatment	Method of application	plant height (cm)	Spike length(cm)	No.seed/spike	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index	1000 seed weight
Control (without fertilizer)		51.3^{d}	6.11^{b}	21.22^{e}	1236.1^{c}	2636.1^{c}	0.32	26.5^{c}
40 K_2O kg/ha @	full dose	54.22^{dc}	6.9^{a}	26.22^{dc}	1300.1^{c}	2938.8^{c}	0.31	28.3^{bc}
60 K_2O kg/ha @	full dose	61.94^{bc}	6.9^{a}	26.8^{dc}	1432.4^{c}	3236.3^{bc}	0.31	28.1^{bc}
80 K_2O kg/ha @	full dose	61.02^{bc}	6.9^{a}	27.8^{bc}	1473.3^{bc}	3210^{bc}	0.32	28.5^{bc}
40 K_2O kg/ha @	split	68.33^{ba}	7.04^{a}	28.9^{bac}	1729.2^{ba}	3602.5^{ba}	0.32	29.8^{ba}
60 K_2O kg/ha @	split	75.2^{a}	7.21^{a}	31.6^{a}	1845^{a}	4025.3^{a}	0.31	32.8^{a}
80 K_2O kg/ha @	split	69.3^{ba}	7.03^{a}	28.9^{ba}	1986^{a}	4245.7^{a}	0.32	31.9^{a}
LSd(0.05)		**9**	0.42	3.4	258.2	660	0.05	3.3
Cv(%)		**8.3**	**3.6**	**7.2**	**9.6**	**11.2**	**8.6**	**6.4**
P level(@0.005)		**0.0007**	**0.0005**	**0.0003**	**<0.0001**	**0.001**	**0.9**	**0.008**

Table 4. Effect of K fertilizer and application time on agronomic efficiency and partial factor productivity

Treatments K_2O (kg/ha)		N (kg/ha)	K (kg/ha)	Total nutrient (kg/ha)	Grain yield (kg/ha)	AE (kg/kg of K_2O)	PFP (kg/kg of K_2O
Control (without fertilizer)					1236.1		
40 K_2O kg/ha @	full dose	64	33.2	97.2	1300.1	0.66	13.4
60 K_2O kg/ha @	full dose	64	49.8	113.8	1432.4	1.72	12.6
80 K_2O kg/ha @	full dose	64	66.4	130.4	1473.3	0.31	11.3
40 K_2O kg/ha @	split	64	33.2	97.2	1729.2	3.05	17.8
60 K_2O kg/ha @	split	64	49.8	113.8	1845	1.02	16.2
80 K_2O kg/ha @	split	64	66.4	130.4	1986	1.97	15.2

AE = agronomic efficiency; PFP= partial factor productivity.

3.2.3 Harvest index and 1000 seed weight

The harvest index was not significantly affected by the K levels and method of application. On the other hand, 1000 seed weight was increased with the application of K levels even though not consistent. Application method of K had significant effect on 1000 seed weight and higher 1000 seed weight under split applications as compared to single application of full dose of K. Moreover, the highest of all was obtained at the rate of 60 kg/ha of K_2O at split method and statistically on par with 40 and 80 kg/ha of K_2O by split application.

3.3 Agronomic Efficiency (AE) and Partial Factor Productivity (PF)

Datain Table 4 showed that the higher agronomic efficiency and partial factor productivity (grain yield per unit quantity of nutrient applied) were observed at the split application methods of K as compared with single full dose application. In line to this, the highest agronomic efficiency and partial factor productivity was obtained at the level of 40 kg/ha K_2O in split forms and the lowest was at 80 kg/ha K_2O in single full dose. This shows that split application of potassium increases agronomic use efficiency and partial factor productivity of wheat in the Cambisols of Enderta district.

4. CONCLUSION

The study was aimed at optimum levels of potassium fertilization and its method of application for wheat cultivation in Cambisols Enderta district. The results indicated that plant height, spike length, number of seeds/spike, grain yield, straw yield, and 1000 seed weight of wheat were significantly responded to the K levels and time of application .In line to this, the highest grain and straw yield of wheat were obtained at a levels of 80 kg/ha K_2O in split application methods and statistically similar with 40 and 60 kg/ha K_2O.This showed that 40 kg/ha K_2O in the form of split application was economically feasible level of K in the Cambisols of Enderta. Similarly, the highest agronomic efficiency and partial factor productivity were also obtained at the level of 40 kg/ha K_2O in split forms. Hence, potassium fertilization it is concluded that the potassium should be applied in split methods rather than full dose at planting for increasing wheat yield and improving agronomic efficiency and partial factor productivity in the Cambisols of Enderta districts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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