Wheat (Triticum Aestivum L.) Response to Applied Potassium on Two Contrasting Soil Types (Vertisols and Cambisols) in The Central Highlands of Ethiopia

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Research

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Abstract

Background: A field experiment was conducted at Basonawerana district, Amhara regional state on two major soil types for three consecutive years to determine the effect of application of potassium fertilizer on yield and yield components of wheat and to verify the soil fertility and fertilizer recommendation Atlas of the study site. Six levels potassium were applied (0, 15, 30, 45, 60 and 75 kg K ha^{-1}). At each potassium levels, a balanced nutrient of 92 kg N, 30 kg P, 30 kg S, 2 kg Zn, 0.5 kg Cu and 0.5 kg B ha^{-1} were applied. The experiment was laid out in a randomized complete block design with tree replications.

Result: The analysis of variance showed that all the measured parameters were Significant influenced by year, soil type and the interaction of year x soil type. The highest grain yield, which was observed from cambisols during the first year was increased grain yield by 176.7 % (3954 kg ha^{-1}) compared with the lowest yield observed from vertisols during the third year. Similar trend was also observed in straw yield and harvest index. On the other hand, all the measured parameters was non-significant influenced by K rate, interaction of K rate x soil type and year x K rate x soil types. Numerically, the highest yield (3878.9 kg ha^{-1}) was observed from the highest K rate. However, the trend was not consistent.

Conclusion: application of different rates of potassium fertilizer brings any significant growth and yield response on two soil types of the study sites. So, application of this fertilizer is not recommended for the crop with such high K soil status.

Background

Bread wheat is the most important cereal crop in Ethiopia. It is cultivated on more than 1.75 million hectare with a total production of 4.8 million tons. The national average productivity of wheat (2.7 tone ha) [1] was still lower than world's average (3.4 tone ha) [2]. To overcome the gap between the actual and potential yield, application of suitable source, type, rate and timing of organic and inorganic fertilizer is crucial as proper combination of fertilizer increase the yield of crop by 50% [3].

In Ethiopia, many of the smallholder farmers have good awareness on the contribution of inorganic fertilizer for crop production. However, only 30 to 40% of them use fertilizer with average rate of 37 to 40 kg ha^{-1}, which is below the recommended rate for the country [4]. Nevertheless, for the past several years, farmers in the country apply nitrogen (N) and phosphorus (P) fertilizer in the form of di-ammonium phosphate and urea respectively. However, studies in Ethiopia indicated that application of N and P without considering other macro and micronutrient including K and cultivation of high yielding genotypes resulted in depletion of soil nutrient, nutrient imbalance and increase the deficiency gap [5,6].

The role potassium fertilizer on crop production was not prioritized since 1960s mainly due to the prevailing belief that Ethiopian soil are rich in potassium (Murphy 1968). This recommendation is based on the research finding of some 50 years ago during a national freedom from the hunger campaign implemented in 1963. Recently deficiency of potassium observed and reported in Ethiopian soil [7–13]. Similarly, recent studies also showed that application of potassium containing fertilizer resulted in positive crop response [14–17].

Hence, the present study were conducted to determine the effect of application of potassium fertilizer on yield and yield components of wheat on two major soil types of the study sites and to verify the soil fertility and fertilizer recommendation Atlas of the study site.

Material And Methods

The study site

The present study was conducted in the district of Basonaworana district for three consecutive years during 2014 to 2017. Geographically, the district is located at $9^0$43'58" to $9^0$52'42" E and $39^0$25'28" to $39^0$40'08" N in the central highlands of Ethiopia. The district is characterized by bimodal rainfall. The average annual rainfall, minimum and maximum temperature of the districts are found to be 1029mm, 13.7 and 18 respectively. The major crops widely grown in the study areas include barley, wheat and faba bean.

Experimental set-up and procedure

The experiment included six levels potassium (0, 15, 30, 45, 60 and 75 kg K ha^{-1}). To maintain the balanced availability of nutrient, at each potassium levels a balanced nutrient of 92 kg N, 30 kg P, 30 kg S, 2 kg Zn, 0.5 kg Cu and 0.5 kg B were applied. Treatment sequencing was randomized using randomized complete block design (RCBD) on a plot size of 3.6m × 3.4m (12.24 m^2) with three replicates. The spaces between treatments and blocks were 1 m and 1.5 m, respectively. Sowing was done end of June and second week of July in cambisols and Vertisols, respectively. Phosphorus, potassium and sulfur were applied as triple supper phosphate, potassium chloride and calcium sulfate at planting, respectively. Nitrogen as urea was applied half at planting and the other half at tillering stage of the crop with presence of soil moisture. Micronutrients including boron as borax, Copper as Copper sulfate and zinc as zinc sulfate were applied on vegetative part of wheat as foliar. Other standard agronomic practices were applied as per the recommendations for the crop. The wheat variety, Diglo was planted with row spacing of 20 cm apart at a seed rate of 131.25 kg ha^{-1}.

Before planting, soil samples (0–20 cm) were collected from ten sampling spot. The soil samples were analyzed for the selected physicochemical properties following the procedure outlined by [18] The analysis result of soil samples were presented in Table 1.

Data Collection and measurement

The following data were collected and analyzed for this study;

Plant height: Plant height was expressed in centimeters by measuring the height of ten randomly taken plants from the ground level to the tip of the spike excluding awn at 50 % flowering and maturity.

Spike length: Measured from base of spike to tip excluding awn from 10 randomly chosen plants.

Number of total tillers per plant: The average number of total tillers developed per plant.

Number of fertile tillers per plant: The average number of productive tillers having spike per plant.

Biomass Yield: Was determined from harvested plant close to the surface from a net plot area. The sample was dried for about 10 days in an open air.

Grain Yield: Was determined by weighing clean threshed seeds from the net plot area. The yield was adjusted to 12.5% grain moisture, which was determined using a grain moisture taster (Gravimetric method).

Straw yield: Was calculated as the difference between above-ground biomass and grain yield.

Harvest Index: Was calculated as the ratio of grain yield to above ground biomass yield on dry weight basis

Data analysis

The data recorded for different parameters were statistically analyzed using the SAS program. The difference between the treatments means were compared by the least significance difference (LSD) test at 5% level of significance after performing ANOVA [19].

Result And Discussion

Plant height and spike length

Plant height is one of the most important agronomic parameter, directly influence straw yield, and sometimes influence grain yield of wheat [20].

The analysis of variance showed that plant height was not significantly influenced by application of different rate of K. The non-significant effect observed with this study was in controversy with the previous research report in Ethiopia and elsewhere in the world [21–23]. However, the effect of year, soil type and the interaction of year × soil type were found to be highly significant. The highest plant height (102.5 cm) was observed in cambisols during the second year. While, the lowest plant height (77.2 cm) was observed in cambisols during the first year. The highest yield obtained from cambisols was explained by the fact that this soil is characterized by well drainage compared with vertisols. Similarly, spike length was not significantly influenced by K rate, interaction of K rate x year, K rate x soil type and K rate x year x soil type . Nevertheless, the effect of soil type, year and the interaction soil type × year were found significant (Table 2).

Total and fertile number of tillers

Tillering allows the plant to expand and to produce more ears and, therefore, more grains per plant when inter plant competition is low. Tillers, thereby permit the wheat crop to compensate partly for adverse conditions such as improper germination and establishment, frost or hail injury, pest attack and grazing damage. The analysis of variance showed that total number of tiller was significantly influenced by soil type, year, and the interaction of year × soil type. The highest number of tiller was observed in cambisols (6.2) during the third year. The analysis of variance also showed that the response of total tiller for K rate, interaction of K rate x year and K rate x year x soil type. was found to be non-significant (Table 3). Similar result was also observed on number of fertile tiller per plant (Table 3)

Biomass Yield (kg ha^{-1})

The analysis of variance showed that biomass of wheat was not influenced by the K rate. The same is true for the interaction of K rate × year, K rate × soil type and K rate x year x soil type (Table 2). Numerically the highest biomass yield was recorded from the highest K rate (75 kg K ha^{-1}) which increased biomass yield by 1.6% (153.2 kg ha^{-1}) compared with the control. In the other hand, biomass yield was significantly influenced by year, soil type and the interaction of year x soil type. The highest biomass yield, which was observed from cambisols (11724.3 kg ha^{-1}) increased biomass yield by 44.5% (5216 kg ha^{-1}) compared with the biomass recorded from vertisols (Table 5).

Similarly, the highest biomass yield was recorded from the second year increase grain yield by 32% (2053.1 kg ha^{-1}) compared with the lowest yield observed from the third year (Table 5)

Grain yield (kg ha^{-1})

Grain yield is one of the most important parameters in assessing crop response to the applied nutrient. The analysis of variance showed that the impact of K rate on yield was found non-significant. Similarly, the interaction of K rate × year and K rate × soil type as well as the three way interaction between K rate × Year × soil type was found non-significant (Table 2). On the other hand, seed yield was significantly responded for soil type, year and the interaction between year x soil type. The highest grain yield, which was observed from cambisols was increased grain yield by 69.9 % (2801.4 kg ha^{-1}) compared with the lowest yield observed from vertisols. The highest yield obtained from cambisols was explained by the fact that this soil is characterized by well drainage compared with vertisols. In Ethiopia, the issue of application of potassium to crops is still a controversy and need well refined research. For instance, the soil atlas map developed by EthioSIS developed in 2016 indicated that 94 % of cultivated lands of the region including the study site are potassium deficient and application of potassium fertilizer was recommended [13] . The present study was in controversy with the previous findings reported by different scholars [16,17,21,24,25]. This might be probably because of the optimum potassium content of the experimental field (Table 1).

Straw yield

Wheat residue, locally known as “Geleba”, is important as a feed resource for livestock especially during the dry months of the year when green fodder is unavailable.

The analysis of variance indicated that straw yield was not significantly affected by the K rate, interaction effect of K rate x year, K rate x soil type and K rate x year x soil type (Table 2). On the other hand, this parameter was significantly influenced by the soil types, year and the interaction of year x soil type (Table 2). The highest straw yield, which was observed from Cambisols increased straw yield by 69.9% (2801.4 kg ha^{-1}) compared with straw yield recorded in Vertisols (Table 5). Similar to the grain yield, numerically the highest straw yield was observed from the plot received 30 kg K ha^{-1} (Table 5).

Harvest Index

Harvest index determines the amount of photosynthates being translocated to the economic parts of plant. The analysis of variance showed that harvest index was significantly affected by soil type, year and interaction effect of year x soil type (Table 2). Like other growth and yield parameters, the highest harvest index (0.48) was recorded from cambisols during the first year. Correspondingly, the highest harvest index was recorded from highest K rate (0.42), cambisols (0.43) and during the third year (0.45) (Table 5).

Conclusion

Generating reliable information on response of wheat to applied potassium fertilizer is important to farmers, policy maker, fertilizer producer and supplier. In this regard, the present study was conducted to determine the effect of application of potassium fertilizer on yield and yield components of wheat on two major soil types and of the study sites. The result indicated that application of potassium fertilizer brings any significant growth and yield response on two soil types of the study sites. So, application of this fertilizer is not recommended for the crop with such high K soil status.

Abbreviations

E: Easting; N: Northing; M.a.s.l: meter above sea level; ^{o}C: degree Celsius; K: Potassium; N: Nitrogen; P: phosphorus; S: Sulfur; Zn: Zinc; Cu: Copper; B: Boron; RCBD: Randomized complete block design; LSD: Least significance difference; ANOVA: Analysis of variance; CV: Coefficient of variation; Ca: Cambisols; Ve: Vertisols; By: Biomass yield; GY: Grain yield: SY: Straw yield; HI: Harvest index; PH: Plant height; SL: Spike; NTT: Number of total tiller; NFT: Number of fertile tiller length; BY: Biomass yield; GY: Grain yield; SY: Straw yield; HI: Harvest Index; SV: Sources of variation.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The authors want to declare that they can submit the data at whatever time based on your request. The datasets used and/or analyzed during the current study will be available from the corresponding author on reasonable request.

Competing Interest

The authors declare that they have no competing interests.

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Authors' contribution

BS conceived the study and design, collected and encode the data, performed the analysis, interpreted the result, wrote the manuscript. SA, KK and GS also assisted in designing, analysis and interpretation of data and drafting of the manuscript. All authors read and approved the final manuscript.

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Tables

Table 1. Soil physic chemical properties of the experimental site

Soil properties	Cambisols	Vertisols	Rating	Reference
Particle size distribution				
Sand (%)	32	25.7		
Silt (%)	31	26		
Clay (%)	37	48.3		
Textural class	Clay loam	Clay		
CEC	42.5	46.7		
pH (1:2.5 suspension)	6.7	7.2	Neutral	Tekalign (1991)
Total Nitrogen (%)	0.1	0.1	Low	Tekalign (1991)
Organic carbon (%)	0.73	0.61	Low	Tekalign (1991)
Soil organic matter (%)	1.26	1.05	Low	Tekalign (1991)
Olsen's P (mg kg-1)	6.5	6.3	Low	Landon (1991)
extractable K	0.6	0.8	High	Berhanu (1985)

Table 2. Mean square value of ANOVA for Rep, Year, K rate, soil type and yield and their interaction

SV	DF	PH	SL	TNT	TNFT	BY	GY	HI
Rep	2	11.5^{ns}	0.383^{**}	1.39^{ns}	1.62^{*}	442563^{ns}	354409^{ns}	992865^{ns}
Y	2	1488.4^{***}	6.859^{***}	5.48^{***}	2.81^{**}	67385006^{***}	7475635^{***}	37973055***
R	5	6.5^{ns}	0.016^{ns}	0.24^{ns}	0.26^{ns}	232767^{ns}	141612^{ns}	36342^{ns}
S	1	2092.6^{***}	21.592^{***}	108.1^{***}	141.98^{***}	734801861^{***}	157530101^{***}	211880902***
R*Y	10	12.5^{ns}	0.044^{ns}	0.31^{ns}	0.35^{ns}	483513^{ns}	132132^{ns}	199639^{ns}
R*S	5	6.9^{ns}	0.179^{ns}	0.21^{ns}	0.26^{ns}	741527^{ns}	201596^{ns}	261611^{ns}
Y*S	2	1823.2^{***}	23.117^{***}	22.36^{***}	29.97^{***}	290079272^{***}	16048419^{***}	170083544^{***}
R*Y*S	10	9.5^{ns}	0.078^{ns}	0.29^{ns}	0.34^{ns}	591515^{ns}	134098^{ns}	213949^{ns}
error	70	8.2	0.077	0.45	0.43	866922	168657	347985

SV Source of variation, DF degree of freedom, Rep replication, Y year, R K rate, S soil type, PH Plant height, SL Spike length, TNT Total number of tiller, TNFT Total number of fertile tiller, By Biomass yield, GY Grain yield, HI Harvest index

*Significant at the 0.05 probability level; **Significant at P<0.01 probability level, *** significant at p<0.001 probability level

Table 3 Main effect of K rate, soil type and year on plant height (PH), Spike length (SL), Total number of tiller (TNT) and Total number of infertile tiller

SV	PH	SL	TNT	TNIT
K Rate				
0	85.2	5.9	4.1	3.7
15	84.4	5.9	4.2	3.9
30	84	5.9	4.4	4.1
45	84.1	5.9	4.2	3.9
60	83.3	5.9	4.1	3.9
75	84.1	6	4.3	4.1
Soil Type				
Cambisols	88.6^{a}	6.4^{a}	5.2^{a}	5.1^{a}
Vertisols	79.8^{b}	5.5^{b}	3.2^{b}	2.8^{b}
Year				
1	77.2^{c}	5.4^{c}	4.2^{b}	3.8^{b}
2	89.9^{a}	6.3^{a}	3.8^{c}	3.7^{b}
3	85.4^{b}	6.1^{b}	4.6^{a}	4.3^{a}
CV	3.4	4.66	15.9	16.6

SV Source of variation, PH Plant height (cm), SL Spike length (cm), TNT Total number of tiller/Plant, TNIT Total number of fertile tiller/Plant

Year 1=2014, 2=2015, 3=2016

Means followed by the same letters for the same parameter are not significantly different at P≤0.05

Table 4 Interaction effect Soil type X year on PH, SL, TNT and TNFT

Year	Soil Type		Soil Type		Soil Type		Soil Type	
	Ca	**Ve**	**Ca**	**Ve**	**Ca**	**Ve**	**Ca**	**Ve**
	PH (cm)		**SL** (cm)		**TNT**		**TNFT**	
1	77.2^{c}	77.3^{c}	5.4^{c}	5.5^{c}	4.3^{c}	4.1^{c}	4^{c}	3.7^{c}
2	102.5^{a}	77.3^{c}	7.7^{a}	4.9^{d}	5.2^{b}	2.6^{e}	5.1^{b}	2.4^{d}
3	86.1^{b}	84.7^{b}	6.1^{b}	6^{b}	6.2^{a}	3^{d}	6.2^{a}	2.3^{d}
LSD (5%)	1.9		0.18		0.44		0.43	

Ca Cambisols, Ve Vertisols, PH Plant height, SL Spike length, TNT Total number of tiller/plant, TNFT Total number of fertile tiller/plant

Year 1=2014, 2=2015, 3=2016

Means followed by the same letters for the same parameter are not significantly different at P≤0.05

Table 5 Main effect of K rate, soil type and year on biomass yield (BY), grain yield (GY), straw yield (SY) and harvest index (HI)

SV	BY	GY	SY	HI
K Rate				
0	8992.4	3654.8	5337.7	0.41
15	9155.5	3715.6	5439.9	0.41
30	9102.9	3651.6	5451.3	0.41
45	9122.5	3729.4	5393.1	0.41
60	9013.5	3646.8	5366.8	0.41
75	9308.7	3878.9	5429.8	0.42
Soil Type				
Cambisols	11724.3^{a}	4920.6^{a}	6803.8^{a}	0.43^{a}
Vertisols	6507.5^{b}	2505.1^{b}	4002.4^{b}	0.39^{b}
Year				
1	8762.3^{b}	3323.8^{c}	5438.5^{b}	0.37^{c}
2	10626.2^{a}	4214.2^{a}	6411.9^{a}	0.42^{b}
3	7959.3^{c}	3600.5^{b}	4358.8^{c}	0.45^{a}
CV	10.21	11.06	10.91	4.89

SV Source of variation, BY Biomass Yield (kg ha^{-1}), GY Grain yield (kg ha^{-1}), SY Straw yield (kg ha^{-1}), HI Harvest index

Year 1=2014, 2=2015, 3=2016

Means followed by the same letters for the same parameter are not significantly different at P≤0.05

Table 6 Interaction effect Soil type X year on BY, GY, SY and HI

Year	Soil Type		Soil Type		Soil Type		Soil Type	
	Ca	**Ve**	**Ca**	**Ve**	**Ca**	**Ve**	**Ca**	**Ve**
	BY (kg ha^{-1})		**GY** (Kg ha^{-1})		**SY** (kg ha^{-1})		**HI**	
1	9338^{b}	8186^{c}	6191^{a}	2733^{d}	10287^{a}	4888^{c}	0.48^{a}	0.42^{c}
2	16478^{a}	4775^{e}	4468^{b}	2545^{d}	5641^{b}	3829^{d}	0.47^{a}	0.38^{d}
3	9357^{b}	6562^{d}	4102^{c}	2237^{e}	5236^{c}	2537^{e}	0.44^{b}	0.31^{e}
LSD (5%)	617		273		392		0.01	

Ca Cambisols, Ve Vertisols, By Biomass yield, GY Grain yield, SY Straw yield, HI Harvest index

Year 1=2014, 2=2015, 3=2016

Means followed by the same letters for the same parameter are not significantly different at P≤0.05

Figures

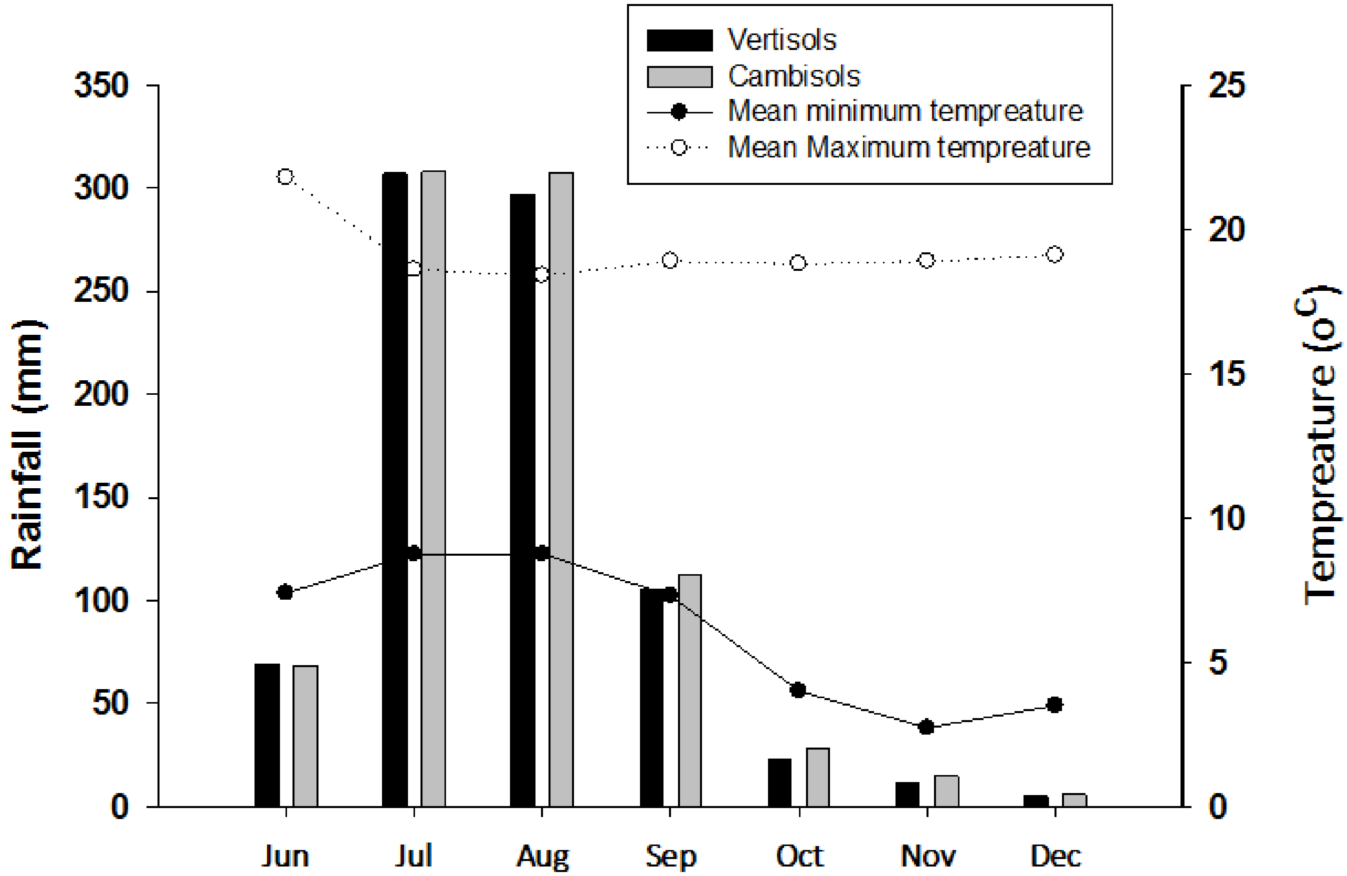

Figure 1

Average rainfall, minimum temperature and maximum temperature for the growth period