

Soil K Status and K Requirement of Potato Growing on Different Soils of Western Amhara

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Abstract

An experiment was conducted in 2005/06 and 2006/07 cropping seasons on Nitisols, Acrisols and Luvisols of Western Amhara to investigate the inherent soil K status and K requirement of potato growing on these soils. The field experiments were conducted in Yilmana Densa (West Gojjam Zone), Farta (South Gondar Zone) and Banja (Awi Zone) woredas. Soil samples were collected from experimental sites before planting of potato and analyzed for exchangeable K status. The treatments included in the field experiment were 6 levels of potassium fertilizer (0, 30, 60, 90, 150 and 210 kg K₂O ha⁻¹) that were arranged in randomized complete block design with three replications. All of the K fertilizer for each treatment was band-applied at planting along and in one side of the rows at a distance of 5 cm below and 5 cm aside the seeds. Muriate of potash (KCl) was used as a source of K. Moreover, 81kg N and 69kg P₂O₅ (recommended rates for western Amhara) were added to all plots. This was done by applying 150kg DAP and 58.5kg urea at planting and side dressing 58.5kg urea at flowering stage. Results of the experiment indicated that there was no significant increase in potato tuber number, plant height, number of main stems per plant, potato dry matter yield due to increase in K fertilizer rate on Nitisols, Acrisols and Luvisols. However, increase in K fertilizer rate significantly increased mean tuber weight and tuber yield of potato on Acrisols of Banja Woreda and improved shelving life of potato collected from all soil types.

Keywords: Acrisol, Luvisol, Nitosol, yield, yield components

Introduction

Of all the essential elements, potassium is the third most likely crop yield limiting nutrient after nitrogen and phosphorus. It plays a critical role in lowering cellular osmotic water potentials, thereby reducing the loss of water from leaf stomata and increasing the ability of root cells to take up water from the soil. Potassium is also essential for photosynthesis, protein

synthesis, nitrogen fixation in legumes and for starch formation and increasing tuber yield (Brady and Weil, 2002). It is also especially important in helping plants adapt to environmental stresses like drought and frost. Nevertheless, this nutrient has received little attention in Ethiopian agriculture. This is mainly because K has been regarded as adequately available nutrient in Ethiopian Soils. Murphy (1963) in his work, which is recognized as the first systematic approach in characterizing the nutrient status of Ethiopian soils, reported that Ethiopian soils have adequate potassium. However, his work lacked adequate data on crop yield response to fertilizers (Taye, 1998). Moreover, more recent information of Mesfin (1998) indicated that Ethiopian Alfisols, as all moderately to intensively weathered soils, have limited amounts of basic rocks that usually contain more easily weatherable potassium, which affects the potassium content of these soils. This situation could be even worse on more weathered and leached Ultisols of Injibara area where potato is widely cultivated.

It is also apparent that intensive cropping in the absence of K replenishment would not only lead to "hidden hunger" but also can precipitate diminished productivity. Therefore, preliminary study on potassium status of Nitisols, Acrisols and Luvisols would help to devise strategies for proper soil fertility management. Moreover, studying the K requirement of potato, a crop which is believed to be highly responsive to K application, may play a significant role in improving land productivity and assist the food security endeavors of the region. Therefore, the objective of this study was to assess the potassium status of Nitisols, Acrisols and Luvisols and investigate the K requirement of potato growing on these three soils of western Amhara.

Materials and Methods

Determination of Soil K Status

Representative soil samples were collected from Nitisols, Acrisols and Luvisols of western Amhara where potato is intensively cultivated. Exchangeable potassium was determined by extracting potassium with 1N NH_4OA and analyzing the K status as outlined in Sahlemedihin and Taye (2000).

Treatments experimental design and field lay out

The field experiment was conducted in Yilmana Densa, Farta and Banja woredas representing three soils of western Amhara. The

treatments included in the experiment were 6 levels of potassium fertilizer; i.e., 0, 30, 60, 90, 150 and 210 kg K₂O ha⁻¹.

The treatments were arranged in randomized complete block design with three replications. The gross plot size of the experimental site was 3.0m x 3.0m (9.0m²) and the net plot size was 1.5m x 2.4m (3.6m²). Spacing between rows was 75cm and between plants was 30cm. The distance between plots was 0.5m and between blocks was 1.0m

Fertilizer application and cultural practice

All of the K fertilizer for each treatment was band-applied at planting along and in one side of the rows at a distance of 5 cm below and 5 cm aside the seeds. Muriate of potash (KCl) was used as a source of K. Moreover, 81kg N and 69kg P₂O₅, recommended rates for western Amhara (personal communication), was added to all plots. This was done by applying 150kg DAP and 58.5kg urea at planting and side dressing 58.5kg urea at flowering stage. Weeding and ridging operations were conducted to all plots as necessary.

Statistical Analysis

Analysis of variance and simple regression analysis were carried out for yield and yield components studied following statistical procedure appropriate for the experimental design. Whenever, treatment effects were found significant, the means were separated using Duncan's Multiple Range Test using SAS statistical package (SAS Institute, 1999).

Results and Discussion

Soil Potassium Status

In 2005/06 and 2006/07 cropping seasons, the experiments were conducted on five and six location, respectively located in Yilmana Densa, Banja and Farta woredas. The results of soil analysis indicated that Nitosols of Yilmana Densa had better K status followed by Luvisols of Farta . Acrisols of Banja had the lowest values (Table 1).

Table 1. Exchangeable K status of different soils covered by the experiment in 2005/06

Location	Woreda	Soil Type	Exchangeable K ($\text{cmol}_c \text{ kg}^{-1}$)
Mossobo	Yilmana Densa	Nitosol	0.814
Adet Hanna	Yilmana Densa	Nitosol	0.712
Wonjella	Banja	Acrisol	0.102
Debre tabor	Farta	Luvisol	0.305
Tsegur	Farta	Luvisol	0.407

Soil analysis results of soils samples collected from six experimental sites in Yilmana Densa, Banja and Farta woredas in 2006/07 cropping season also indicated in Table 2. Based on the results, Nitosols of Yilmana Densa Woreda contained relatively higher amount of exchangeable K followed by Luvisols of Farta Woreda and Acrisols of Banja Woreda.

Table 2. Exchangeable K status of different soils covered by the experiment in 2006/07

Location	Woreda	Soil Type	Exchangeable K ($\text{cmol}_c \text{ kg}^{-1}$)
Mossobo	Yilmana Densa	Nitosol	1.41
Debre Mewi	Yilmana Densa	Nitosol	1.32
Biden Jebella	Banja	Acrisol	0.18
Injibara	Banja	Acrisol	0.22
Debretabor	Farta	Luvisol	0.51
Tsegur	Farta	Luvisol	0.41

The two years results indicated that, based on Beerneart (1990), K status is high and very high in Nitosols of Yilmana Densa, medium in Luvisols of Farta and low in Acrisols of Banja.

Potato Tuber Number

Potassium fertilizer rate did not have a significant effect on potato tuber number at four of the five locations in 2005/2006. A significant difference in potato tuber number per plant due to K fertilizer application was achieved only on Acrisols of Wonjella in Banja Woreda (Table 3). However, the significant increase was achieved up to application of $30\text{kg ha}^{-1} \text{ K}_2\text{O}$.

Increasing the rate beyond this rate did not bring a significant effect on the parameter considered.

Table 3. The Effect of K Fertilizer Rates on Potato Tuber number in 2005/06 cropping season (number/3.6m²)

Treatments	Location				
	Mossobo Nitosol	Adet Hanna Nitosol	Wonjella Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha ⁻¹	166.7a	135.0a	33.7b	126.0a	94.7a
30 kg ha ⁻¹	141.0a	130.0a	57.0a	133.3a	122.0a
60 kg ha ⁻¹	195.0a	101.7a	55.3a	94.7a	94.7a
90 kg ha ⁻¹	171.7a	124.3a	34.0b	112.3a	103.0a
150 kg ha ⁻¹	187.3a	112.7a	39.3b	109.7a	146.0a
210 kg ha ⁻¹	149.0a	115.0a	32.7b	107.7a	136.7a
CV (%)	17.6	20.3	15.9	28.3	31.4
<i>P</i> (0.05)	ns	ns	*	ns	ns

* = significant; ns= not significant

However, results of the experiment conducted in 2006/07 cropping season indicated that application of K fertilizer also did not give a significant effect on number of tubers produced per plant across all locations (Table 4). It is worthy enough to note that locations incorporated in the experiment in this year in each Woreda had relatively higher exchangeable K levels as compared to sites included in each Woreda in the previous year which generally diminished the effect of K fertilizer on this parameter.

Table 4. The Effect of K Fertilizer Rate on tuber number in 2006/07 cropping season (number per 3.6 m²)

Treatments	Location					
	Mossobo Nitosol	Debre Mewi Nitosol	Biden Jebella Acrisol	Injibara Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha ⁻¹	76.3 a	76.3 a	89.0 a	94.0 a	104.0 a	71.7a
30 kg ha ⁻¹	79.3 a	76.3 a	85.0 a	117.0 a	93.7 a	71.0 a
60 kg ha ⁻¹	57.0 a	62.0 a	76.7 a	108.7 a	116.3 a	89.0 a
90 kg ha ⁻¹	78.3 a	59.0 a	90.7 a	113.7 a	112.3 a	93.3 a
150 kg ha ⁻¹	64.0 a	75.3 a	99.7 a	105.3 a	86.3 a	101.0 a
210 kg ha ⁻¹	57.3 a	55.7 a				

The result obtained in 2006/07 cropping season also indicated that potassium fertilizer did not give a significant effect on plant height of potato plants on four of the five testing sites included in the experiment (Table 6).

Table 6. The Effect of K Fertilizer Rate on plant height of potato in 2006/07 cropping season (cm)

Treat- ments	Location					
	Mossobo Nitosol	Debre Mewi Nitoso l	Biden Jebella Acrisol	Injibara Acrisol	Debre Tabor Luviso l	Tsegur Luvisol
0 kg ha ⁻¹	49.2 a	46.6 a	46.6 a	20.3 b	49.6 a	49.1 a
30 kg ha ⁻¹	51.2 a	47.2 a	44.3 a	23.0 ab	52.2 a	48.6 a
60 kg ha ⁻¹	49.3 a	44.5 a	44.9 a	24.1 ab	54.3 a	52.8 a
90 kg ha ⁻¹	51.8 a	43.8 a	45.7 a	25.9 ab	56.1 a	53.2 a
150 kg ha ⁻¹	45.6 a	43.3 a	44.9 a	25.5 ab	52.6 a	52.3 a
210 kg ha ⁻¹	50.0 a	44.7 a	46.9 a	26.9 a	55.8 a	49.7 a
CV (%)	8.9	5.4	11.8	12.1	6.4	7.6
<i>P</i> (0.05)	ns	ns	ns	*	ns	ns

* = significant; ns= not significant

It is, therefore, possible to suggest that potassium nutrient may not have a significant contribution in increasing the height of potato plants.

Number of Main Stems per Plant

Application of different rates of K fertilizer did not affect the number of main stems per plant of potato at all of the locations included in 2005/06 cropping season (Table 7).

Table 7. The Effect of K Fertilizer Rates on number of main stems per plant of potato in 2005/06 cropping season (number/plant)

Treatments	Location				
	Mossobo Nitosol	Adet Hanna Nitosol	Wonjella Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha ⁻¹	5.0a	4.7a	3.0a	4.0a	6.3a
30 kg ha ⁻¹	3.7a	4.7a	3.7a	3.7a	5.7a
60 kg ha ⁻¹	5.0a	5.0a	3.0a	4.3a	5.7a
90 kg ha ⁻¹	4.3a	5.3a	3.3a	3.7a	5.3a
150 kg ha ⁻¹	4.7a	5.3a	3.0a	4.3a	6.0a
210 kg ha ⁻¹	4.3a	5.0a	3.0a	3.7a	6.3a
CV (%)	28.7	19.7	14.1	12.8	12.7
<i>P</i> (0.05)	ns	ns	ns	ns	ns

ns= not significant

Similar trend was observed in 2006/07 cropping season as that of the previous year. Significant effect was observed only at Acrisol of Injibara on-

Mean Tuber Weight

Application of K fertilizer gave a significant effect on mean tuber weight of potato at 3 locations (Adet Hanna Nitosol, Wonjella Acrisol and Tsegur Luvisol) out of the five locations incorporated in the experiment in 2005/06 cropping season (Table 9).

Table 9. The Effect of K Fertilizer Rate on mean tuber weight of potato in 2005/06 cropping season (gm/tuber)

Treat-ments	Location				
	Mossobo Nitosol	Adet Hanna Nitosol	Wonjella Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha ⁻¹	59.1 a	70.5 ab	19.3 b	35.4 a	63.2 ab
30 kg ha ⁻¹	61.5 a	61.1 b	24.1 ab	35.6 a	53.6 ab
60 kg ha ⁻¹	50.4 a	82.5 a	24.8 ab	44.0 a	75.3 a
90 kg ha ⁻¹	56.3 a	65.6 ab	30.1 ab	45.4 a	68.2 ab
150 kg ha ⁻¹	47.4 a	70.3 ab	24.3 ab	46.1 a	52.3 b
210 kg ha ⁻¹	60.5 a	68.8 b	33.1 a	46.9 a	55.0 b
CV (%)	12.9	13.5	22.0	18.9	17.1
<i>P</i> (0.05)	ns	*	*	ns	*

* = significant; ns= not significant

However, in 2006/07 cropping season only two locations in Banja woreda which have Acrisol soil type gave significant difference in mean potato tuber weight (Table 10). From the results of the experiments of the two years it is possible to conclude that this yield component affected tuber yield of potato on Acrisol of Banja Woreda. Therefore, in both years, significant effect on mean tuber yield was obtained on Acrisols of Banja Woreda.

Table 10. The Effect of K Fertilizer Rate on mean tuber weight of potato in 2006/07 cropping season (gm/tuber)

Treat-ments	Location					
	Mossobo Nitosol	Debre Mewi Nitosol	Biden Jebella Acrisol	Injibara Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha ⁻¹	88.7 a	63.3 a	29.5 b	29.6 c	61.1 a	53.9 a
30 kg ha ⁻¹	87.3 a	61.7 a	45.9 a	32.4 cb	76.3 a	47.7 a
60 kg ha ⁻¹	95.5 a	70.7 a	43.6 ab	36.1 ab	59.0 a	58.2 a
90 kg ha ⁻¹	97.5 a	69.4 a	45.1 a	41.0 a	59.3 a	55.5 a
150 kg ha ⁻¹	83.4 a	65.5 a	48.2 a	40.3 a	71.2 a	50.1 a
210 kg ha ⁻¹	93.7 a	65.9 a	46.5 a	42.0 a	68.3 a	54.8 a
CV (%)	8.4	10.3	19.4	9.1	23.9	22.6
<i>P</i> (0.05)	ns	ns	*	*	ns	ns

* = significant; ns= not significant

Percent Tuber Dry Matter Yield

Application of different rates of K fertilizer did not affect the % tuber dry matter yield at four of the five locations. At Adet Hanna Nitosol, where significant difference was achieved, the data seem inconsistent and lack clear trend to make a conclusion (Table 11). Therefore, it is possible to suggest that K nutrient does not contribute a lot in determining potato dry matter yield.

Table 11. The Effect of K Fertilizer Rates on % tuber dry matter yield of potato in 2005/06 cropping season

Treatments	Location				
	Mossobo Nitosol	Adet Hanna Nitosol	Wonjella Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha ⁻¹	17.1a	22.5ab	22.4a	24.6a	24.1a
30 kg ha ⁻¹	16.6a	22.9ab	18.7a	23.4a	23.2a
60 kg ha ⁻¹	18.2a	21.9b	21.5a	23.6a	23.8a
90 kg ha ⁻¹	18.2a	24.7a	19.4a	24.3a	23.0a
150 kg ha ⁻¹	18.2a	22.8a	21.6a	25.2a	23.1a
210 kg ha ⁻¹	17.6a	22.0ab	20.2a	23.4a	23.5a
CV (%)	10.2	5.0	10.7	4.7	2.6
<i>P</i> (0.05)	ns	ns	ns	ns	ns

ns= not significant

Potato Tuber Slices Shelving Life

Application of K fertilizer improved shelving quality of sliced potato tubers by hindering oxidation of starch and darkening of the tuber surface at four of the five locations (Table 12). Nitosols of Mossobo and Adet Hana, which had relatively higher soil K level, exhibited no response for K application in terms of shelving quality of sliced potato tubers shelved for 48 hours after being sliced.

Table 12. The effect of K fertilizer rates on darkening of potato tuber tissue surface due to oxidation of starch in 2006/07 cropping season (%)

Treatments	Location				
	Mossobo Nitosol	Adet Hanna Nitosol	Wonjella Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha ⁻¹	54.7a	64.4a	74.2c	81.3ab	89.4c
30 kg ha ⁻¹	48.3a	58.3a	59.4cb	86.1b	75.8b
60 kg ha ⁻¹	56.7a	63.9a	41.1ab	73.5ab	64.5ab
90 kg ha ⁻¹	43.5a	60.6a	40.9ab	76.7ab	60.0a
150 kg ha ⁻¹	45.0a	62.0a	32.2a	67.6a	68.3ab
210 kg ha ⁻¹	37.5a	52.5a	38.0ab	70.0ab	66.9ab
CV(%)	25.6	23.3	26.4	10.9	9.5
<i>P</i> (0.05)	ns	ns	*	*	*

* = significant; ns= not significant

Potato Tuber Yield

Results of the experiment indicated that K fertilizer rate does not have a significant effect on potato tuber yield on Nitosols of Yilmana Densa and Luvisols of Farta Woredas. A significant difference was attained only on Acrisols of Wonjella in Banja Woreda (Table 13). However, a significant yield increase was obtained up to application of 30 kg ha⁻¹. Beyond this rate significant yield increase was not observed.

It is important to note that the yield from Wonjella location was very low as compared to other locations which indicated overall deficiency of major nutrients and deteriorated soil physical condition. In such cases, increasing K rate alone cannot bring yield increase unless the demand for other yield limiting nutrients is met.

Table 13. The effect of K fertilizer rate on tuber yield of potato in 2005/06 cropping season (Kg ha⁻¹)

Treat-ments	Location				
	Mossobo Nitosol	Adet Hanna Nitosol	Wonjella Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha ⁻¹	21259a	19407a	1805.6b	11019.0 a	16287a
30 kg ha ⁻¹	19259a	17185a	3101.9a	12685.0 a	17852a
60 kg ha ⁻¹	21704a	18222a	3796.3a	11481.0a	18167a
90 kg ha ⁻¹	21037a	18000a	2850.6ab	13882.0a	18713a
150 kg ha ⁻¹	19630a	17481a	2731.5ab	13981.0a	20944a
210 kg ha ⁻¹	20000a	17630a	2618.5ab	13982.0a	20213a
CV (%)	9.2	17.9	29.9	13.9	22.4
<i>P</i> (0.05)	ns	ns	*	ns	ns

* = significant; ns= not significant

Results of the experiment conducted in 2006/07 cropping season also indicated that potato planted on Acrisols of Banja Woreda responded for K application. Similar to the previous year, potato planted on Nitosols of Yilmana Densa and Luvisols of Farta (one location) did not respond to K application (Table 14).

Table 14. The Effect of K Fertilizer Rate on Tuber Yield of Potato in 2006/07 cropping season (Kg ha⁻¹)

Treat-ments	Location					
	Mossobo Nitosol	Debre Mewi Nitosol	Biden Jebella Nitosol	Injibara Acrisol	Debre Tabor Luvisol	Tsegur Luvisol
0 kg ha ⁻¹	18519.0 a	13334.0 a	7296.0 c	7750.0 b	17639.0 a	8704.0 b
30 kg ha ⁻¹	19074.0 a	13148.0 a	8213.0 bc	10481.0 ab	18009.0 a	11065.0 ab
60 kg ha ⁻¹	15185.0 a	11944.0 a	9305.6 b	10926.0 ab	18287.0 a	14352.0 a
90 kg ha ⁻¹	21296.0 a	11667.0 a	11287.0 a	12889.0 a	18287.0 a	14213.0 a
150 kg ha ⁻¹	18667.0 a	13426.0 a	12250.0 a	11824.0 a	16065.0 a	14120.0 a
210 kg ha ⁻¹	14815.0 a	10000.0 a	12064.8 a	13222.0 a	17593.0 a	12130.0 ab
CV (%)	20.2	28.7	9.1	14.3	21.3	18.8
<i>P</i> (0.05)	ns	ns	*	*	ns	*

* = significant; ns= not significant

Relationships between Soil K and Potato Tuber Yield

From the experiment, it was also clearly seen that there was curvilinear and positive relationships between soil exchangeable K levels and potato tuber yield (Figure 1). Those sites that had lower exchangeable K levels gave lower tuber yield and vice versa. However, the intensity of the response diminishes as the soil K level increases and significant difference in potato tuber yield among treatments was not achieved on locations with relatively higher K status and vice versa.

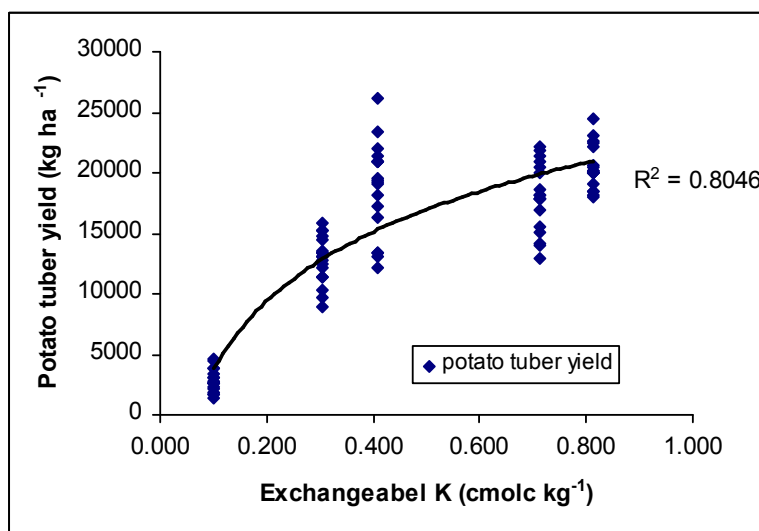


Figure 1. The relationships between soil exchangeable K status and potato tuber yield in 2005/06 cropping season

It is also possible to suggest that those sites that had relatively lower K status can also have lower levels of other macro and micro nutrients and unfavorable soil properties that can produce lower yield. This was justified by previous works of Yihenew (2002) indicating that Acrisols of Injibara area has lower levels total N and base saturation. Conversely, these soils have higher levels of C:N ratio and acidity levels as compared to the other areas covered in this experiment (Table 15).

Table 15. Selected chemical properties of some soils of western Amhara

Site	Soil type	Total N (%)	OC (%)	C/N	Available P (ppm)	Base saturation (%)	Soil pH (1:1)	Exchangeable	
								H ⁺	Al ³⁺
								(cmol. kg ⁻¹)	
Adet	Nitosol	0.17	1.7	10	2.64	41.07	5.38	0.14	0.10
Injibara	Acrisol	0.03	3.5	117	9.50	35.69	4.81	0.08	2.32
Debre-Tabor	Luvisol	0.08	3.2	40	3.70	45.19	5.17	0.04	0.24

Source (Yihenew, 2002)

Conclusions and recommendations

From the results of the experiment, it is possible to draw the following conclusions:

- 1) Increasing K fertilizer rate did not significantly increase potato tuber number, plant height, number of main stems per plant and potato dry matter yield on Nitosols, Acrisols and Luvisols;
- 2) Increase in K fertilizer rate significantly increased mean tuber weight, and tuber yield of potato on Acrisols;
- 3) Increase in K fertilizer rate significantly improved shelving life of potato.
- 4) Potato tuber yield had linear and positive relationship with soil exchangeable K status. However, potato tuber yield response level to K fertilizer application had negative relationship with soil K status.

From the results of the experiment, it is possible to recommend that application of 30kg ha⁻¹ on Acrisols of Banja Woreda could be taken as blanket fertilizer recommendation. For those soils with exchangeable K values of greater than 0.3 cmol_c kg⁻¹, it is less likely that response for K fertilizer may be obtained. Therefore, it is advisable to make soil analysis prior to determine whether to apply K fertilizer or not. But still, further investigation is required to reach to firm recommendation.

References

- Brady, N. C. and R. R. Weil. 2002. Elements of the Nature and Properties of Soils. 12th ed. Printice-Hall Inc, Upper Saddle River, New Jersey. 759p.
- Mesfin Abebe. 1998. Nature and Management of Ethiopian Soils. Alemaya University of Agriculture. Alemaya, Ethiopia. 272 p.
- Murphy, H. F. 1963. Fertility and other data on some Ethiopian soils.

- Cited by* Taye Bekele. 1998. Soil Fertility Research in Ethiopia. Paper presented at the Soil Fertility Management Workshop. April 21-22, 1998. Addis Ababa, Ethiopia.
- Sahlemedihin Sertsu and Taye Bekele. 2000. Procedures for Soil and Plant Analysis. Technical paper no. 74. National Soil Research Center, Ethiopian Agricultural Research Organization, Addis Ababa, Ethiopia. 110p.
- SAS Institute. 1999. SAS/STAT. The SAS system for Windows, Version 8.0. SAS Institute, Cary, NC.
- Taye Bekele. 1998. Soil Fertility Research in Ethiopia. Paper presented at the Soil Fertility Management Workshop. April 21-22, 1998. Addis Ababa, Ethiopia.
- Yihenew Gebreselassie. 2002. Selected Chemical and Physical Characteristics of Soils of Adet Research Centre and Its Testing Sites in North Western Ethiopia. Ethiopian Journal of Natural Resources 4: 199-215.