Response of Maize (Zea mays L.) Varieties to Potash Fertilizer Rates Under Irrigation Condition in Northern Ethiopia

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Abstract
Response of three maize varieties (Local/Berihu, Melkassa I and Katumani) to four rates (0, 50, 100 & 150kg/ha) of Potash fertilizer was examined under irrigated condition. The result of the physic-chemical analysis of the soil from the test plots has shown that the soil is potassium deficient (0.106 cmol(+)/kg). Application of the potash fertilizer (50kg/ha K_2O) has brought about a significant difference ($P<0.05$) in yield and yield components namely thousand grain weight, grain number per cob, grain yield per plant, grain yield per hectare and total above ground biomass/ha. But the application of the potash fertilizer beyond 50kg/ha has no significant effect on maize yield and yield components. Melkassa I and Katumani were found to be more responsive to this fertilizer rate than the local variety. Therefore, optimum rate for application of potash fertilizer in the study area is 50kg K_2O/ha above which amount of fertilizer added was not agronomically and economically efficient.
Keywords: Maize varieties, Potash fertilizer, irrigation

1. Introduction

Maize (Zea mays L.) is an annual monocotyledonous diploid crop belonging to the poaceae family and is grown in more diverse areas of the world than any other food crop (Raemaekers, 2001). However, in terms of production, maize ranks second to wheat among the world's cereal crops. Farmers in developing countries grow over 60% of the world's maize. In Ethiopia, more than 80% of the total area is covered with cereals of which maize is the second after tef in area coverage and the first in production. However, the average national productivity of is low which is 34.31 quintal/ha (CSA, 2015). Nutrient deficiency is one of the reasons for low crop productivity. Currently the recommended rate and type of fertilizers used in the study area are only 100kg urea (46kg/ha N) and DAP (46kg/ha P in the form of P_2O_5 and 18kg/ha N). However, findings showed that nutrients such as potassium (Astatke *et al*., 2004; Haileselassie, 2006), is also becoming a crop yield limiting nutrient.

Potassium is absorbed by plants in larger amounts than any other mineral element except nitrogen (Brady and Weil, 2002) and helps in the building of protein, photosynthesis, fruit quality and reduction of diseases (CFAITC, 2009). In contrast more nitrogen and potassium than phosphors get depleted from soils. This disparity necessitates for using optimum potash fertilizer to boost crop production (Fassil, 2008). According to this author, in the history of Ethiopian Agriculture the role of potash fertilizer in crop production is overlooked for various reasons. His report revealed that only 20% of the soils have sufficient exchangeable K, whereas 80% of the soils are deficient in exchangeable K. Thus, it is high time to consider potash fertilizer for substantially increasing crop production.

Maize reacts well to the application of mineral fertilizer. Within a 30 to 40 day period prior to pollination, maize plant absorb 75% of all essential nutrients (Raemaekers, 2001). The amount of fertilizer to apply varies with the phosphorus and potassium content of the soil, its moisture content and the maturity period of the cultivars. The water requirement of maize plant is high, as it produces an enormous amount of organic matter during the growing season. Maize demands maximum moisture during the tasseling and silking periods. Therefore, this study was conducted to evaluate response of different maize varieties to potash fertilizer rates under irrigation conditions.

2. Materials and methods

2.1 Description of the study area

The experiment was conducted in Wukro Kilte-Awlaelo District, Tigray Regional State, Northern Ethiopia (Figure1). Geographically the study area is located at $13^0 46'$ N latitude and $39^0 35'$ E long-itude. The altitude of the study site is 1850masl.

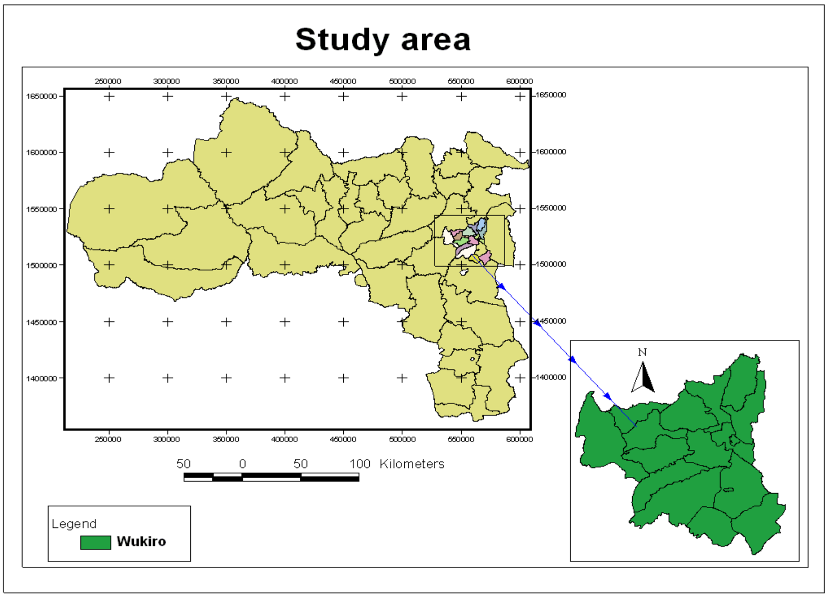

Figure 1: Location Map of the study area

The long term mean annual rainfall of the study areas for the past 16 years was 573.1 mm with mean annual minimum and mean annual maximum temperatures of 9.3^{0}C in January and 32^0 C in April, respectively (Alem, 2003). According to the modern climatic zone classifications of Ethiopia (Alemneh 2003), which was based on altitude, rainfall, average annual temperature and length of growing season, the study areas belong to semi-arid agro-climatic zone.

2.2 Experimental design and treatments

Response of three maize varieties namely, Berihu (Local), Melkassa-I and Katumani to four different levels of potash fertilizer 0, 50, 100, and 150 kg K_2O/ha was examined in a randomized complete block design. The experimental site was designed to accommodate 12 treatment combinations which had been replicated three times, totally 36 plots. Potassium oxide fertilizer (K_2O) was used as a source K for the experiment. Recommended amount of nitrogen and phosphorus sourced from urea and triple super phosphate were applied for all the plots. The spacing between plants and between rows was 25cm and 75cm respectively. The plots were bounded by ridges to protect over flow of water from one plot to the other.

R-1	V1K3	V1K1	V2K1	V3K	V1K0	V3K3	V2K2	V3K2	V3K1	V2K3	V2K0	V1K2
R-2	V1K3	V1K1	V2K2	V3K3	V2K3	V2K1	V2K0	V3K0	V3K2	V1K0	V1K2	V3K1
R-3	V3K1	V2K2	V3K0	V1K2	V2K3	V2K0	V1K1	V1K0	V3K3	V2K1	V3K2	V1K3

R= replication, V= variety, K = potassium
Figure-2: Experimental field layout

2.3 Soil sample collection and analysis

A composite soil sample was taken from a 0-30cm depth was taken from the experimental field, dried under shade and was taken for laboratory analysis the national soil laboratory in Addis Ababa for analysis of the required parameters. The basic parameters analyzed from the soil sample before sowing were: soil pH, EC, CEC, Total N, Organic Carbon, Available phosphorous, Exchangeable K and Texture. The soil laboratory procedures used to analyze the selected soil physical and chemical properties were: Texture determined by the hydrometer method (Bouyoucos, 1962); Soil pH in a suspension of 1:2.5 soil water ratio by using pH meter (Peach, 1965); Electrical conductivity of the soil extract determined using EC meter (Sahlemedin and Taye, 2000). Organic matter content of the soil was estimated from the organic carbon content determined using Walkley and Black (1934) method. Total Nitrogen determination was done by macro Kjeldahl method (Khee, 2001). Olsen method was used to determine available phosphorous content of the soil (Olsen and Sommers, 1982). Available K was analyzed by using Flame Photometer (Sahlemedin and Taye, 2000) and Cation exchange capacity was determined by ammonium acetate extraction method (Okalebo *et al*, 1993).

2.4 Agronomic practices, data collection and analysis

The nitrogen and potassium sources of fertilizers were applied in two equal splits (half at sowing and the other half at knee height. Whereas, phosphorus source of fertilizer was applied during planting. Irrigation water was pumped from a shallow well and applied to plots along the furrow. All experimental plots were irrigated uniformly maintaining the field capacity based on the crop water requirement during the entire growing season. To reduce crop and weed competition, plots were inter cultivated three times during the growing season.

Agronomic parameters such as Ear height, number of grains per cob, cob weight per plant, 1000 seed weight, grain yield per plant, grain yield per hectare and above ground biomass yield per hectare were collected. Ten maize plants were randomly selected from each plot to measure Ear height, number of grains per cob, cob weight per plant, 1000 seed weight. On the other hand, after crop harvesting, the cobs were shelled manually, grains were adjusted to 12.5 % moisture content and finally grain yield was recorded from a net plot size of 11.25m^2. The seed moisture content was measured using electronic moisture meter.

All the agronomic data collected were statistically analyzed through Analysis of Variance using Genstat Version-12 software. List significant difference (LSD) was used for mean comparison of treatment at 95% confidence interval.

3. Result and discussion

3.1 Soil properties of the study area

The pre-sowing soil physical and chemical laboratory analysis of the study area indicated that soil of the study area is deficient in potassium content, 0.106 cmol(+)/kg (Table-1) and hence a response is expected from the application of potash fertilizer. While soil of the study area has medium phosphorus level, total nitrogen, cation exchange capacity and organic carbon content were recorded to be deficient. According to Soil Survey Staff (2003) textural classification, soil of the study area was sandy clay loam.

Table 1: Pre-sowing soil physical and chemical properties of the study area

Parameter	Uint	Output
PH		8.8
EC	ds/m	0.211
Textural class name class		Sandy Clay loam
CEC	C*mol* (+)/kg	16.94
TN	%	0.088
OC	%	0.98
C/N		11
Available P	PPM	5.88
Exchangeable K	C*mol* (+)/kg	0.106

3.2 Effect of variety and potash fertilizer on maize yield and yield components

Grain number per cob

The number of grains per cob has significantly ($P<0.05$) differed with a difference in variety. The number of grains per cob recorded from Melkassa I, katumani, and local varieties were 248.3, 234.55, 205.55 respectively (Table-11). Melkassa I has resulted in a significantly higher number of grains per cob as compared to Katumani and the local varieties. The effect of potash fertilizer application of the treatment maize has also shown that there is a significant difference ($P<0.05$) in the grain number per cob. The number of grains per cob was 208.95, 234.77, 239.78 and 235.68 respectively indicating that the different potassium levels have a considerable difference in grain number per cob especially as compared to the control plot. However the difference in between the different potassium levels is not significant. The fertilizer* variety interaction effect has shown a significant difference in the number of grains per cob at $P<0.05$ showing that the variety and fertilizer treatments have jointly acted in the number of grains per cob.

Table 1: Effects of variety and potash fertilizer rates on grain number per cob

Treatment	Grain number per cob
Variety	
Local (Berihu)	206.558c
Melkassa I	248.3a
Katumani	234.55b
Mean	229.8
LSD (5%)	6.09
CV (%)	3.1
Potassium (kg K_2O/ha	
0	208.956b
50	234.778a
100	239.789a
150	235.689a
Mean	229.8
LSD (5%)	7.03
CV (%)	3.1

Thousand Grain weight (gm)

A significant difference was observed at P<0.05 due to a difference in variety. The weights of seeds obtained were 247.02, 241.1, 213.83 for Katumani, Melkassa I and local varieties respectively (Table-3). There was no a significant difference between Katumani and Melkassa I. However; a significant variation was observed between these two varieties and the local variety. The different levels of potassium application have also resulted in a significant difference in the thousand seed weight of the maize crop. 217.38, 240.0, 239.96, 238.58 gm of thousand seed weight was obtained for 0, 50, 100 and 150 kg/ha of K_2O levels. Though, no significant difference was observed among the different levels of potash fertilizer, all the three levels have resulted in a significant difference in thousand grain weight from the control plot. This is in congruence with the finding of (Mumtaz *et al*., 1998) who found that highest thousand grain weight was significantly affected by potassium because it regulates the enzyme activities and translocation of photosynthesis.

Grain yield

The analysis of variance ANOVA has revealed that both grain yield per plant and total grain yield (t/ha) have significantly differed at P<.001 due to varietal difference. Katumani and Melkassa I have exhibited the highest total grain yield tone/ha and grain yield per plant. However the local variety has the lowest yield compared to the other two varieties. The grain yield was found out to be 2.90, 3.88, 3.98 tone /ha for the local, Katumani and Melkassa I varieties respectively (Table-3). Similarly, the two varieties have shown that they can bear the highest yield due to the difference in the fertilizer application rates. But the control plot has a significantly lower amount of grain yield compared to the other application rates. The control plot has brought about the lowest yield 2.97 ton/ha compared with the average grain yield of 3.79 ton/ha yield with the fertilizer application as there is no significant difference in the yield due to difference in the fertilizer levels. This result is in congruence with the results by Nazim *et al.* (2007) who suggested that 50kg K/ha and 2-5 kg Zn/ha as adequate for an early maturing maize crop. The experimental maize crop varieties used for this study were also early maturing varieties which strengthens the similarity of the result with the above suggestions. A significant difference was also obtained due to the combined effect of variety and fertilizer application. Thus both variety and fertilizer application worked jointly on the yield of maize.

Table 3: Effects of variety and potash fertilizer rates on 1000 grain weight, grain and biomass yield

Treatment	Thousand grain weight (gm/1000 seeds)	Grain Yield		Total weight of biomass
		(ton/ha)	(gm/plant)	(ton/ha)
Variety				
Local	213.83b	2.903b	43.01b	7.527a
Melkassa I	241.1a	3.985a	58.79a	5.695c
Katumani	247.02a	3.880a	57.79a	6.618b
Mean	234	3.589	53.2	6.614
LSD(5%)	6.91	0.071	1.19	0.182
CV (%)	3.5	2.3	2.7	3.3
Potassium level				
0	217.389b	2.975b	45.06b	5.741c
50	240.000a	3.753a	55.95a	6.943b
100	239.967a	3.853a	55.87a	7.225a
150	238.589a	3.775a	55.93a	6.744b
Mean	234	3.589	53.2	6.614
LSD(5%)	7.97	0.0824	1.38	0 .211

According to Mumtaz *et al*. (1998) and Ijaz *et al*. (2014), potassium application generally improved grain yield of maize. The report by Neilson *et al*. (1963) as well as by Nazim *et al.* (2007) revealed that application of potassium increases grain yield significantly when applied in combination with nitrogen and phosphorus. All the treatment varieties have responded to the addition of K fertilizer compared to the control plots for which only P and N fertilizers have been applied as basal fertilizers. Melkassa I (Figure-3) has been found to be more responsive than the other two for the lower rate of the fertilizer application.

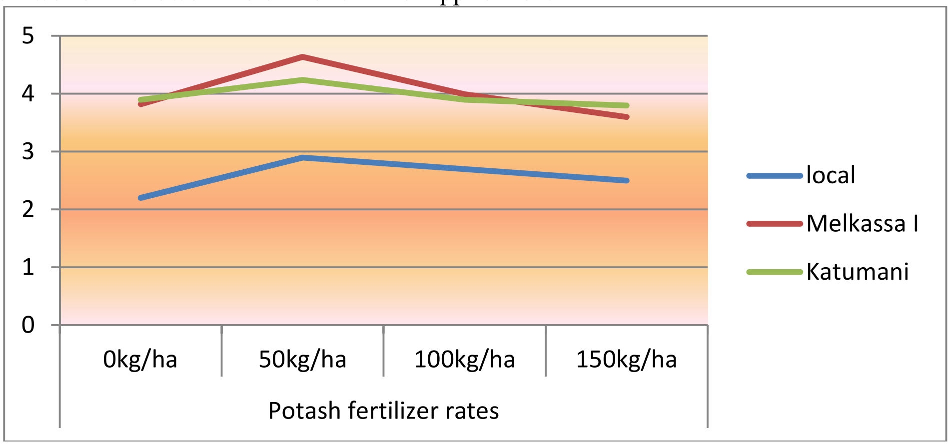

Figure 3: Grain Yield (ton/ha) for the maize varieties with the different K fertilizer levels

Total plant biomass

The analysis of variance for the total dry biomass of maize showed that there is a significant difference ($P<0.05$) in the total above ground biomass of the maize crop as revealed by difference in the varieties. The local variety has exhibited the highest total biomass which can be correlated with the plant height because this variety had the highest plant height over the other two varieties. Katumani has also had taller plant height next to the local variety. Similarly this crop variety has exhibited a higher total plant biomass next to the local variety. The total plant biomasses obtained were: 7.52, 6.61, 5.69 ton/ha for the local variety, Katumani and Melkassa I respectively (Table 3). The difference in the K fertilizer application levels has also revealed a significant difference over the control plot.

3.3 Partial Economic Analysis of Potash fertilizer

The yield obtained from the local variety is generally low compared to Melkassa I and Katumani. However, in all cases there is a yield increment at 50kg/ha the application of K fertilizer. But when it goes beyond this rate, a stagnation or decline of yield has been observed in all varieties (Table-3)

The revenue obtained as a result of the added K fertilizer was generally higher in nutrient treated with 50kg/ha of K. But the marginal revenue immediately starts to decline (Table-4) when more of the fertilizer is applied. Thus, though it may not end up in a loss especially in the case of Melkassa I, the amount of marginal revenue does not encourage the application of the K fertilizer in the upper levels.

Table 4: Partial economic analysis of potassium fertilizer rates

K Level (Kg/ha)	Description	Variety		
		Local	Melkassa I	Katumani
0	Price	380	420	472
	Yield	2.2	3.82	3.9
	Total Revenue	8360	16044	18408
	M. Revenue			
50	Yield	2.9	4.64	4.24
	Total Revenue	11020	19488	20012.8
	M. Revenue	2660	3444	1604.8
100	Yield	2.7	3.99	3.9
	Total Revenue	10260	16758	18408
	M. Revenue	760	2730	1604.8
150	Yield	2.5	3.6	3.8
	Total Revenue	9500	15120	17936
	M. Revenue	760	1638	472

4. Conclusion

The results of the physico-chemical analysis of the soils in the study area have revealed that the soil is deficient in their exchangeable potassium content. Thus the age old perception of the scientific arena that Ethiopian soils are rich in potassium content is violated with this study. This makes it surprising why we Ethiopians use only N and P fertilizers while K is still deficient for our crops. It was found out that the maize varieties have shown a significant response to the lower levels (50kg/ha K_2O) application. The application potassium fertilizer more than 50kg/ha was not also economical. Improved maize varieties (Melkassa I and Katumani) were found to be more responsive than the local variety (Berihu). Therefore, the use of potash fertilizer improves maize productivity and profitability with these varieties.

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