Research Article

Response of enset (*ensete ventricosum (welw.) cheesman)* to different application rates of potassium application in Hula District, Sidama region, Ethiopia

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Abstract

Field experiment was conducted in Hula district, Sidama region, Ethiopia to investigate the response of *enset* to potassium (K) fertilizer for two years (2016-2018). The treatments were: Control (0),80, 150 and 200 kg K/ha as KCl along with the recommended nutrients to the area; 20 kg P/ha, 11.15 kg S/ha and 0.57 kg B/ha as NPS+B; and 138 kg N/ha as Urea and NPS+B. Application of K in two consecutive years increased *enset* production and enabled the *enset* to reach the second edible stage (*etancho*) in two year and four months after transplanting. Thus, *enset* matured two years earlier as compared to the farmers' experience, which takes four years to reach this stage and crops in control plots matured at one year later stage (*malancho*) than those with K application. Application of K also increased the growth, dry matter and yield (*Kocho* and *bulla*) of *enset* as compared to the control plants. Among the treatments, twice application of 80 kg K/ha during the life of *enset* significantly ($p< 0.05$) increased the growth, yields and net benefits of *enset* production than the other treatments as indicated by the highest marginal rate of return. Hence, twice application of 80 kg K/ha is recommended for the study area.

Key words: Growth parameters, *kocho* and *bula* yields, maturity, agro-ecology

1. Introduction

Enset (*Enseteventricosum* (Welw.) Cheesman) is a perennial horticultural plant that is cultivated from home vicinity to far fields and it is usually called "false banana". It has several hundred landraces (clones), having different characteristics and uses (Mohammed et al. 2013). According to Brandt et al. (1997) *enset* is a staple crop for an estimated 15-20 million people in Ethiopia and a reliable food source where failure of annual crops is common (Dalbato 2000; Mikias et al. 2010).

Thus, *enset* cultivation is one of the tremendous potentials of the country to nourish the rapidly increasing part of population, particularly those below food poverty line. Moreover, e*nset* provides a range of services such as, forage (Funte et al. 2010), fiber (Tsehaye and Kebebew, 2006) and traditional medicine (Nyunja et al. 2009), construction and soil protection.*Enset* grows at altitudes between 1500- 3100 m above sea level (Tsegaye and Struik 2003). Rainfall above 1100 mm, temperature [1] between 16 and 20°C, and fertile soils are good conditions for *enset* production and productivity. Among these growth determinants, soil fertility is the major one

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(Tsegaye and Struik 2001). Moreover, adequate moisture plays a great role for the growth and productivityof *enset*, though *enset* has remarkable capacity to withstand heat. Brandt et al. (1997) and Shank and Ertiro (1996) reported that it is adapted to ample rainfall areas.

Enset is distributed in the wild throughout much of central, eastern and southern Africa (Brandt et al. 1997). However, its cultivation, domestication and farming system is established in Ethiopia (Brandt, 1996). Supporting this, CSA and MoA (1994) reported that about183,765.87 ha of land is cultivated with *enset* of which 57.38% is found in the southern parts of Ethiopia.

Enset requires high amount of organic matter for desirable production and productivity (Haile and Abay 2012). However, limitation in the number of livestock in *enset* growing areas is causing reduction in the amountof animal dung (Ayele 1975). This situation calls for the use of chemical fertilizers to tackle the problem (Forsido et al. 2013). Supporting this, a research conducted at Areka south Ethiopia, indicated vigorous growth and prompted maturity when 138 kg N/ha and 20 kg P/hawere applied twice throughout the life of *enset* (Ayalew and Yeshitila 2011). Until recently, there has been a general perception that soils of Ethiopia contain sufficient amount of potassium based on the report by Murphy (1968). Thus, fertilizer extension program in Ethiopia did not include potassium until 2014. However, national soil fertility survey conducted by Ethiopian Soil Information System (EthioSIS) found vast areas, especially highland vertisols and acidic soils in the country, that respond to potassium fertilization (EthioSIS 2014). These findings indicate the importance of potassium application to increase crop yield in the different agricultural areas. Thisresearch was therefore aimed at evaluating the response of *enset* to potassium application in Sidama region, Ethiopia and to determine the rate and frequency of K application to *enset* for optimum growth and productivity.

2. Materials and methods

2.1 Description of the study area

The study was conducted in Hula district, Sidama region, Ethiopia (Figure 1) from 2016 - 2018. Sidama administrative region is located between 5°45'- 6°45' N latitude and 38°39°E longitude, covering a total area of 6,538.17 km^2 (SZPEDD, 2004). The regional capital, Hawassa, is located in the northern tip of Sidama region, at a distance of 275 km from Addis Ababa. As per traditional agro-ecological zone classification of Ethiopia, the districtis characterized by tepid to cool humid mid highlands and the type of soil was nitisol. The experimental site was located at 6º33.0'64''N and 38°28.8'20"E; and at an altitude of 2502 masl.

2.2 Soil sampling, preparation and analysis

A composite sample was taken from a total of twelve systematic random soil samples (0-50 cm) collected prior to land clearing and preparation. The sampling depth was chosen to be 0-50 cm since the study planned to explore the K status within the enset rooting depth. The samples were air-dried and passed through 2 mm sieve to remove large particles, debris and stones (Tan, 1996). Particle size analysis was performed using the Bouyoucous hydrometer method (Bouyoucos 1951) and the textural classes were categorized using United State Department of Agriculture soil textural triangle.

The pH was determined in 1:2.5 soil-water suspensions using a glass electrode (Jackson, 1973). Electrical conductivity was determined from the saturation extract (l:5 soil water ratio) of soils (Gupta, 2009). Organic carbon (OC) was determined following wet oxidation method of Walkley and Black (1934). Total nitrogen (N) was determined by Kjeldhal method (Bremner and Mulvaney, 1982). Mehlich III extractant was used to extract, phosphorus (P), exchangeable potassium (K), calcium (Ca), magnesium (Mg), sulfur (S) and boron (B) (Mehlich 1984). Cation exchange capacity (CEC) was determined using ammonium acetate method (Sumner and Miller, 1996).

2.3 Experimental design and field management

Field trials were conducted in three consecutive years (2016-2018). The experiment was laid out in a randomized complete block design (RCBD) with three replications. The treatments included: 0, 80, 150 and 200 kg K/ha as KCl. One hundred eight seedlings of *enset* suckers were transplanted a year after sprouting to the main field at a depth of 20 cm.

Muriates of potash (KCl) were split applied two times per year. Recommended levels of P (20 kg/ha), N (138 kg/ha) (Ayalew and Yeshitila 2011), S (11.15 kg/ha) and B (0.57 kg/ha) were also used. Application times were once for P while twice for N per year. Inter and intra row spacing was 2 × 2 m. Urea and NPS+B were used as sources of N while only NPS+B was used as a source of P,S and B. The fertilizers were applied in a circular band (side dress) at a depth of 3 to 5 cm after one month of planting and then yearly as per treatments as suggested by Borges et al. (2002). All the other agronomic managements (weeding, cultivation etc.,) were carried out properly and equally for all the treatments.

2.4 Plant sampling and agronomic data collection

Prior to harvesting, a total of thirty six enset plants were sampled randomly from the experimental site (Tsegaye and Struik 2003). Plant and pseudostem height, pseudostem circumference, leaf length and the leaf width were measured using a tape meter. Moreover, all the fully expanded and green leaves were counted starting from the emergence of new leaves until the time of harvest to determine total number of leaves while weighing corms using portable balance.

2.5 Measurement of fresh weight

Fresh weights of shoot and corm were determined separately. Then, 500 g samples from each were taken, packed in cellulose paper folders and dried at 105°C for 24 h in an oven (Jones, 2001).

2.6 Kocho and bula production

Leaf sheaths were decorticated using a sharp-edged bamboo scraper while pulverizing the corm by sharp edged animal bone and combined with the decayed corm. After fermentation, fresh kocho was squeezed by applying human force till it loses all its moisture content and the weight of squeezed kocho was recorded.

2.7 Plant leaf sampling and analysis

Enset leaves were sampled based on sampling techniques used for banana plant since *enset* and banana have similar leaf morphology (Tsegaye and Struick, 2003). In supernatant solutions, potassium was determined by flame photometer while P was determined by Colorimetry (Housecroft and Constable, 2006). Sulfur and boron were determined by atomic absorption spectrophotometer (AAS).

2.8 Statistical analysis

Using the SAS package (SAS Institute 2012), LSD test (at P = 0.05), ANOVA (one-way analysis of variance) and correlation studies were undertaken according to CIMMYT (1988).

2.9 Economic analysis

Partial budget analysis of selected treatments was done

3. Results

3.1 Some soil physico-chemical properties of the experimental site

The soil was strongly acidic (pH < 5.5) while the textural class was sandy loam (Table 1). According to EthioSiS (2014) available P and total N was low; and S was very low while K contents were optimum. According to Maria and Yost (2006), Calcium contents were high while the magnesium contents were medium. The organic carbon was very low (Landon 2014). In accordance with EthioSIS (2014), the B contents were very low (< 0.5 mg kg^{-1}) while the CEC was high based on Landon (2014).

3.2 Nutrient contents of the *enset* leaf

The nitrogen content was increased from control to T4 and varied from 2.06 to 2.5 (Table 2). Statistically similar contents of N were recorded at T2, T3 and T4 and these contents were significantly (($p<0.05$)) different from that of the control treatment (Table 2). Overall, the N contents in all treatments were below 2.5% and low as proposed by Kalira (1998). The lowest and highest values of P were recorded at T3 and T4 treatments, respectively (Table 2). The P contents varied from 0.34 to 0.47% (Table 2) and itwas sufficient as proposed by Kalira (1998). Sulfur contents of the leaves were statistically similar, varied from 0.12 to 0.22% (Table 2) and were deficient

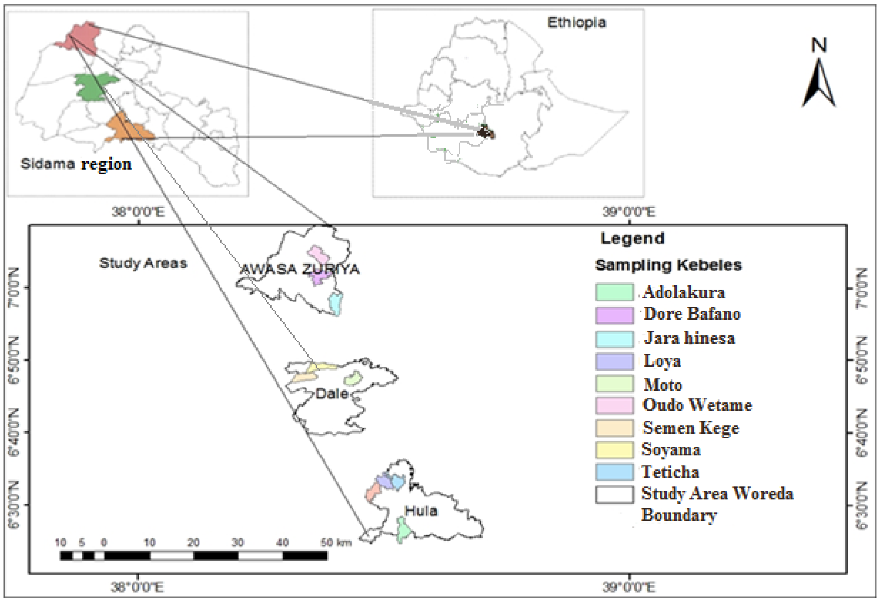

Table 1. Selected physico-chemical characteristics of the experimental soil.

n	Sampling depth	pH (H2O)	OC (%)	CEC (meq/kg)	Total N (%)	Available P	Exchangeable bases mg/kg K	Ca	Mg	S	B	Sand	Clay%	Textural class
1	50 cm	5.40	2.71	26.46	0.12	2.91	240	2039	326	8.22	0.31	60	20	Sandy loam

Table 2. Effect of potassium levels on nutrient contents of *enset* leaves of experimental site.

Treatments (kg K/ha)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	B (mg/kg)
Control (0)	2.12^{b}	0.35^{b}	3.10^{c}	0.35^{b}	0.23^{b}	0.12	11^{b}
T2 (80)	2.30^{a}	0.40^{b}	3.60^{b}	0.40^{ab}	0.19^{c}	0.13	9.5^{c}
T3 (150)	2.35^{a}	0.34^{b}	4.10^{a}	0.34^{b}	0.23^{b}	0.16	7.7^{d}
T4 (200)	2.38^{a}	0.47^{a}	4.21^{a}	0.47^{a}	0.25^{b}	0.22	13^{a}
Minimum	2.12	0.34	3.10	0.34	0.19	0.12	7.7
Maximum	2.38	0.47	4.21	0.47	0.25	0.22	13
LSD0.05	0.183	0.03	0.25	0.082	0.05	0.16^{NS}	4.0
SEM±	0.039	0.01	0.14	0.018	0.01	0.02	10

Means within a column followed by the same letter is not significantly different at $p < 0.05$, Total number of leaf samples per experimental site was 12.

according to Kalira (1998). Despite the optimum K status of experimental soils, leaf K concentrations were increased with increasing K application from T2 to T3 (Table 2). It ranged from 3.10 to 4.21% and was sufficient as proposed by Kalira (1998).

Calcium ranged from 0.34 to 0.47% while magnesium varied between 0.19 and 0.25% having statistically similar contents at control, T3 and T4 (Table 2). Leaf Ca and Mg were deficient at all treatments in accordance with Kalira (1998). Boron content varied from 7.7 to 13 mg/kg and the highest values were recorded at T4 (Table2). The concentrations of B in plant leaves decreased with increasing rates of potassium application.

3.2 Effect of applied potassium on vegetative growth parameters

Enset plants were harvested at two years and four months after transplanting. The vegetative growth and number of leaves were increased with increasing level of potassium application (Table 3). The growths were also increased with increasing contents of N, P and K in the leaves of plant (Table 2) as was also reported by Uluro and Mengel (1994). The number of leaves per plant and vegetative growth in controls were significantly different ($p<0.05$) from those with K application. Plant heights ranged from 317 to 514 cm while the pseudostem heights range between 97 and 168 cm. Pseudostem circumferences varied from 121 to 177 cm. On the other hand, total number of leaves ranged from 46 to 74 while leaf lengths fall between 228 and 346 cm. Finally, leaf widths varied from 68 to 86 cm (Table 3).

3.3 Effect of increasing levels of potassium applicationon dry matter production

Above ground dry matter (Shoot)

The shoot dry weights were increased with increasing level of potassium application from T4 to T4 (Figure 2) and also increased with increasing contents of N, P and K in the leaves of plant (Table 2). Significant (P□ 0.05) differences in shoot dry weights were recorded between the controls and K treated plots (Figure 2). However, the differences among the applied K levels were not significant.

Below ground dry matter (Corm)

The corm dry matter production increased with increasinglevel of applied potassium (Figure 2). Dry weights of controls were statistically different ($p<0.05$) from K treated plots while T3 and T4 were at par. The dry weights were increased with increasing contents of N, P and K in the leaves of plant (Table 2).

Table 3. Effect of different rates of potassium on vegetative parameters.

Treatment (kg/ha)	Plant height, cm	Pseudostem, height, cm	Pseudotesm circumference, cm	3rd leaf length, cm	3rd Leaf width, cm	Total number of leaves
Control (0)	317^{b}	97^{b}	121^{b}	228^{b}	68^{b}	46^{b}
T2 (80)	467^{a}	152^{a}	165^{a}	322^{a}	82^{a}	67^{a}
T3 (150)	497^{a}	166^{a}	172^{a}	313^{a}	85^{a}	71^{a}
T4 (200)	514^{a}	168^{a}	177^{a}	345^{a}	86^{a}	74^{a}
Minimum	317	97	121	228	68	46
Maximum	514	168	177	345	86	74
$LSD_{0.05}$	61	27.2	19.5	50.8	6.5	8.2
SEM±	18	7.2	5.5	12.1	1.7	2.5
CV%	17.2	22.3	16	19.8	8.4	19.4

Means within a column followed by the same letter(s) is/are not significantly different at $p< 0.05$. Total number of leaf samples per experimentalsite was 12.

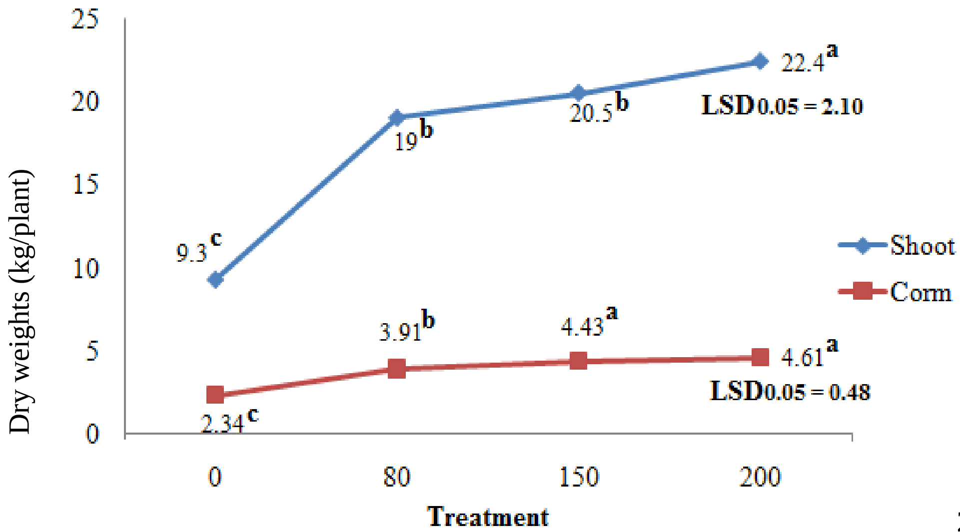

Figure 2. Effect of increasing rates of potassium on above and below ground dry weights. Means with the same letters are not significantly different at $p < 0.05$.

3.4 Maturity and yields of enset

Enset crops with K application reached the second edible stage (Sidamic term: etancho) in two year and four months after transplanting. Thus, it matured two years earlier as compared to the farmers' experience in the area, which takes four years to reach this stage. On the other hand, crops in control plots matured at one year later stage (Sidamic term: malancho) than those with K application. *Enset* yields were increased with increasing levels of applied potassium and significant differences ($p<0.05$) in yield were recorded between controls and the K applied treatments (Table 4). Yields were also increased with increasing contents of N, P and K in the leaves of plant (Table 2). Among the treatments, T4 resulted in the highest dry squeezed (36.8 kg/plant) weights of *kocho*. On the other hand, the lowest dry or squeezed (15.2 kg/plant) weights were recorded at control. Lastly, squeezed *kocho* yields at T2, T3 and T4 were higher by 49.5, 54 and 58.6%, respectively than yields obtained from control (Table 4). The highest *bula* weight (1.9 kg/plant) was recorded at T4 while recording the lowest (0.8 kg/plant) at control. The *bula* yields at T2, T3 and T4 were higher by 50, 52.9 and 57.9%, respectively than yields obtained from the control.

3.5 A cross-correlation among total dry matter, yields, potassium rates and leaf nutrient contents

The results of cross-correlation showed strong positive relationships between K rates and leaf K contents, *kocho and bula* yields and total DM (Table 5). Additionally, K rates showed strong positive associations with leaf percent N and P. Moreover intermediate negative correlations existed between B, K rates and K. Leaf K correlated positively and strongly with *kocho, bula* and total DM (Table 5). Leaf N correlated positively and strongly with *kocho* and *bula* yield while correlating strongly and positively only with total DM. It also correlated positively and intermediately with percent P. The leaf percent P correlated positively and intermediately with *kocho* and total DM while correlating positively and strongly with *bula* yield. Overall, the *kocho* and *bula* yields and total DM correlated strongly and positively with each other.

Table 4. Effects of increasing rates of potassium on *kocho* and *bula* yields.

Treatment(kg K/ha)	Squeezed *Kocho*	*Bula*	% Increase in squeezed *kocho* yield over control kg/plant	% Increase in *bula* yield over control
Control (0)	15.2[c]	0.8[c]	-	-
T2 (80)	30.1[b]	1.6[b]	49.5	50.0
T3 (150)	33.1[b]	1.7[b]	54.1	52.9
T4 (200)	36.8[a]	1.9[a]	58.7	57.9
LSD0.05	3.7	0.2	-	-
SEM±	1.6	0.1	-	-
CV%	12.8	14.8	-	-

Means in a column followed by the same letter(s) is/are not significantly different at p<0.05.

Table 5. Cross correlation among *enset* leaf nutrient content, K rates, yields and total dry matter.

Parameter	N	K	P	S	B	K rates	Kocho yield	Bula yield	Total DM
N	1								
K	0.675*	1							
P	0.675*	0.687*	1						
S	0.339	0.418	0.241	1					
B	-0.479	-0.646*	-0.218	-0.211	1				
K rates	0.748**	0.962*****	0.778***	0.411	-0.654*	1			
Kocho yield	0.879****	0.865****	0.717**	0.286	-0.705*	0.914*****	1		
Bula yield	0.868****	0.863****	0.745**	0.278	-0.694*	0.904*****	0.991*****	1	
Total DM	0.899*****	0.899*****	0.669*	0.336	-0.726**	0.898*****	0.992*****	0.986*****	1

*Significant at p<0.05; ** p <0.01; *** p <0.005; **** p<0.001; ***** p<0.0001.

3.6 Economic analysis

The results of partial budget and economic analysis pertaining to the data on fermented and squeezed *kocho* and *bula* (Tables 6 to 9) showed that the highest marginalrate of return was obtained from K application at 80 kg K/ha while the highest net benefits were obtained from 200 kg K/ha in the district.

4. Discussion

The low pH of experimental site soil indicates the leaching loss of crop nutrients. Moreover, the low total N, available P, S and B contents could also reduce crop growth and yield (Kochet al. 2019).

Table 6. Economic Analysis of squeezed *kocho* yield.

Variable	Hula district			
	T1	T2	T3	T4
Total yield (t/ha)	38	75.25	82.75	92
Adjusted yield (t/ha)	34.2	67.73	74.5	82.8
Value in birr	205200	406380	447000	496800
Cost of KCl applied in birr	-	2775	5203	6937
Cost that vary birr	-	2775	5203	6937
Net benefits birr	205200	403605	441797	489863

T1= Control or no K, T2 = 80 kg K/ha, T3 =150 kg K/ha, T4 =200 kg K/ha.

Table 7. Partial budget analysis data of squeezed *kocho*.

Treatment		Hula district		
		Cost that vary (birr/ha)	Net Benefits (birr/ha)	Marginal rate ofreturn (%)
T1	Control	0	205200	-
T2	80	2775	403605	7149
T3	150	5203	441797	1573
T4	200	6937	489863	2772

T1= Control or no K, T2 = 80 kg K/ha, T3 =150 kg K/ha, T4 =200 kg K/ha.

Table 8. Economic Analysis of *bula* yield.

	Hula district			
	T1	T2	T3	T4
Total yield	2	4	4.25	4.75
Adjusted yield	1.8	3.6	3.83	4.3
Value in birr	126000	252000	268100	301000
Cost of KCl applied in birr	-	2775	5202.8	6937
Cost that vary birr	-	2775	5203	6937
Net benefits birr	126000	249225	262897	294063

T1= Control or no K, T2 = 80 kg K/ha, T3 =150 kg K/ha, T4 =200 kg K/ha.

Table 9. Partial budget analysis data of *bula* yield.

Treatment		Cost (birr/ha)	Net Benefits (birr/ha)	Marginal rate of return (%)
T1	Control	0	126000	-
T2	80	2775	249225	4440.5
T3	150	5203	262897	563.1
T4	200	6937	294063	1797.3

T1= Control or no K, T2 = 80 kg K/ha, T3 =150 kg K/ha, T4 =200 kg K/ha.

potassium in balanced nutrition as was also reported by MoA and ATA (2012). An increase of yield revealed that K promotes carbohydrate production when applied along with limiting nutrients as was also reported by White et al. (1974). This was confirmed by an increase of limiting nutrients concentrations; N, P and K in the leaves of *enset* plant with increasing levels of K application as was also reported by Uloro and Mengel (1994). This indicated the need for further investigation to determine site and crop type based critical K levels for different crops. Application of potassium also increased the maturity of *enset*. Thus, the results call for K recommendation in order to boast crop productivity. On the other hand, leaf Ca (< 0.50%) and Mg (< 0.20%) was deficient probably due to the antagonistic effect of K on the uptake of Ca and Mg (IPNI, 1998). Furthermore, due to B deficiency in the soil, increased growth caused by K reduced B concentration via dilution (Mengel and Kirkby 2001). The results of cross-correlations that strong positive relationships existed between K rates, yields and total DM; and leaf K, N and P contents indicated an increase of nutrient contents in *enset* leaves and yield with increasing K levels (Table 4). Positive relationship existed among K rates and leaf percent N is convincing, since leaf N contents increase with increasing K levels (IPNI, 1998) while positive correlation with percent leaf P indicated that applied P level was low to be affected by K levels. An intermediate negative correlation existedbetween B and K rates; and B and K indicates the dilution effect of increasing biomass production on boron (Mengeland Kirkby 2001).

5. Conclusion

Further site and crop specific investigations on critical levels of available K and application of K along with limiting nutrients in the study area are vital to increase *enset* yield. Hence, application of 80 kg K/ha two times throughout the life of *enset* is recommended since significant ($p<0.05$) growth, yield increase and marginal rate of return were obtained from this rate.

Conflict of Interests

The authors have not declared any conflict of interests.

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