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Effect of potassium on yield and growth of Enset (*Ensete ventricosum* (Welw.) Cheesman) in Dale District, Sidama Region, Ethiopia

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Only limited work has been done on fertilizer requirement of *Enset* crop. An experiment was conducted in Dale district, Sidama region, Ethiopia to investigate the response of *Enset* to potassium (K) fertilizer for two years (2016-2018). The treatments were: 0, 80, 150 and 200 kg K/ha as potassium chloride (KCl), single levels of phosphorus (P) (20 kg/ha), sulfur (S) (11.15 kg/ha) and boron (B) (0.57 kg/ha) as blended NPSB and nitrogen (N) (138 kg/ha) as Urea and NPSB. Regardless of the high yield obtained at 200 kg K/ha application, the maturity of the plant was similar at all rates of K, except for control. However, application of K twice along with the recommended nutrients enabled the *Enset* to reach the second edible stage (Sidamic term: *etancho*) in two years and four months after transplanting. Thus, *Enset* matured two years earlier as compared to the farmers' experience of four years to reach this stage in the area. *Enset* crops in control plots matured at one year later stage (Sidamic term: *malancho*) than those with K application. All growth parameters, dry matter and *Enset yi*elds (*kocho, bulla and* fiber) were high as compared to those of control plots. In the district, application of 200 kg K/ha twice during the life of *Enset* significantly (P ≤ 0.05) increased the growth, yields and net benefits of *Enset* production than the other treatments. Hence, application of 200 kg K/ha twice during the life of *Enset* is recommended.

Key words: Growth parameters, kocho and bula yields, maturity time, agroecology, economic analysis.

INTRODUCTION

Enset farming system is among the four major agricultural systems in Ethiopia (Amede and Diro, 2005). *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

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country to nourish the rapidly increasing part of population, particularly those below food poverty line. Moreover, *Enset* 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 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 (Tsegaye and Struik, 2001). Moreover, adequate moisture plays a great role for the growth and productivity of *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 (Taye and Feleke, 1966), domestication (Brandt, 1996) and farming system is established in Ethiopia (Ehret, 1979). CSA and MoA (1994) reported that about 183,766 ha of land is cultivated with *Enset* of which 57% is found in the southern parts of Ethiopia. In southern Ethiopia, *Enset* is cultivated among Sidama, Hadiya, Gedeo, Gurage and related groups existing side by side as a co-staple to tuber crops or cereals (Amede and Diro, 2005). The central statistical authority estimated the area coverage by *Enset* as; 37, 000, 18, 000 and 13, 000 ha in Sidama, Hadiya, and North Omo (where Wolaita is located), respectively (Tsegaye, 2002).

Enset requires application of high amount of organic fertilizers and soil amendments (household refuses, farmyard manure and compost) for desirable production and productivity (Haile and Abay, 2012). High N content was found in *Enset* indicating its high N uptake (Haile and Abay, 2012). Although *Enset* has high demand for organic residues, limitation in the number of livestock in *Enset* growing areas is causing reduction in the amount of animal dung to be added (Ayele, 1975). This situation is alarming, especially in the areas where population density is high, and calling for the use of chemical fertilizers to tackle the problem (Forsido et al*.,* 2013). A research conducted at Areka, south Ethiopia, indicated vigorous growth and prompted maturity when 138 kg N/ha and 20 kg P/ha were applied twice throughout the life of *Enset* (Ayalew and Yeshitila, 2011) revealing the importance of chemical fertilizers to prevent yield loss.

Until recently, there has been a general perception that soils of Ethiopia contain sufficient amount of potassium (K) based on the report by Murphy (1968). Thus, fertilizer extension program in Ethiopia did not include K 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 K fertilization (EthioSIS, 2013, 2014). Furthermore, the study conducted by Haile (2009) in Sidama zone, showed significant effect of K fertilizer on the yield of Irish potato. These findings indicate the importance of K application to increase crop yield in the different agricultural areas.

This research was therefore aimed at evaluating the response of *Enset* to K application in Sidama region, Ethiopia and to determine the rate and frequency of K application to *Enset* for optimum growth and productivity.

MATERIALS AND METHODS

Description of the study area

The study was conducted in Dale district of Sidama region, Ethiopia (Figure 1) from 2016 - 2018. Sidama region is located between 5°45'- 6°45' N latitude and 38°39° E longitude, covering a total area of 6,538 km^2 of which 98% is land and 2% is covered by water (SZPEDD, 2004). It lies in the area varying from lowland to highland (Sidama Development Corporation, 2000). The regional capital, Hawassa, is located in the northern tip of the region, at a distance of 275 km from Addis Ababa. As per traditional agro-ecological zone classification of Ethiopia, the area is characterized by mid highland and low land agro-ecology. The experimental site was located at 6°49.0'94'' N and 38°23.1'83'' E (Soyama farmers' association) at an altitude of 1782 masl.

Soil sampling, preparation and analysis

A composite sample was taken from a total of twelve random soil samples (0-50 cm) collected prior to land clearing and preparation. It was air-dried and passed through 2-mm sieve to remove large particles, debris and stones.

Particle size analysis was performed using the Bouyoucous hydrometer method (Bouyoucos, 1951) and the textural classes were categorized using United States 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 (1:5 soil water ratio) of soils (Gupta, 2009). Organic carbon 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, calcium, magnesium, sulfur (S) and boron (B) (Mehlich, 1984). Cation exchange capacity (CEC) was determined using ammonium acetate method (Sumner and Miller, 1996).

Experimental design and field management

Field trial was 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: were 0, 80, 150 and 200 kg K/ha as potassium chloride (KCl). *Ganticha* clone (Sidamic term) *Enset* suckers were propagated at Hula district Halaka *kebele* and 108 seedlings of *Enset* suckers were transplanted a year after sprouting to the main field at a depth of 20 cm.

Potassium chloride (KCl) was split applied two times per year. Recommended levels of P (20 kg/ha), nitrogen (N) (138 kg/ha) (Ayalew and Yeshitila, 2011), sulfur (S) (11 kg/ha) and boron (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.

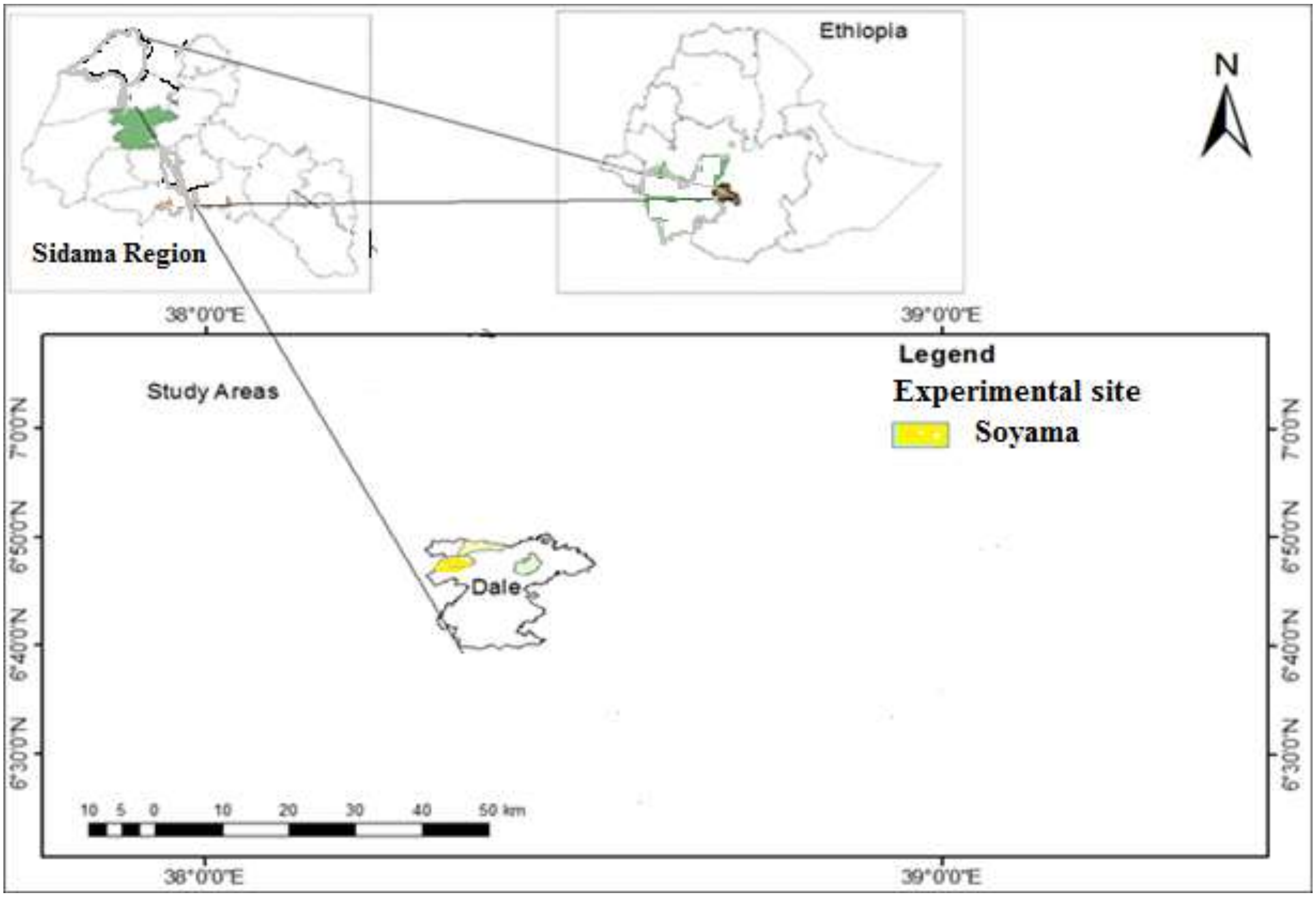

Figure 1. Map of Sidama region in Ethiopia, study district in Sidama region and experimental site 'kebele' in the study district.

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.

Plant sampling and agronomic data collection

Prior to harvesting, a total of thirty-six *Enset* plants were sampled randomly from the experimental site. 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.

Enset sampling and *kocho*, *bula* and fiber production

After random sampling of three plants per plot, fresh weights of all leaves, midribs, central tender pseudostem and edible leaf sheaths and corm were determined. Then, 500 g samples from each were taken and packed in cellulose paper folders. Samples were dried at 105°C for 24 h in an oven (Jones, 2001). Leaf sheaths of the pseudostem were decorticated using a sharp-edged bamboo scraper while pulverizing the corm by sharp edged animal bone. The resulting pulps were thoroughly mixed with purposely decayed and pulverized corm (Sidamic term: *Gamancho*) in order to accelerate the fermentation process and put into a pit. Fermentation pits were opened, and the contents were pressed and re-arranged to enhance the fermentation process. Thereafter, the un-squeezed *kocho* was weighed, squeezed by human force to the maximum dryness and the weight was recorded.

Plant leaf sampling, preparation and analysis

A total of twelve *Enset* samples were collected from experimental site based on sampling techniques used for banana plant (Borges et al*.,* 2002) since *Enset* and banana have similar leaf morphology (Tsegaye and Struick, 2003).

After dry ashed, samples were dissolved in concentrated acid and potassium was determined by flame photometer while P was determined by Colorimetry (by Ammonium Vanadate-Ammonium Molybdate yellow color method). On the other hand, sulfur, calcium, magnesium and boron were determined by atomic absorption spectrophotometer (AAS). Lastly, total N was determined by an acid digestion following the Kjeldahl method (Kjeldahl, 1883).

Statistical analysis

The statistical analyses were conducted using the SAS package

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

pH (H_2O)	EC (dS/m)	OC (%)	CEC (meq/100 g)	Total N (%)	Available P	Exchangeable bases K	Ca	Mg	S	B	Particle size Sand (%)	Clay	Textural class
						(mg/kg)							
6.35	0.08	2.49	23.70	0.14	4.16	450	2278	325	9.32	0.46	56	22	Sandy clay loam

Table 2. Effect of levels of potassium on % nutrient contents of *Enset* leaves.

Treatment	Nutrient content N	P	K	Ca	Mg	S	B (mg/kg)
	(%)						
T1 Control (No K)	2.44^{b}	0.17^{b}	2.30^{b}	0.30^{ab}	0.20^{c}	0.10	85^{a}
T2 (80 kg K/ha)	2.66^{ab}	0.21^{a}	3.67^{a}	0.36^{a}	0.27^{a}	0.12	20^{b}
T3 (150 kg K/ha)	2.74^{ab}	0.18^{b}	3.70^{a}	0.24^{b}	0.18^{d}	0.14	7^{d}
T4 (200 kg K/ha)	3.01^{a}	0.18^{b}	3.95^{a}	0.31^{ab}	0.22^{b}	0.17	12^{c}
Minimum	2.44	0.17	2.30	0.30	0.20	0.10	7
Maximum	3.01	0.21	3.95	0.36	0.27	0.17	85
$LSD_{0.05}$	0.55	0.02	0.33	0.08	0.069	0.07^{NS}	69
SEM±	0.09	0.01	0.2	0.02	0.0096	0.01	9.5

Means within a column followed by the same letter is not significantly different at P ≤ 0.05, Total number of leaf samples was 12.

(SAS Institute, 2012). The differences in vegetative parameters and yields among treatments were analyzed using a Fisher's protected least significant difference (LSD) test at P = 0.05. One-way analysis of variance (ANOVA) was done during data analysis. Moreover, correlations among total dry matter (DM), yields (*kocho*, *bula* and fiber), potassium rates and leaf nutrient contents of selected elements were undertaken.

Economic analysis

Partial budget analysis of selected treatments was done according to CIMMYT (1988).

RESULTS AND DISCUSSION

Selected physico-chemical properties of the experimental soil

The textural class of the experimental site soil was sandy clay loam (Table 1) and it indicates the exposure of crop nutrients to leaching. The soil pH was in the moderately acid range (pH 5.6-6.5). The EC values of the soil were below 2 dS/m indicating the soils are salt free in accordance with EthioSIS (2014).

In the district, the soil available P was low, S was very low while total N was low (EthioSiS, 2014). Calcium contents of the soils were high (2000-4000 mg kg^{-1}) (Maria and Yost, 2006) while K contents were optimum (190-600 mg kg^{-1}) in accordance with EthioSIS (2014). The magnesium contents of the soils were medium (180-396 mg kg^{-1}), whereas the organic carbon was very low (Landon, 2014). According to the classification proposed by EthioSIS (2014), the B contents of the experimental sites were very low (< 0.5 mg kg^{-1}). Based on the rating by Landon (2014), the CEC of the soils in the district fall in the high range (25 – 40 cmol (+) kg^{-1}).

Nutrient contents of the *Enset* leaf

The N content increased from T1 (control) to T4 (200 kg K ha^{-1}) and varied from 2.44 to 3.01 (Table 2). Generally, the highest N content was recorded at T4 though its content in plant leaves was significantly (P ≤ 0.05) different only with that of the control treatment (Table 2). Leaf N fall in the sufficient range (2.5-4.5%) proposed by Kalra (1998), at T2, T3 and T4 while T1 (control) was below 2.5%. The low values of N in control could be due to low soil K.

The lowest and highest values of leaf P were recorded at T1 (control) and K applied (T2) treatments, respectively. The contents varied from 0.17 to 0.21% (Table 2). Leaf P was below 0.20% and the low levels of P could be due to the status of soil moisture.

Despite the optimum K status of experimental soil, *Enset* responded to the applied K levels (Table 2). This indicated the importance of further investigation to determine crop type based critical K levels for different crops. Generally, K concentrations in the leaves increased with increasing K application and the increments ranged

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

Treatment (kg/ha)	Plant height	Pseudostem height	Pseudostem circumference	3^{rd} Leaf length	3^{rd} Leaf width	Total number of leaves
	(cm)					
T_1	520^{b}	162^{b}	118^{c}	360^{b}	73^{b}	81^{b}
T_2	577^{ab}	182^{ab}	132^{bc}	395^{ab}	77^{ab}	84^{b}
T_3	619^{a}	198^{a}	139^{ab}	421^{a}	84^{a}	84^{ab}
T_4	635^{a}	209^{a}	149^{a}	425^{a}	83^{a}	88a
Minimum	520	162	118	360	73	81
Maximum	635	209	149	425	84	88
$LSD_{0.05}$	86.4	33.9	16.2	54.3	8.6	4.7
SEM±	16.2	6.4	3.4	10	1.6	0.9
CV%	15.3	18.8	13	14.1	11.4	5.8

Means within a column followed by the same letter(s) is/are not significantly different at $P \leq 0.05$. T_1= Control or no K, T_2 = 80 kg K/ha, T_3 = 150 kg K/ha, T_4 = 200 kg K/ha, Total number of plants sampled was 36.

from 2.30 to 3.95%. This could be due to the presence of higher K in a readily available form in soil solution (Anjaiah et al., 2005). Among the treatments, the lowest K was recorded at T1 (control) while the highest value was indicated by T4. Overall, leaf K falls in the sufficient range (1.50-5.50%) that was proposed by Kalra (1998).

Sulfur contents of the leaves varied from 0.10 to 0.17% (Table 2) and increased from T1 (control) to T4 (200 kg K/ha). However, the increase was not significant among the treatments ($P \geq 0.05$) and the content was in the deficiency level (< 0.20%) according to Kalra (1998).

Calcium ranged from 0.30 to 0.36% while magnesium varied between 0.20 and 0.27%. The highest percent Mg was recorded at T2 (Table 2). Leaf Ca was deficient at all treatments (< 0.50%), while Mg was deficient (< 0.20%) nearly at all treatments in the district (Kalra, 1998). This could be due to the antagonistic effect of K on the uptake of Ca and Mg (IPNI, 1998).

Boron content varied from 7 to 85 mg kg^{-1} and the highest values were recorded at T1 (control). Generally, the concentrations of B in plant leaves decreased with increasing rates of K application probably due to dilution by high growth and biomass production of the plants with application of K (Mengel and Kirkby, 2001). This could be confirmed by increasing total B uptake by the plants, which increased from 0.06 to 0.12 kg ha^{-1} with increasing K rates.

Effect of applied potassium on vegetative growth parameters

Two years and four months after transplanting, the *Enset* plants were harvested to measure vegetative parameters. Generally, vegetative growth parameters increased with increasing contents of N, P and K in the leaves of plant as was also reported by Uloro and Mengel (1994) indicating the effects of N and P when K is not deficient. Among the treatments, the lowest vegetative growth was recorded at T1 (control). This indicated K deficiency in the experimental soils, although the contents were rated as optimum in accordance with EthioSIS (2014).

In general, the plant height increased with increasing level of K application and ranged from 520 to 635 cm (Table 3). Statistically significant difference ($P \leq 0.05$) was observed between the control and K treated plants at T3 and T4 while T1 and T2 treatments did not significantly differ (Table 3).

The data on pseudostem height showed significant ($P \leq 0.05$) variation between control and K applied plots (Table 3). Statistically significant ($P \leq 0.05$) differences were observed between the control (T1) and K applied plots (T2, T3 and T4), although T1 and T2 were not different in ($P \geq 0.05$). The pseudostem heights ranged from 162 to 209 cm (Table 3).

The pseudostem circumference increased with increasing levels of K application, whereby it varied from 118 to 149 cm (Table 3). The highest pseudostem circumferences were produced at T4, which were significantly different ($P \leq 0.05$) from the plants at T1 (control) (Table 3).

Total leaf number increased with increasing levels of K application and ranged from 81 to 88 (Table 3). Control plants (T1) had the least number of leaves per plant while the plants at the highest K rates had the highest number.

Leaf lengths varied from 360 to 425 cm (Table 3) and increased with increasing K application. Significant differences ($P \leq 0.05$) in leaf lengths were recorded between the control and K applied plots and highest and the lowest leaf lengths were recorded at T4 and T1, respectively.

Leaf widths of the plants varied from 73 to 84 cm (Table 3) and the highest leaf widths were recorded at T4. Significant differences ($P \leq 0.05$) in leaf width were recorded between the control and K treated plots. The significant increase in leaf width when K was applied

Table 4. Effects of increasing rates of potassium on above and below ground dry weights.

Treatment (kg/ha)	Leaf sheaths	Corm	Leaves and midribs	Centeral tender Pseudostem	Shoot
	(kg/plant)				
T_1	7.69^c	1.73^d	1.83^d	0.15^c	9.70^c
T_2	9.39^b	2.17^c	2.26^c	0.20^b	11.90^b
T_3	9.49^b	2.39^b	2.50^b	0.20^b	12.20^b
T_4	12.44^a	3.06^a	2.78^a	0.27^a	15.50^a
$LSD_{0.05}$	0.60	0.20	0.20	0.03	0.70
SEM±	0.31	0.09	0.07	0.01	0.40
CV%	6.40	8.60	8.6	12.8	5.60

In a column, means with the same letters are not significantly different at P ≤ 0.05. T_1 = Control or no K, T_2 = 80 kg K/ha, T_3 =150 kg K/ha, T_4 =200 kg K/ha, Total number of plants sampled is 36.

suggests the inadequate K contents of the experimental soils.

Effect of increasing levels of potassium application on dry matter production

Above ground dry matter

Generally, the above ground dry matter weight increased with increasing contents of N, P and K in the leaves of plant (Table 2). This indicated the importance of K application along with N and P for an increase of the above ground dry matter weight (Uloro and Mengel, 1994). Overall, the dry matter production of *Enset* plant increased with increasing levels of applied K (Table 4). Moreover, the lowest dry matter production was recorded at T1 (control) indicating K deficiency in the experimental soils.

Significant differences (P ≤ 0.05) in leaf and midribs dry weights were recorded among all treatments. This showed the effects of increasing levels of K.

Significant (P ≤ 0.05) differences in dry central tender pseudostem and dry weights of leaf sheaths were recorded between T1 and K treated plots (T2, T3 and T4), although there was no significant difference (P > 0.05) between T2 and T3 (Table 4). The highest central tender pseudostem and leaf sheath dry weights were recorded at T4, which were significantly different from the other treatments.

With regard to shoot dry weights, significant (P ≤ 0.05) differences were recorded between the controls and K treated plots (T2, T3 and T4) (Table 4). However, the plant dry weights at T2 and T3 were not significantly different indicating the K contents of the experimental soil was not sufficient for optimum *Enset* production.

Below ground dry matter

The corm dry matter production increased with increasing level of applied K (Table 4). Dry weights of corm of all treatments significantly (P ≤ 0.05) differed from each other. On the other hand, the corm dry weight of control was statistically different (P ≤ 0.05) from K treated plots. Overall, the lowest corm dry weights were recorded at T1 (control) indicating that K was deficient in the experimental soils. Conversely, the corm dry weights increased with increasing contents of N, P and K in the leaves of plant (Table 2). Thus, the results revealed the effect of K on corm dry weights when the limiting nutrients applied along with it, indicating that K promotes carbohydrate production in the state of balanced nutrition.

Maturity and yields of *Enset*

Enset crops to which K applied 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, *Enset* crops in control plots matured at one year later stage (Sidamic term: malancho) than those with K application.

Generally, *Enset* yields increased with increasing levels of applied K (Table 5) and the yields also increased with increasing contents of N, P and K in the leaves of plant (Table 2). Thus, the effect of potassium on *Enset* yield could be achieved when applied along with N and P (Uloro and Mengel, 1994). The result is in line with the report by Romheld and Kirkby (2010) and MoA and ATA (2012) which indicated the importance of balanced nutrient management on crop yields. Moreover, the lowest weights of *Enset* yields were recorded at T1 (control), indicating K deficiency in the experimental soils.

Among the treatments, T4 resulted in the highest weight (44 kg/plant) of fresh un-squeezed *kocho*. Moreover, significant differences (P ≤ 0.05) in fresh un-squeezed *kocho* weights were recorded only between controls and the K applied treatments (Table 5).

Among the treatments, T4 gave the highest fermented

Table 5. Effects of increasing rates of potassium on *kocho, bula and* fiber weights.

Treatment (kg/ha)	Un-squeezed *kocho*	Squeezed *Kocho*	*Bula*	Fiber	% Increase in squeezed *kocho* yield over control	% Increase in *bula* yield over control	% Increase in fiber yield over control
	(kg/plant)						
T_1	31.0[c]	14.1c	0.8[c]	0.46[c]	-	-	-
T_2	37.0[b]	16.7[b]	0.9[bc]	0.68[b]	16	11	32
T_3	37.0[b]	16.8[b]	1.0[b]	0.71[ab]	16	20	35
T_4	44.0[a]	20.1[a]	1.2[a]	0.78[a]	30	33	41
$LSD_{0.05}$	2.5	1.2	0.1	0.08	-	-	-
SEM±	0.9	0.4	0.03	0.02	-	-	-
CV%	7.1	7.1	9.8	13.27	-	-	-

Means in a column followed by the same letter(s) is/are not significantly different at P ≤ 0.05. T_1= Control or no K, T_2 = 80 kg K/ha, T_3 =150 kg K/ha, T_4 =200 kg K/ha. Total number of plants sampled per district is 36.

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

Economic variable	Dale district			
	T_1	T_2	T_3	T_4
Total yield (t/ha)	35	42	42	50
Adjusted yield (t/ha)	32	38	38	45
Value in birr	190350	225600	226800	271350
Cost of KCl applied in birr	-	2775	5203	6937
Cost that vary birr	-	2775	5203	6937
Net benefits birr	190350	222825	221597	264413

T_1= Control or no K, T_2 = 80 kg K/ha, T_3 =150 kg K/ha, T_4 =200 kg K/ha.

squeezed *kocho* dry weight, 20.1 kg/plant, whereas the lowest fermented squeezed *kocho* yields of 14.1 was recorded at T1. In general, significant (P ≤ 0.05) differences in dry weights of fermented squeezed *kocho* were recorded between controls and the K applied treatments. The squeezed *kocho* yields at T2, T3 and T4 were higher by 16, 16 and 30%, respectively than the yields obtained from control (Table 5).

The highest *bula* weight (1.2 kg/plant) was recorded at T4, whereas the lowest *bula* yield (0.8 kg/plant) was recorded at T1. Significant difference was recorded only between control and T3 and T4. The *bula* yields at T2, T3 and T4 treatments were higher by 11, 20 and 33%, respectively than yields obtained from control (Table 5). The results also indicated the significant effect K application on the *bula* yield per plant and the need for external supply of K for optimum yield.

Among the treatments, the highest K rate (T4) resulted in the highest fiber yield, 0.78 kg/plant, whereas the lowest fiber yield, 0.46 kg/plant, was recorded at T1 indicating K deficiency in the experimental soils. In general, significant (P ≤ 0.05) differences in fiber yields were recorded between controls and the K applied treatments. However, the fiber yield at T3 was not significantly different from those at T2 and T4. Fiber yields at T2, T3 and T4 were higher by 32, 35 and 41%, respectively than yields obtained from control (Table 5).

Economic analysis

The results of partial budget analysis pertaining to the data on fermented and squeezed *kocho* and *bula* (Tables 6 to 9) showed that the highest net benefit was obtained from K application at 200 kg/ha the experimental site in the district. Therefore, twice application of 200 kg K/ha during the life of *Enset* is recommended to increase the yield *of Enset* in the district.

A cross-correlation among total dry matter (DM), yields (*kocho, bula* and fiber), potassium rates and leaf nutrient contents of selected elements

The results of cross-correlation (Table 10) showed strong positive relationships between K rates and yield parameters such as leaf percent K contents, *kocho*, *bula*, fiber yields and total DM in both districts. Additionally, percent N and S had positive intermediate association with K rates. These associations indicated an increase of

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

Treatment	Dale district		
	Cost that vary (birr/ha)	Net Benefits (birr/ha)	Marginal rate of return (%)
T1	0	190350	-
T2	2775	222825	1170
T3	5203	221597	D
T4	6937	264413	2469

T_1= Control or no K, T_2 = 80 kg K/ha, T_3 =150 kg K/ha, T_4 =200 kg K/ha.

Table 8. Economic analysis of *bula* yield.

Economic variable	Dale district			
	T_1	T_2	T_3	T_4
Total yield	2	2	3	3
Adjusted yield	2	2	2	3
Value in birr	126000	142100	161000	189000
Cost of KCl applied in birr	-	2775.2	5203	6937
Cost that vary birr	-	2775	5203	6937
Net benefits birr	126000	139325	155797	182063

T_1= Control or no K, T_2 = 80 kg K/ha, T_3 =150 kg K/ha, T_4 =200 kg K/ha.

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

Treatment		Dale district		
		Cost that vary (birr/ha)	Net Benefits (birr/ha)	Marginal rate of return (%)
T1	Control	0	126000	-
T2	80 kg K/ha	2775	139325	480
T3	150 kg K/ha	5203	155797	678
T4	200 kg K/ha	6937	182063	1515

T_1= Control or no K, T_2 = 80 kg K/ha, T_3 =150 kg K/ha, T_4 =200 kg K/ha.

nutrient contents in *Enset* leaves and yield with increasing K levels. Moreover, 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.

The strong and significant negative correlation existed between B, K rates and K indicates the dilution effect of increasing biomass production on boron (Mengel and Kirkby, 2001).

Percent K correlated positively and strongly with *kocho, bula*, fiber and total DM (Table 10) indicating positive association. Leaf N correlated positively and strongly with *kocho*, *bula* and fiber yield. The leaf percent P correlated positively and intermediately with *kocho,* fiber and total DM indicating positive proportionality. Sulfur correlated positively and intermediately with total DM. Overall, the *kocho*, *bula*, fiber yields and total DM correlated strongly and positively with each other.

CONCLUSION AND RECOMMENDATIONS

Despite the adequate K level in the experimental soils, *Enset* responded to increasing levels of K application calling for site and crop specific investigation on critical levels of available K.

An increase in above and below ground dry matter production, perceptibly rapid vegetative growth of *Enset* and increase of yield with increasing level of applied K show the effect of K when limiting nutrients are applied along with it. Noticeable increase in plant heights, pseudostem heights, leaf lengths and total number of leaves recorded show the effect of K, when applied together with other limiting nutrients. Maturity difference between controls and K applied crops could also be due

Table 10. Cross correlation among percent *Enset* leaf nutrient contents, K rates, yields and total dry matter.

Parameter	N	K	P	S	B	K rates	Kocho yield	Bula Yield	Fiber Yield	Total DM
N	1									
K	0.62*	1								
P	0.06	0.09	1							
S	0.16	0.46	-0.45	1						
B	-0.51	-0.96*****	-0.40	-0.44	1					
K rates	0.62*	0.87****	0.09	0.59*	-0.87****	1				
Kocho yield	0.82***	0.81***	0.13	0.51	-0.74**	0.87****	1			
Bula yield	0.82***	0.62*	0.01	0.49	-0.51	0.77***	0.93*****	1		
Fiber yield	0.75**	0.87****	0.34	0.40	-0.86****	0.85****	0.86****	0.76***	1	
Total DM	0.71**	0.79***	0.10	0.57*	-0.74**	0.93*****	0.96*****	0.91*****	0.82***	1

*Significant at P ≤ 0.05; ** at P ≤ 0.01; *** at P ≤ 0.005; ****at P ≤ 0.001; ***** at P ≤ 0.0001.

to the effect of K applied along with limiting nutrients.

The correlation study indicated significantly positive effects of K rates, leaves percent K and N on the yields of *kocho, bula* and fiber and DM. On the other hand, B was negatively correlated with leaf nutrient contents, yields and the dry matter. This indicates that the applied B was diluted by high biomass produced. Finally, positive relationships existed among yields and DM, indicating the direct relationships existing between them.

Finally, as findings of this study implies adequate supply of potassium (K) fertilizer to Enset crop will not only increase the production of the crop but also help avoid environmental damages to the soils. For the details on the relationship between use of potassium (K) fertilizer and sustainability of soil is the subject for further study based on the outcomes of this paper.

Generally, application of 200 kg K/ha twice throughout the life of *Enset* significantly (P ≤ 0.05) increased the growth, yields and net benefits of *Enset* production than other treatments. Hence, application of 200 kg K/ha twice during the life of *Enset* is recommended.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Amede T, Diro M (2005). "Optimizing soil fertility gradients in the Enset (*Ensete ventricosum*) systems of the Ethiopian highlands: Trade-offs and Local Innovations." In: Improving Human Welfare and Environmental Conservation by Empowering Farmers to Combat Soil Fertility Degradation (Bationo et al., eds). African highlands initiative (AHI), working papers No 15.

Anjaiah T, Padmaja G, Sreenivasa Raju A (2005). Influence of levels of K and FYM on yield and K uptake by carrot (*Daucus carota* L.) grown on an Alfisol. Journal of Research, ANGRAU 33(3):82-86.

Ayalew A, Yeshitila M (2011). The Response of Enset (Ensete ventricosum (Welw) Cheesman) production to Rate and Frequency of N and P Nutrients Application at Areka, in Southern Ethiopia. Innovative Systems Design and Engineering 2:26-32.

Ayele GM (1975). The forgotten Aborigines Livestock and meat Board, Addis Ababa.

Borges AL, van Raij B, Magalhães AF, de C, Bernardi AC (2002). Nutrição e adubação da bananeira irrigada. Embrapa Mandioca e Fruticultura. Cruz das Almas, BA. (Circular Técnica, 48).

Bouyoucos GJ (1951). Recalibration of hydrometer method of mechanical analysis of soil Agronomy Journal 43(9):434-435.

Brandt AS (1996). A model for the origins and evolution of Enset food production. In: A. Tsedeke, H. Clif¬ton, B.A. Steven & S. Gebre-Mariam (eds.), Proceedings from international workshop on Enset. Enset-Based Sustainable Agriculture in Ethiopia. Edited by. Institute of Agricultural Research, Addis Ababa pp. 172-187.

Brandt, Steven A, Anita S, Clifton H, McCabe TJ, Endale T, Mulugeta D, Gizachew WM, Gebre Y, Masayoshi S, Shiferaw T (1997). The tree against hunger: Enset- Based Agricultural systems in Ethiopia. http://users.clas.ufl.edu/aspring/publications/enset.pdf

Bremner JM, Mulvaney CS (1982). Nitrogen-Total. In: Page, A.L., Ed., Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties, American Society of Agronomy, Soil Science Society of America pp. 595-624.

CIMMYT (1988). From Agronomic Data to Farmer Recommendations : An Ecconomics Training Manual. Completely revised edition. Mexico, DF.

Central Statistical Authority (CSA) and Ministry of Agriculture (MOA) (1994). Area production and yield of crops, private holdings, 1993/1994 Meher season, Addis Ababa, Ethiopia.

Dalbato AL [publ. as: Lagibo A.] (2000). An overview of population and food production situation in SNNPR. Population Newsletter, Awassa–Ethiopia 4:10-13.

Ehret C (1979). On the antiquity of agriculture in Ethiopia. Journal of African History 20(2):161-177.

Ethiopia Soil Information System (Ethiosis) (2014). Soil fertility status and fertilizer recommendation atlas for Tigray regional state, Ethiopia. July 2014, Addis Ababa, Ethiopia.

Ethiopian Soil Information System (EthioSIS) (2013).Towards improved fertilizer recommendations in Ethiopia – Nutrient indices for categorization of fertilizer blends from EthioSIS woreda soil inventory data. A discussion paper. Addis Ababa, Ethiopia.

Forsido SF, Vasantha Rupasinghe HP, Tess A (2013). "Antioxidant capacity, total phenolics and nutritional content in selected ethiopian staple food ingredients." International journal of food sciences and nutrition 64(8):915-920.

Funte S, Negesse T, Legesse G (2010). Feed resources and their management system in Ethiopian highlands: the case of UmbuloWacho watershed in southern Ethiopia. Tropical and Subtropical Agroecosystems 12:47-56.

Gupta PK (2009). Soil water plant and fertilizer analysis. 2nd Edition, Agronomy and bioscience. Publishers 5(3):398-406.

Haile W (2009). Onfarm verification of potassium fertilizer effect on the yield of irish potato grown on acidic soils of Hagere selam, Southern Ethiopia. Ethiopian Journal of Natural Resources 11(2):207-221.

Haile W, Abay A (2012). Potential of Erythrinabrucei, Erythinaabyssinica and Enste venticosom, Indigenous Organic Nutrient Sources for Improving Soil Fertility in Small Holder Farming Systems in Ethiopia p. 16.

International Plant Nutrition Institute (IPNI) (1998). Potassium Availability and Uptake. Better Crops 82:3.

Jackson ML (1973). Soil analysis. Prentice Hall of India Pvt. Ltd. New Delhi. Swaminathan, M.S. (Ed.). Taylor and Francis, UK.

Jones JB Jr. (2001). Laboratory guide for conducting soil tests and plant analysis. CRC Press.

Kalra YP (1998). Handbook of Reference Methods for Plant Analysis CRC Press, Boca Rotan, FL, USA.

Kjeldahl J (1883). "Neue Methode zur Bestimmung des Stickstoffs in organischen Körpern" (New method for the determination of nitrogen in organic substances), Zeitschrift für analytische Chemie 22(1):366-383.

Landon JR (2014). Booker tropical soil manual: a handbook for soil survey and agricultural land evaluation in the tropics and subtropics. Routledge, Abingdon, UK. 532 p.

Maria RM, Yost R (2006). A Survey of soil fertility status of four agro ecological zones of Mozambique. Soil Science 171(11):902-914

Mehlich A (1984). Mehlich 3 soil test extractant: A modification of Mehlich 2 extractant. Communications in Soil Science & Plant Analysis 15(12):1409-1416.

Mikias Y, Handaro F, Mulugeta D, Zerihum Y, Zadik M (2010). Improved Enset production Technology, Ethiopian and SNNPR Institute of Agricultural Research (in Amharic).

Ministry of Agriculture (MoA) and Agricultural Transformation Agency (ATA) (2012). 5-year strategy for the transformation of the soil health and fertility in Ethiopia, Addis Abeba, Ethiopia. https://www.canr.msu.edu/

Mohammed B, Gabel M, Karlsson LM (2013). Nutritive values of the drought tolerant food and fodder crop Enset. African Journal of Agricultural Research 8(20):26-33.

Murphy HF (1968). A Report on Fertility Status and Other Data on Some Soils of Ethiopia. Experimental Station Bulletin No. 44. Hailesilassie College of Agriculture, Oklahoma State University.

Nyunja ARO, Onyango JC, Erwin B (2009). The Kakemaga forest medicinal plant resource and their utilization by the adjacent Luhya community. International Journal of Tropical Medicine 4(3):82-90.

Romheld V, Kirkby EA (2010). Research on Potassium in Agriculture: Needs and Prospects. Plant and Soil 335(1-2):155-180.

SAS institute (2012). User's Guide. SAS/STAT® 9.3. Statistical Procedures, Second edition. SAS institute inc, Cary, NC, USA.

Shank R, Ertiro C (1996). Enset crop assessment. United Nations World Food Programme, Bureau of Agriculture, Southern Nations, Nationalities, Peoples' Regional State UNDP Emergencies Unity for Ethiopia, Addis Ababa, Ethiopia P 56.

Sidama Development Corporation (2000). Planning and Statistics. en.m.wikipedia.org.

Sidama Zone Planning and Economic Development Department (SZPEDD) (2004). Hawassa, Ethiopia. www.oecd.org

Sumner ME, Miller WP (1996). Cation exchange capacity and exchange coefficients. In: D. L. Sparks, A. L. Page, and P. A. Helmke, editors, Methods of Soil Analysis. Part 3, Chemical Methods. Soil Science Society of America, Madison, Wisconsin, USA pp. 1201-1229.

Taye B, Feleke A (1966). The production and utilization of the genus Ensete in Ethiopia 20(1):65-70.

Tsegaye A (2002). On indigenous production, genetic diversity and crop ecology of Enset (Ensete ventricosum (Welw.) Cheesman). Ph.D. Thesis. Wageningen University, Wageningen, The Netherlands P 198.

Tsegaye A, Struik PC (2001). Enset (Ensete ventricosum (Welw.) Cheesman) kocho yield under different crop establishment methods as compared to yields of other carbohydrate rich food crops, Netherlands Journal of Agricultural Science 49(1):81-94.

Tsegaye A, Struik PC (2003). "Growth, radiation use efficiency and yield potential of Enset (Ensete ventricosum) at different sites in southern Ethiopia."Annals of applied biology 142(1):71-81.

Tsehaye Y, Kebebew F (2006). Diversity and cultural use of Enset (Ensete ventricosum (Welw.) Cheesman) in Bonga in situ conservation site, Ethiopia, Ethnobotany Research and applications 4:147-157.

Uloro Y, Mengel K (1994). Response of Ensete to mineral fertilizers in southwest Ethiopia. Fertilizer Research 37(2):107-113.