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Customized Potassium Foliar Feed for Optimum Yield of Maize in Nyeri County, Kenya

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Abstract Majority of farmers in Nyeri County apply Nitrogenous and Phosphorous fertilizers to boost maize productivity. However, the acreage yield has remained low. Potassium (K) and micro nutrients fertilizers application in this region is limited. There is limited report on foliar feed application in this region. In the current study, nutrients levels in various farm soils of selected farms in Nyeri County were determined, customized potassium foliar feed was formulated to address their deficiencies. Grid sampling technique was used. Total nitrogen registered 0.0645- 0.067% below the recommended level of 0.25%, phosphorous recorded 1.6-1.9mg/L below the critical level of 10mg/L. The available Potassium had 7.769±1.104 mg/L; Calcium and Magnesium had 6.28±0.16mg/L and 10.164±0.199 mg/L respectively. This is below the critical values of 160 mg/L, 15mg/L and 25mg/L respectively. Zinc, copper, iron and manganese registered 0.1484±0.006mg/L, 0.1501±0.001mg/L, 0.1141±0.003mg/L and 0.1004±0.0003 mg/L respectively compared to critical values of 5mg/L, 5mg/L, 6mg/L and 2mg/L respectively. Customized K foliar contained Potassium, Phosphorous, Nitrogen, Magnesium and Calcium with 13.00±0.13mg/L, 6.64±1.02mg/L, 0.75±0.01%, 6.19±0.18 mg/L, and 23.90±1.10 mg/L respectively. In addition, zinc, copper, iron and manganese recorded 0.159±0.005mg/L, 0.668±0.008 mg/L, 0.34±0.18 mg/L and 0.46±0.003 mg/L respectively. Maize was grown in 12 plots of 5m by 5m with spacing of 50cm between the adjacent plots at each of the 4 selected farms. The 12 plots received same N and P basal fertilizer dosage of 70kg/ha. 3 plots received commercial foliar (20mg/L), 3 plots received half dosage (10mg/L) of customized K foliar, 3 plots received a full dosage (20mg/L) of customized K foliar while 3 plots received no foliar feed (control). Plant height, stem girth, ear length and grain yields were analyzed. Customized K foliar (20mg/L) increased plant height, ear length stem girth and maize yields. This study established that customized foliar feed significantly improved the maize yield in the region.

Keywords Basal fertilizers, Soil nutrients, Maize yields, Foliar feed, Growth parameters, Yield parameters

1. Introduction

Maize is a key cereal and a major staple food in Kenya with about 88% of households consuming it as a staple food (Olielo, 2013). It can be grown in a wide range of agro-ecological zone and climatic conditions (Bukhsh *et al.,* 2012).

Despite the fact that maize has wide ranges of environmental adaptability, its yield is still very low especially in Nyeri County (Ayaga *et al.*, 2004). The acreage yields have constantly declined due to use of insufficient fertilizers which results to depletion of nutrients in the soil (Kiiya *et al.*, 2006). One major problem affecting agriculture is low soil fertility (Kiiya *et al.,* 2006). The nutrients distribution in the soil determines the soil fertility. Continuous use of land without proper replenishment of utilized nutrients has greatly resulted to decline in soil fertility (Wiebold and Scharf, 2006). The depletion of nutrients is caused by poor agricultural practices. These poor practices include: removal of crop residual for livestock, overgrazing and burning during the land preparation (Oborn *et al.,* 2005). These poor agricultural practices have lead to drop in nutrients stocks where the annual depletion of nitrogen (112 kg ha^{-1}), Phosphorous (31 Kg ha^{-1}) and potassium (70Kg ha^{-1}) nutrients (Ayaga *et al.*, 2004). An adequate supply of nitrogen, phosphorous and potassium is essential for good growth and high yield of Maize. Nitrogen and phosphorous are very important nutrients for good vegetative growth and grain development. Potassium on the other hand is very crucial because it plays a very important role in physiological process in plants. Presence of potassium in crops affects more than 50 enzymes responsible for energy transfer, formation of sugar, starch and proteins (Taiz and Zeiger, 2006). It is the main requirement for maximum maize growth and yields (Saidou, *et al.*, 2012). Potassium also helps plants to resist fungal and bacterial attacks by strengthening stalks of plants. In addition to this potassium also promotes the formation of good quality seeds as well as fruits. Calcium and magnesium are the other micro

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nutrients which are of good importance to the growth of maize. Magnesium in particular is very essential in very many biological systems (Bukhsh *et al*., 2012). A good example is adenosine triphosphate (ATP) which is the main source of energy in cell must be bound to a magnesium ion in order to be biologically active. This nutrient is very important in the synthesis of chlorophyll for photosynthesis. Calcium on the hand regulates the transport of other nutrients in to the plant, enforces the structural systems and plays a role in activation of certain plant enzymes. Deficiencies of calcium will results to stunted growth and rotting of plant (Romaniuk *et al*., 2018).

Micro nutrients such as Boron, iron, copper, zinc and manganese cannot be ignored. They are equally important especially in plants development, they activates enzymes that are responsible for the synthesis of certain proteins as well as responsible for the formation of chlorophyll and conversion of carbohydrates, starches to sugar (Bukhsh *et al*., 2012). Deficiency of Boron in the soil may cause the weakening of pectin (Romaniuk *et al*., 2018). This is a fiber that is required by the plants to remain physically stable. It may also cause plants to stop growing. Food shortage in Kenya has been attributed to increased human population, shortage of land for cultivation and declining yields (Makhanu, et al., 2012). Use of phosphorus and nitrogen basal inorganic fertilizers and organic manure which is of low quality is the common practice by most small scale farmers across the country (Romaniuk *et al*., 2018).

Foliar Feed

Foliar is a liquid, water soluble fertilizer absorbed by crops through the leaves when sprayed. The leaves of plants are able to absorb essential nutrients directly (Fageria *et al.*, 2009). Leaves stomata are used during the absorption of the essential nutrients. Plants are also able to absorb essential nutrients through their bark (Oborn *et al.*, 2005). Potassium foliar can correct nutrients deficiency (potassium), increase resistance to pests and diseases, promote fruits growth and development, facilitates movement of water and other nutrients (Bukshsh *et al.*, 2012) and reduces environmental pollution.

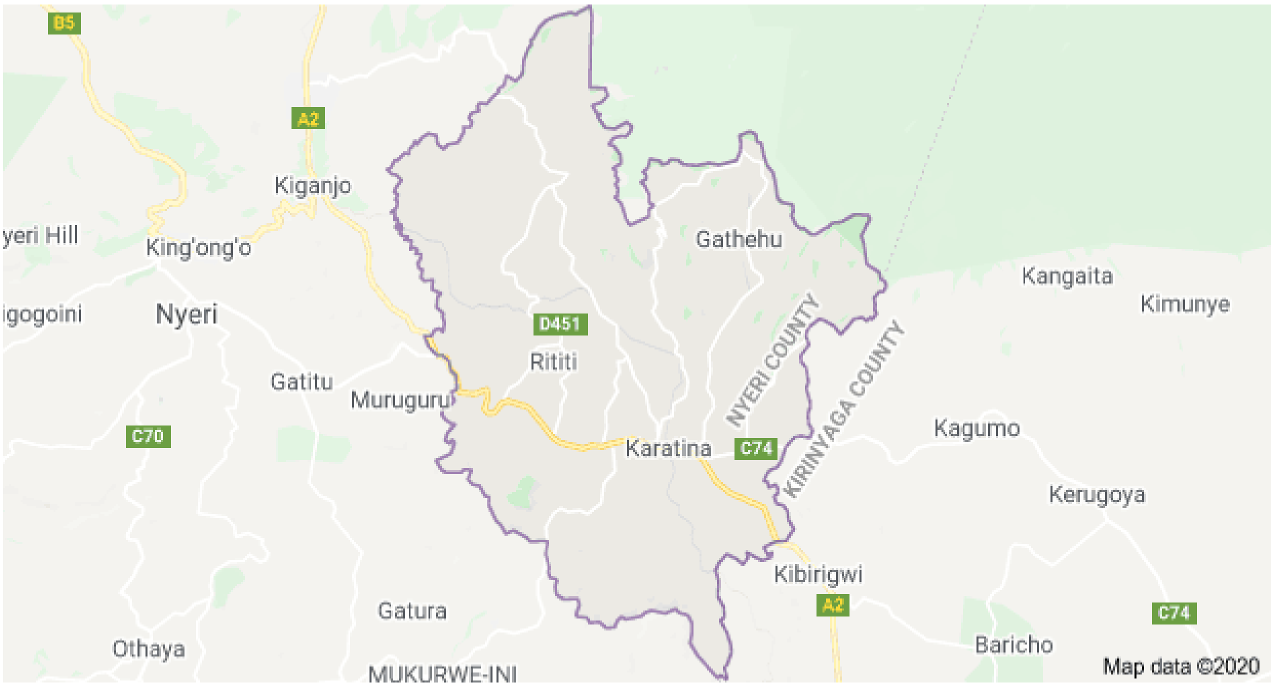
Foliar feed has been used efficiently to supplement nutrient to crops (Kiiya *et al.*, 2006). Foliar feeding nutrients are absorbed more effectively than soil-administered fertilizing. Foliar application has its advantages especially in avoiding the problem of leaching out in soils and facilitates quick reactions in plants.

For nutrients required by plants in large quantities, soil application is more common. Application of foliar feed consisting of N, P and K has been found to have significant increase on the yields of soya beans (Wortmann *et al*., 2009). Foliar sprayed at the right time has been found to increase yields e.g. foliar sprays consisting urea and triple superphosphate increases the yields by 10-50% and 15-65% in trials on spinach, cabbage and pea (Fageria *et al.*, 2009). Potassium foliar can be customized, that is, enriched with other important nutrients. This study aims at determining the available soil nutrients and formulating a customized foliar feed for optimum yield of maize.

2. Materials and Methods

Farm site

The experiment was carried out in Mathira constituency (0°25' 12.47"N and 36°56'51.32"E) in Nyeri County, Kenya (0°24' 59.99"N and 36°56'59.99"E).



The area has a well-drained loam soil. Mathira constituency receives annual rainfall of between 500mm to 1500mm. Crops grown in this area include: maize, beans, arrow roots, coffee, tea, cassava, variety of fruits and vegetables. Large portions of the land are under cultivation while the rest are preserved for pasture or for soil regeneration. Four farm sites from Konyu and Karatina sub counties were selected. The selection was purposive based on soil characteristics (colour, soil structure and soil water) and extensive farming.

Land Preparation and Research Design

Soil samples were collected from each farm site and analyzed for nutrient levels to establish nutrients deficiencies. The farm sites were prepared by digging and harrowing to pulverize the soil. Each of the four experimental farm sites was divided into twelve plots of 5m by 5m. A randomized complete block design with 4 blocks was used to lay the experiment at each farm site. The blocks were labeled site A, B, C and D. Each site had 12 square plots of 5m by 5m with spacing of 50 cm between the adjacent plots. All the plots in each of the farm sites were treated with the same dosage of nitrogen and phosphorous basal fertilizers of 75 kg/ha. In addition to the common treatment of phosphorous basal fertilizer, four treatments A, B, C and D were applied to the maize plant grown in the various plots in triplicates such that three of twelve plots were subjected to the same treatment. Treatment A was the control whereby no foliar feed was applied. This is the common practice of the majority of the farmers from this region. B constituted treatment with 10mg/L (half dosage) of customized K foliar feed fertilizer, treatment C (commercial Foliar) constituted treatment with 20mg/L full dosage of potassium nitrate multi K classic rich in N (13.4%), K(38.1%) and K_2O (46%) while D constituted treatment with 20mg/L (full dosage) of customized K foliar feed. 3 Plots per farm site received treatment A, another 3 plots received treatment B, another 3 plots received treatment C while the last three plots received treatment D two weeks after germination and three more treatments in three weeks intervals . Growth parameters that included stem girth and plant height as well as yield parameters of ear length and maize yields measured were determined for each plot and data collected from the experiment analyzed statistically using (ANOVA to compare the impact of the foliar feed fertilizer per the treatment applied.

Sample collection

The study involved four farms which have been under serious cultivation. The locations of these farms were Gathugu (site 1) (0°25' 12.47"N and 36°56'51.32"E), kiratina (site 2) (0°23' 13.30"N and 36°56'54.20"E), Karatina Girls secondary (site 3) (0.4848°S and 37.127°E) and Sygoni (site 4) (0.4848°S and 37.1339°E) villages. Top soil samples were collected from the four farms to a depth of between 0-30cm randomly. This is because most soil nutrients and maize roots are found within this depth. In order to obtain soil with uniform characteristics, grinding of the soil samples was employed. The soil samples collected were dried, grounded, passed through a 2 mm sieve and packed in clean bags. The samples were later stored in cool and dry place ready for analysis.

Soil Samples Analysis

The pH was determined for a 1:2:5 soils to water paste using pH meter. Soil Electrical conductivity was determined where 20 grams of soil was weighed and placed in a conical flask. Distilled water was added to prepare saturated soil content; this soil paste was allowed to stand for 30 minutes. This was followed by vacuum filtration whereby the paste was transferred to Buchner funnel. The Electrical conductivity of the filtrate was measured (Rayment and Higginson, 1992) while the total soil organic carbon determined using the method described by Walkey Black 1947 rapid titration method. Total Nitrogen was determined by the method described by Kjeldahl (1993). The concentration of potassium, magnesium and sodium was determined using the flame photometer. Phosphorous was determined by Olsen method and determined calorimetrically at a wavelength of 880nm. Micro nutrients such as zinc, manganese, copper and iron were determined using AAS.

Foliar Feed Preparation

Analysis of the soil samples obtained at the four farm sites established macro nutrient deficiencies in potassium, phosphorous, nitrogen, magnesium and calcium. Further, micro nutrients of manganese, copper, zinc and iron also registered deficiencies. This prompted the formulation of a customized foliar feed that can correct these nutrients deficiencies. To this end, 100g of dried egg shells (source of calcium and magnesium) 50 grams of dried banana peels (source of potassium), 50 grams of wood ash (source of potassium, phosphorous and magnesium) and 100 grams of dried fish guts and bones (source of phosphorous, potassium, nitrogen and Iron) were mixed in a 500 mL conical flask. Bones and fish guts were crushed and reduced to small pieces and then mixed banana peels, wood ash, egg shells all grounded into fine powder using mortar and pestle. This mixture was sun dried in the open, then treated with 50mL of 0.25M nitric acid. 50mL of 0.25M NaOH was then added to raise the pH to 7. Filtration was done to the resulting solution and nutrients were analyzed using Flame photometer (calcium, potassium and magnesium), AAS (zinc, manganese, iron and copper) and Uv-Vis Spectrophotometer (phosphorous). The resulting solution was treated with soap-less detergent, Urea and humic acid to act as a sticker for the enhancement of the uptake of nutrients by the maize plant on the surface of the leaf.

Planting and measuring of growth parameters.

Maize was planted in four rows with spacing of 30cm and 75 cm between holes and rows respectively. One seed was placed in each hole. Weeding, disease and pest control were done. Growth and yield Parameters of stem girth, ear length and height of the plant were measured at intervals of 14 days while grains weight was measured on harvesting.

Statistical Analysis

The data collected from the experiment was analyzed statistically using the analysis of variance (ANOVA). The graphs were drawn using Microsoft Excel. Mean comparisons were done using the Post-Hoc Turkey Two way ANOVA at 5% probability.

3. Results and Discussion

Physicochemical parameters of farm soil samples

A summary of selected physicochemical properties and nutrient levels are provided in table 1. As indicated on the table, the soil samples had moderate range of total organic carbon of between 1.91-2.43% with a mean value of 2.17±0.2246 %. This range is within the moderate range of 1.5-3.0%. The farm soil samples were found to be deficient of phosphorus nutrient which ranged between 1.6-1.9 mg/L with a mean value of 1.75±0.1291 mg/L far below the recommended critical level of 10 mg/L. This deficiency can be attributed to the fact that there is low occurrence of phosphorous containing minerals in this region and due to long term farming (Wortmann *et al*., 2009). This study established that the soil sample had deficiency in the total Nitrogen levels which ranged between 0.064-0.067 percent with a mean value of 0.066±0.001%, values far below the recommended critical value (0.25%) (Bukhsh *et.al.* 2012). Although the soils were found to be deficient of nitrogen and phosphorus nutrients, it is important to note that majority of the farmers in this region mainly replenish them during planting.

Table 1. Summary of Some Chemical Properties of the Soil Analyzed

Parameters	Units range	Mean values n=4	Critical Values
Electric conductivity	mmhos/cm	0.975±1.0213	-
soil pH	-	6.48±0.87	-
Total organic carbon	%	2.17±0.2246	3%
CEC	cmol/kg	31.25±16.137	-
Nitrogen	%	0.06634±0.00148956	0.25%
Manganese	Mg/L	0.1004±0.000356	2mg/L
Iron	Mg/L	0.114133±0.003628	6mg/L
Copper	Mg/L	0.150133±0.000818	5mg/L
Zinc	Mg/L	0.148407±0.000647	5mg/L
Potassium	mg/L	7.769±1.104	160mg/L
Calcium	Mg/L	6.2823±0.1648	25mg/L
Magnesium	Mg/L	10.164±0.199	15mg/L
Phosphorous	mg/L	1.75±0.1291	10mg/L

The concentration level of bio-available potassium that was extracted from soil samples using ammonium acetate ranged from 6.66-8.973mg/L with a mean value of 7.769±1.104 mg/L, a value that is far below the recommended critical value of 160mg/L (Bukhsh *et.al.* 2012). This is a critical finding of this study since majority of the farmers in the region hardly replenish potassium during planting. Indeed, this could be the limiting nutrient and foremost factor that is contributing to low acreage yields in the region.

The soil pH value ranged from 5.32-7.31 with a mean value of 6.48±0.87 indicating that the soils were weakly acidic. The soils had a mean of 31.25±16.137 Cmol/kg as Cation Exchange Capacity with a range of 12.5-50 Cmol/kg. These are medium values that indicate that the soil can hold nutrients moderately. CEC values greater than 25 Cmol/kg indicate that the soil has high organic matter content and large quantity of cations (Bukhsh *et.al.* 2012). The electrical conductivity of these soils ranged from 0.23-2.47 mmhos/cm with a mean value of 0.975±1.0213 mmhos/cm. Most crops including maize require a soil with electrical conductivity which does not exceed 4 mmhos/cm. Electrical conductivity of 0.975±1.0213 mmhos/cm is a moderate value which indicate that the soil samples from this region has the ability to absorb water and soluble nutrients (Bukhsh *et.al.*, 2012). Soil samples also recorded deficiencies in micronutrients such as iron, copper, manganese, calcium, magnesium and zinc that is, 0.114±0.003mg/L, 0.15±0.01, 0.10±0.001, 6.283±0.168, 10.164±0.19 and 0.148±0.001mg/L respectively.

Customized Potassium Foliar Feed Characteristics

Table 2 gives a summary of the nutrients present in the customized K foliar feed which was formulated to address the soil nutrients deficiency. In this region farmers are not used to foliar feed application or application of potassium based fertilizers. Soil in this region is usually furnished with nitrogen and phosphorous basal fertilizers which during the rainy seasons are lost through leaching. This alone may results to imbalanced nutrition which is a limiting factor to high yields of maize. Application of foliar feed results to balanced nutrition which plays a vital role in increasing crop production.

The pH of the customized K foliar feed was adjusted to 7.00 at 25.2℃ to make it a neutral solution the concentrations of key macronutrients N, P, K, and Mg in the customized foliar feed fertilizer were 0.75±0.001%, 1.3±0.13mg/L, 6.64±1.02mg/L and 6.19±0.18 mg/L respectively. This was meant to correct their deficiencies found in the farm soils. The concentrations of key micronutrients Cu, Fe, Mn and Zn in the customized foliar feed fertilizer were 0.65±0.08, 0.34±0.04, and 0.45±0.03 and 0.15±0.05 mg/L respectively. This was meant to correct the deficiencies of copper, iron, manganese and zinc found in the farm soils. The concentration of potassium ions was found to be in the range of 6.3421-6.9381 mg/L. Maize plants requires potassium ions in large quantities for leaf and stem development. Maize plants are heavy feeders of potassium (Okaleb *et al.*, 2002). Therefore there is need to supplement potassium to the soil. The range of calcium ions in the foliar feed was 23.904-24.0382mg/L. Calcium helps in proper roots development. The mount of phosphorous in the foliar feed ranged from 1.2- 1.4mg/L, When phosphorous is applied to maize plants at early stages, it helps in boosting the growth of the leaf (Fageria *et al.,* 2009). While magnesium ions concentration ranged from 5.9842-6.3872 mg/L, this level again didn't surpass the critical level of magnesium in the soil (15mg/L). Where deficiency symptoms appears visible, water soluble fertilizers or foliar sprays can be applied (Fageria *et al.,* 2009). The nitrate level ranged from 0.8-0.9mg/l, available nitrogen in the foliar feed ensured that the plants leaves remained green up to maturity.

This ensured that there is enough chlorophyll for photosynthesis purposes. However, fertile soils require just one-third of this quantity for the yields to be high (Mora-Vellejo *et al.,* 2013). Customized K foliar feed contained micronutrients such as copper, iron, manganese and zinc. The level of zinc ions ranged from 0.1583-0.1601mg/L. Zinc helps in production plant growth hormones as well as proteins which are useful in sugar consumption, it also helps in healthy roots development (Taiz and Zeiger 2006) while the level of copper ions ranged from 0.2134-0.2430 mg/L. About 0.9g of iron is required by the maize plants to yield 1kg of grains, Iron is very essential for plant growth and development (Syrers, 2001). The range of Copper was 0.643-0.6683 mg/L. Copper activates some enzymes in plants which are involved in lignin synthesis and it is essential in several enzyme systems (Debele, 2011). The range of Manganese was 0.5823-0.5945 mg/L. 1.09 g of manganese is required by maize plants to produce 1kg of maize grains, Manganese sustains metabolic roles within different plant cell compartments (Debele, 2011). Availability of these micro nutrients in the customized potassium foliar feed cannot be ignored. Foliar feed sprayed with at least 1% of iron, manganese and copper can be used to correct nutrients deficiency when applied at weekly intervals while zinc deficiency can be corrected by spraying foliar feed that contains 0.5% Zinc (Wiebold and Scharf 2006).

Table 2. Characteristics of Customized Potassium Foliar Feed

Element	Mean (mg/l)	Units Range
Calcium	23.9711±0.0949	Mg/L
Magnesium	6.1857±0.2850	Mg/L
Potassium	6.6401±0.4214	Mg/L
Zinc	0.1592±0.001273	Mg/L
Copper	0.6558±0.0177	Mg/L
Nitrate	0.7±0.0707	%
Phosphorous	1.3±0.1414	Mg/L
Iron	0.34±0.18	Mg/L
Manganese	0.46±0.003	Mg/L
pH at 25.2°C	7.00	-

Growth parameters

Growth parameters of maize plants grown under four different types of treatments A, B, C and D were monitored in four farm sites, where the treatments were done in triplicates. Doses of 70 kg/ha of basal nitrogenous and phosphorous fertilizers respectively were applied to all the farms under all the treatments as is usually the case with majority of the farmers in the region. In addition, no foliar feed was applied to farms under treatment A which acted as the control while 10 mg/L (half dosage) of customized foliar, 20 mg/L of commercial foliar and 20mg/L (full dosage) of customized K foliar feed fertilizers were applied to farms under treatments B, C and D respectively. The growth parameters measured included stem girth, ear length and plant height while the yields parameter measured was the maize yields.

Ear Length

Table 3 shows the mean of ear lengths of the maize grown in plots 1, 2, 3 and 4 subjected to treatments A, B, C and D after every two weeks in the first 10 weeks after planting. As indicated in the table, the ear length measurements were taken two weeks after the first treatment with foliar feed fertilizer which corresponds to four weeks after planting. Thereafter, the measurements were taken after every two weeks up to 10 weeks after planting. Treatment D which corresponds to full dose of customized foliar feed recorded the highest ear length two weeks after the first treatment at 69.57±12.55, 98.19±16.23, 86.81±11.20 and 69.95±5.82 for plots 1, 2, 3 and 4 respectively. Indeed, treatment D gave the highest ear length with the highest recorded 10 weeks after planting at 101.81±5.92, 103.24±5.94, 104.10±6.34 and 92.43±4.17 for plots 1, 2, 3 and 4 respectively. These values were higher than those obtained upon treatment with commercial foliar feed that is 51.44±9.97, 57.19±5.17, 63.91±7.32 and 71.14±15.17 for plot 1, 2, 3 and 4 after 4 weeks and 101.81±5.92, 103.24±5.94, 104.10±6.34 and 92.43±4.17 for plots 1, 2, 3 and 4 respectively 10 weeks after planting. When the mean values of treatment C and D were compared, the two were found to be significantly different (p=0.001). Similar comparison was done between treatment A which corresponds to control and treatment D. Treatment A recorded the lowest ear length two weeks after the first treatment at 33.14±14.28, 45.48±5.69, 49.29±13.49 and 61.05±14.83 for plot 1, 2, 3 and 4 respectively and 77.74±5.68, 69.86±5.23, 78.24±6.86 and 87.43±3.37 for plots 1, 2, 3 and 4 respectively 10 weeks after planting. When the mean values of treatment A and D were statistically compared, they were found to be significantly different (p=0.001).

Plant heights

Comparison test was further employed to test the performance of the four treatments on the plant height. Plant height is considered as the distance of the maize plant tip from the ground. It is an important parameter that indicates plant growth and development. Table 4 shows the mean of plant height of maize grown in plots 1, 2, 3 and 4 subjected to treatments A, B, C and D after two weeks and in the first 10 weeks after planting. Treatment D which corresponds to full dose of customized foliar feed recorded the highest plant height two weeks after the first treatment at 73.57±13.25, 99.76±15.73, 81.43±14.25 and 73.33±8.37 for plots 1, 2, 3 and 4. Treatment gave the highest of plant heights with highest recorded 10 weeks after planting at 180.23±11.38, 260.33±4.58, 273.67±8.07 and 277.00±4.90 for plots 1, 2, 3 and 4 respectively. These values were higher than those obtained upon treatment with commercial foliar feed 52.76±18.68, 67.52±14.58, 53.67±7.39 and 51.81±7.58 for plot 1, 2, 3 and 4 respectively after 4 weeks and 237.90±5.21, 248.52±6.62, 244.43±4.30 and 179.38±9.42 for plot 1, 2, 3 and 4 respectively 10 weeks after planting. When the plant height mean values of treatment C and D were statistically compared, the two treatments were found to significantly different (p=0.001). Treatment A which corresponds to the control recorded the lowest plant height two weeks after the first treatment at 24.71±10.29, 47.81±11.18, 38.67±4.10 and 31.95±3.33 for plot 1, 2, 3 and 4 respectively and 198.67±7.97, 141.57±10.72, 192.24±9.24 and 142.57±6.75 for plot 1, 2, 3 and 4 respectively 10 weeks after planting. To assess the specific difference in treatment, post hoc Turkey test was conducted. It was found that 94.8% of the variation in the plant height was explained by the variation in the time of application (duration) and treatment applied. At 95% confidence level, As shown in the table 5 and table 6 when the plant height mean values of treatment A and D were analyzed statistically, the two were found to be significantly different (m= 28.18 p=0.001). Treatment D improved the plant height more than treatment A.

Table 3. Ear Length Descriptive Summary

Duration	Treatment	Plot	Mean±SD	Duration	Treatment	Plot	Mean±SD
Week 4	A	1	33.14±14.28	Week 6	A	1	64.24±9.54
		2	61.05±14.83			2	81.95±9.32
		3	49.29±13.49			3	49±14.20
		4	45.48±5.69			4	74.14±7.32
	C				C		
		1	51.44±9.97			1	70±6.29
		2	71.14±15.27			2	102.95±15.65
		3	63.90±7.32			3	63.95±7.91
		4	57.29±5.17			4	74.14±7.32
	B	1	64.19±6.94		B	1	74.62±7.57
		2	84.38±13.73			2	102.81±13.45
		3	72.43±7.52			3	72.48±8.07
		4	53.38±7.54			4	71.24±8.05
	D	1	69.57±12.55		D	1	86.24±12.24
		2	98.19±16.23			2	151.38±27.42
		3	86.81±11.20			3	88.52±11.08
		4	69.95±5.82			4	86.38±8.01
Duration	Treatment		mean±SD	Duration	Treatment		mean±SD
week 8	A	1	66.19±11.02	week 10	A	1	77.74±5.68
		2	76.38±10.15			2	69.86±5.23
		3	63.24±5.64			3	87.43±3.37
		4	69.29±5.85			4	78.24±6.86
	C				C		
		1	70.56±10.06			1	84.24±3.28
		2	86±7.39			2	69.62±4.85
		3	74.38±9.20			3	91.05±5.68
		4	82.43±7.53			4	82.15±5.84
	B	1	76.29±11.22		B	1	87.67±4.45
		2	90.81±10.91			2	93.05±3.45
		3	81.76±7.32			3	92.62±3.00
		4	79.48±8.41			4	85.33±6.11

Duration	Treatment	Plot	Mean±SD	Duration	Treatment	Plot	Mean±SD
	D	1	**86.52±7.85**		**D**	1	**101.81±5.92**
		2	**93.43±8.71**			2	**103.24±5.94**
		3	**83.90±7.10**			3	**104.10±6.34**
		4	**93.14±6.35**			4	**92.43±4.17**

Table 4. Plant height Descriptive Summary

Duration	Treatment	Plot	Mean±SD	Duration	Treatment No:	Plot	Mean±SD
4 weeks	A	1	24.71±10.29	6 weeks	A	1	60.57±7.67
		2	47.81±11.18			2	100.67±8.23
		3	38.67±4.10			3	77.95±13.08
		4	31.95±3.33			4	59.76±8.13
	C	1	52.76±18.68		C	1	91.67±14.58
		2	67.52±14.58			2	137.48±19.71
		3	53.67±7.39			3	102.24±14.47
		4	51.81±7.58			4	82.38±14.74
	B	1	49.05±13.24		B	1	92.90±13.63
		2	73.57±7.79			2	157.62±5.58
		3	66.81±10.89			3	102.10±14.45
		4	48.57±5.38			4	79.90±8.72
	D	1	73.57±18.89		D	1	122.05±13.85
		2	99.76±15.73			2	183.57±16.68
		3	81.76±14.25			3	150.48±31.20
		4	73.33±8.37			4	98.38±9.96
Duration	**Treatment**	**Plot**	**mean±SD**	**Duration**	**Treatment**	**Plot**	**mean±SD**
8 weeks	A	1	120.90±23.79	10 weeks	A	1	198.67±7.97
		2	122.95±31.22			2	141.57±10.72
		3	126.86±10.32			3	192.24±9.24
		4	111.29±14.50			4	142.57±6.75
	C	1	148.43±32.27		C	1	237.90±5.21
		2	171.76±22.91			2	248.52±6.62
		3	147.57±27.27			3	244.43±4.30
		4	141.24±7.19			4	179.38±9.42
	B	1	148.43±32.27		B	1	245.95±5.86
		2	173.10±26.01			2	238.81±7.96
		3	142.14±19.49			3	237.05±7.05
		4	127.29±7.77			4	165.10±14.70
	D	1	174.19±14.09		D	1	273.67±8.07
		2	203.86±34.85			2	277.00±4.90
		3	175.57±21.74			3	260.33±4.58
		4	151.43±10.59			4	180.23±11.38

Table 5. Two Ways ANOVA on Plant Height for plot 1

(I) Treatment		Mean Difference (I-J)	Sig.
	A	32.89*	.000
B	C	4.45*	.333
	D	29.76*	.000
	C	28.18*	.000
D	A	59.65*	.000
	B	26.79*	.000

Table 6. Two Ways ANOVA on Maize Plant Height for plot 2

(I) Treatment		Mean Difference (I-J)	Sig.
	C	4.45*	.366
B	A	50.15*	.000
	D	30.76	.000
	C	34.73*	.000
D	A	87.80*	.000
	B	30.27*	.000

Table 7. Maize stem girths Descriptive Summary

Duration	Treatment	Plot	Mean±SD	Duration	Treatment	Plot	Mean±SD
		1	3.94±0.61			1	5.17±0.61
	A	2	4.03±0.57		A	2	5.65±0.59
		3	3.81±0.81			3	5.02±0.44
		4	3.81±0.53			4	5.82±0.41
		1	5.03±0.85			1	6.10±0.22
	C	2	5.93±0.71		C	2	6.56±0.51
		3	4.78±0.57			3	5.75±0.46
		4	5.48±0.46			4	7.27±0.48
4 weeks				6 weeks			
		1	4.55±0.83			1	5.85±0.67
	B	2	4.96±0.68		B	2	6.59±0.66
		3	4.66±0.83			3	5.54±0.54
		4	4.51±0.99			4	6.83±0.41
		1	7.09±0.71			1	6.90±1.20
	D	2	8.04±0.68		D	2	8.20±0.56
		3	4.49±0.88			3	6.34±0.37
		4	6.57±0.68			4	7.91±0.69
Duration	**Treatment**	**Plot**	**mean±SD**	**Duration**	**Treatment**	**Plot**	**mean±SD**
		1	5.49±0.65			1	6.25±0.45
	A	2	6.06±0.51		A	2	6.32±0.37
		3	5.38±0.58			3	6.34±0.37
		4	6.33±0.74			4	6.09±0.66
		1	6.40±0.76			1	7.26±0.49
	C	2	6.57±0.53		C	2	7.21±0.35
		3	5.45±0.43			3	6.78±0.42
		4	7.39±0.82			4	7.26±0.50
8 weeks				10 weeks			
		1	6.44±0.72			1	6.54±0.45
	B	2	6.81±0.81		B	2	6.82±0.45
		3	5.53±0.47			3	6.59±0.42
		4	6.84±0.77			4	7.448±0.74
		1	7.34±0.88			1	7.77±0.56
	D	2	7.25±1.14		D	2	8.46±0.41
		3	6.13±0.66			3	7.51±0.59
		4	8.10±0.44			4	8.17±0.55

Table 8. Two Ways ANOVA on Maize Stem Girth for plot 2

(I) Treatment		Mean Difference (I-J)	Sig.
B	A	0.950*	.000
	C	.0043*	.026
	D	1.657*	.000
D	A	1.772*	.000
	B	2.480*	.000
	C	1,693*	.000

Stem Girth

Stem girth indicates the stem thickness and this important agronomic yield component of maize. Table 7 shows the mean of stem girth of the maize grown in plots 1, 2, 3 and 4 subjected to treatments A, B, C and D after every two weeks in the first 10 weeks after planting. Treatment D which corresponds to full dose of customized potassium foliar feed registered the highest stem girth two weeks after the first treatment at 7.09±0.71, 8.04±0.68, 4.49±0.88 and 6.57±0.68 for plots 1, 2, 3 and 4 respectively. Indeed, treatment D gave the highest stem girth with highest recorded 10 weeks after planting at 7.77±0.56, 8.46±0.41, 7.51±0.59 and 8.17±0.55 for plots 1, 2, 3 and 4 respectively. These values were higher than those obtained upon treatment with commercial foliar feed 5.03±0.85, 5.93±0.57, 4.78±0.57 and 5.48±0.46 and 7.26±0.49, 7.21±0.35, 6.78±0.42 and 7.26±0.50 for plots 1, 2, 3 and 4 respectively 10 weeks after planting. A comparison test to assess whether there is mean difference in treatment using two-way ANOVA. The results showed 66.6% of the variation in the stem girth was explained by the model. At 5% level of confidence, when the mean values of plant stem girth for treatment D and C were compared, the two were found to be significantly different ($m=1.693$, $p<0.0001$). Treatment A which corresponds to the control recorded the lowest ear length two weeks after the first treatment at 3.94±0.61, 4.03±0.57, 3.81±0.81 and 3.87±0.53 for plots 1, 2, 3 and 4 respectively and 6.25±0.45, 6.32±0.37, 6.34±0.37 and 6.09±0.66 for plots 1, 2, 3 and 4 respectively 10 weeks after planting. When the mean values of treatment A which corresponds to control were compared with treatment D, the mean difference is significant ($m=1.772$, $p=0.000$) as shown in table 8. Plant stem girth increased with application of treatment A, B, C and D at all stages of growth. Application of treatment D resulted to increase of stem girth by 44.4±15.63%.

Maize Yields

Analysis was conducted on the maize yields in kilogram per hectares. Table 9 shows the mean yields of the maize grown in plots 1, 2, 3 and 4 subjected to treatments A, B, C and D. It is good to note that the measurements were taken after maize matured and harvested after 15 weeks after planting. Treatment D which corresponds to full dose of customized potassium foliar feed recorded the highest yields of 3990.33±207.15, 4570.03±346.12, 4800.12±830.52 and 4633.33±934.13 for plot 1, 2, 3 and 4 respectively. These values were higher than those obtained upon application of treatment C which corresponds to commercial foliar feed that is 3780.80±720.00, 3320.67±365.500.17, 3012±600.25 and 3990.33±207.16 for plot 1, 2, 3 and 4 respectively. A post hoc test was to compare the mean values as a result of application of treatment D and C on maize yields resulted to a mean difference of ($m=1766.667$, $p=0.006$). This implies that the two treatments are not significantly different ($p>0.005$). Treatment A which corresponds to the control recorded the lowest yields of maize that is 1840±1260, 1670±200.00, 1575±360.00 and 1233.33±295.65 for plot 1, 2, 3 and 4 respectively. Comparing the two treatments that is D and A, the mean values are significantly different ($m=2050$, $p=0.000$). This is shown by the table 10 below. Figure 1 shows the performance of the four farm sites where Gathugu farm produced the highest yields. Maize yield was compared with foliar feed applied as shown in figure 2.

Table 9. Maize Yields Descriptive Summary

Treatments	Plot	Yields in kg/ha Mean ± S.D
A	1	1840 ± 1260.00
	2	1670 ± 200.00
	3	1575 ± 360.00
	4	1233.33 ± 295.65
B	1	2730 ± 2160.02
	2	2845 ± 1425.55
	3	3078 ± 550.75
	4	2583.33 ± 357.34
C	1	3780 ± 720.00
	2	3320 ± 500.17
	3	3012 ± 600.25
	4	2866.67 ± 365.15
D	1	3990.33 ± 207.16
	2	4570.03 ± 346.12
	3	4800.12 ± 830.52
	4	4633.33 ± 934.13

Table 10. Maize Yields Mean Difference in Comparison to Customized K Foliar Full Dose

(I) Treatment	(J) treatment	Mean Difference (I-J)	Sig.
D	B	2050.00000*	0.002
	C	1766.66667*	0.006
	A	3400.00000*	0.0001

From the results, the ear length increased by (76.7±21.05%) with the application treatment D which comprised of N&P basal fertilizer and 20 mg/l full dosage of Customized K foliar feed, this can be attributed to fresh thin leaves of the maize plants which are permeable to absorb foliar feeding efficiently. Renuka et al (2002) reported that premature loss of chlorophyll in leaves could be retarded by applying foliar fertilization. Ling and Moshe (2007) reported that increase in leaf length (ear length) of the maize plants is due to weekly application of foliar feed.

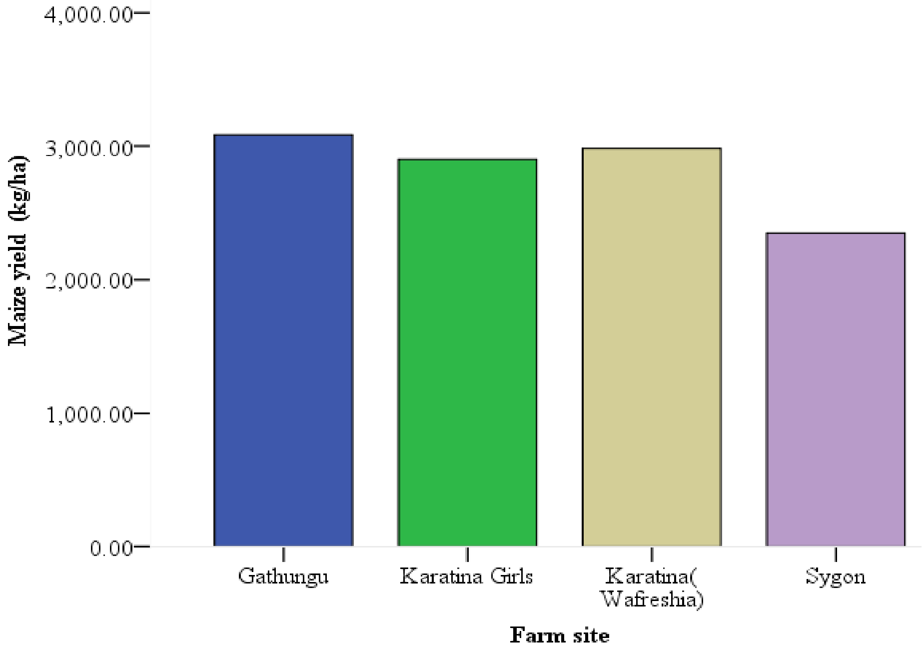


Figure 1. Maize Yield Weight Bar Plot

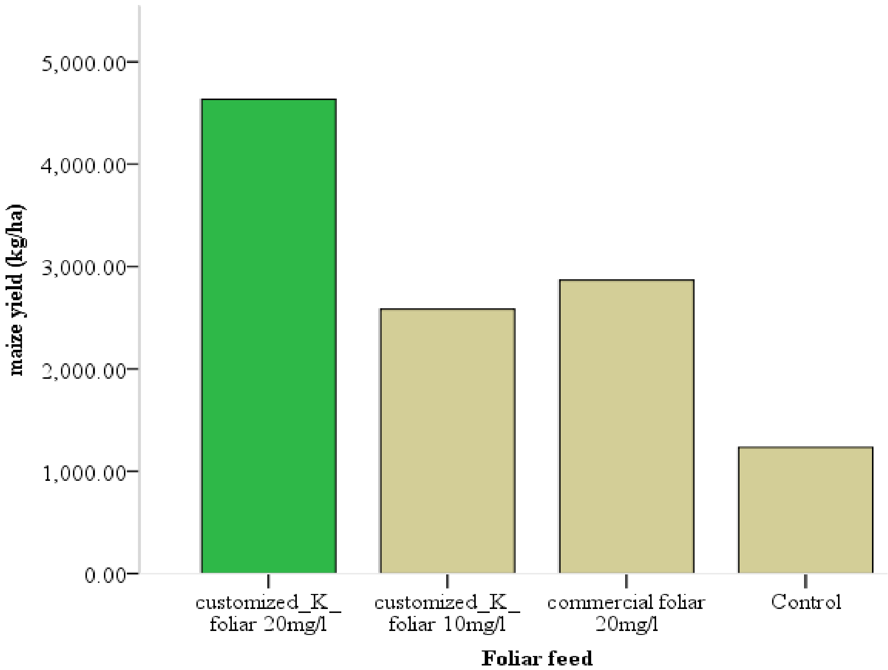


Figure 2. Maize Yield Weight Bar Plot Based on Foliar Feed

Emerson (2008) reported that nitrogen deficiency at early stage of maize growth may result to smaller leaves hence there is a need to supplement nitrogen to maize plants at early stage of growth and development. Addition of foliar feed results to balanced nutrition. Balanced nutrition plays a vital role increasing crop production. In this region, farmers are not used to foliar feed application or application of potassium based fertilizers to boast maize productivity.

Plant height describes rate of growth and show relationship between growth and chemical composition in plants. Maize plants require small quantities of phosphorous at early stages of crop development. Treatment D provided substantial amount of phosphorous for shoot development which result to a good plant height. Potassium ions are also required in the leaf and stem development(Renuka *et al.*, 2002). Similar to Yuncai et al (2008), we associate high plant heights with a good consumption of nutrients in the foliar feed that results to high osmotic potential hence an increase in cell and length expansion. Higher plant height might be due to vegetative growth and development triggered by nitrogen treatments (Mahmoodi *et al.*, 2011). Nitrogen is very important for building up protoplasm amino acids and proteins, which are very important in cell division and initiate meristimatic activity. Phosphorous (P) is part of molecular structure of nucleic acid the energy transfer compounds and also proteins whereas potassium is a necessary element for overall metabolic and enzymatic activities especially photosynthesis (Yuncai *et al.*, 2008). All these factors translate to proper growth and development in maize. Treatment D increased the plant height by 45.5±42.23%.

The maize stem girth is a good parameter that can be used to determine the plants ability to resist lodging. For proper stem development foliar feed containing phosphorous, nitrogen and potassium is required. When the application of the foliar feed is done early enough to supplement these macro nutrients, strong and healthy plants will grow. Maize yields were affected by the type of the foliar feed applied. Any fertilizer or foliar feed with a good level of potassium ions will results to high yields of maize. According to Emerson (2008) potassium ions are very essential in stomata regulations that is opening and closing of stomata which prevents water wastages. Potassium also facilitates the uptake of the other nutrients improving the growth conditions of the maize plant. Similar to Ahmed et al (1992), potassium ions improves cell division and grains yield per row Similar. The availability of micronutrients in the foliar feed such as zinc and iron helps in improving the seed formation resulting to high yield of maize.

Data from Table 6 shows that application of treatment D had a significant effect on maize plant height. According to Mahmoodi et al (2011), Nitrogen increases plant height and high doses of nitrogen have potential al to give comparatively higher grains yield of maize and higher plant height might be due to more vegetative growth and development triggered by nitrogen in treatments. Customized K foliar feed increased the maize yield by 275.7±23.92%. From the results above, the ear length increased by (76.7±21.05%) with the application treatment D which comprised of N&P basal fertilizer and 20 mg/l full dosage of Customized K foliar feed, this can be attributed to fresh thin leaves of the maize plants which are permeable to absorb foliar feeding efficiently. Renuka et al (2002) reported that premature loss of chlorophyll in leaves could be retarded by applying foliar fertilization. Ling and Moshe (2007) reported that increase in leaf length (ear length) of the maize plants is due to weekly application of foliar feed. Emerson (2008) reported that nitrogen deficiency at early stage of maize growth may result to smaller leaves hence there is a need to supplement nitrogen to maize plants at early stage of growth and development. Addition of foliar feed results to balanced nutrition. Balanced nutrition plays a vital role increasing crop production. In this region, farmers are not used to foliar feed application or application of potassium based fertilizers to boast maize productivity. Farmers in this region furnish the soil with Nitrogen and Phosphorous based fertilizers which in most cases are lost through leaching during rainy seasons.

Plant height describes rate of growth and show relationship between growth and chemical composition in plants. Our study, just like Ling and Moshe (2007), takes plant height is a good determinant for high yield for individual maize plant. Maize plants require small quantities of Phosphorous at early stages of crop development. Treatment D provided substantial amount of phosphorous for shoot development which result to a good plant height. Potassium ions are also required in the leaf and stem development.

4. Conclusions

This study aimed at determining the soil fertility indices such as the soil Organic Carbon, Cation exchange Capacity, Soil pH, available nitrogen, Potassium and available phosphorous and consequently to formulating Customized K foliar feed for farms in the selected farms in Nyeri County. The soil had a moderate range of total organic carbon with a mean of 2.17±0.2246%. Low levels of phosphorous (1.75±0.1291 mg/l), total nitrogen (0.21±0.0392%) and potassium (47.928±10.336 mg/L) were recorded from the soil samples. The soil recorded high pH values (6.48±0.87); moderate soil cation exchange capacity (12.5-50 Cmol/kg Cmol/kg) and moderate soil electrical conductivity (0.975±1.0213 mmhos/cm) Customized Potassium foliar feed was formulated to improve crop production in Nyeri country. The formulated Customized K foliar feed was neutral (pH value of 7.00 at 25.2℃), moderate levels of potassium ions (6.3421-6.9381 mg/L). Calcium (23.904-24.0382 mg/l), Phosphorous (1.2-1.4mg/l), Magnesium (3.445-3.555mg/L), and Nitrogen (0.8-0.9mg/L) levels were also moderate. Low levels of micronutrients such as Zinc (0.1583-0.1601mg/L), Iron (0.643-0.6683 mg/L), Manganese (0.46±0.003mg/L) and copper (0.34±0.18mg/L) were available in the formulated customized K foliar feed. As shown in the analysis section, maize plant ear length will increase if the nutrients are complemented. Results imply that application of treatment C in earlier stages improve leaf formation hence the ear length will be large in comparison to plants in the control sites. As shown in majority of maize plant height post hoc test, the significant mean difference is observed between plots that received treatment A and the other plots that received other treatment that is, treatment D, both B and C. This indicates that for long maize plant large quantities of potassium is required.

Similarly, maize stem girth is shown to differ significantly with the applied foliar feed applied. Results shows that stem girth will increase from plots that received treatment A to the plots that received treatment D. On the analysis of the maize yield weight, it was observed that any difference in maize yields is as a result of supplement application. Results have shown a remarkable improvement of the foliar feed and result to even more weighted maize yield. Maize yields, stem girth, ear length and plant height increased significantly when the dosage of treatment B was increased from 10 mg/L to 20 mg/L. Treatment C increased the maize yields. However, the treatment could not increase the yields to much extent compared with treatment D. Plots that didn't receive any foliar feed (Control) recorded the lowest maize yields. No mean difference was observed between treatment B and treatment C in terms of the maize yields.

5. Recommendations

This study has shown that the soil nutrients in this region has depleted. Therefore there is need to supplement nutrients to the soil. Farmers and policy makers should put a lot of efforts to add more nutrients to the soil for optimum yield of maize. Customized K foliar feed can be used to correct nutrients deficiency especially soils with low levels of nutrients such as potassium, nitrogen, phosphorous and micronutrients. This study has shown that in this region, the soil is weakly acidic with a pH value of 6.48±0.87, continuous liming is required to improve the soil pH. Farmers and extension officers are therefore advised to first determine nutrients deficiency before choosing the kind of fertilizer to apply to the soil. Thus, the study recommends concentration of at least 20 mg/L of customized K foliar feed to be used for optimum yield of maize. This will result to healthier maize plant, strong and high maize yield.

In conclusion, the application of customized foliar feed significantly improved plant growth (height, ear length and girth) and maize yields in Nyeri County.

REFERENCES

[1] Ahmed, F., Abid, M.M., Mahmood, N., Anwar, M.A., and Sandhu, N.A., (1992). Effect of potassium in different proportions with nitrogen and phosphorus on growth yield and oil content. Journal of Agricultural Research, 30, 353-357.

[2] Ayaga G., Kibunja, C.N., Kanyanjua, S.M., Gikonyo E.W. and Wamae D.K. (2004). Improving soil fertility through integrated nutrient management. Conference proceedings. Agriculture Research and Development for sustainable Resource management and Food Security in Kenya. 11th -12th Nov. 2003. KARI, Nairobi Kenya pp 1-11.

[3] Bukhsh, M, A, A, H, A., Ahmad, R., Iqbal, J., Maqbool, M.M., Anser, A., Ishaque, M., and Safdar, H., (2012). Nutritional and physiological significance of potassium application in maize hybrid crop production. Pakstan journal of nutrition, 11(12), 187-202.

[4] Debele, T, (2011). The effect of minimum and convection tillage systems on maize grain yield and soil fertility in western Ethiopia, proceedings of the 5th world congregation on conservaton Agriculture incorporating 3rd farming system conference, September 26-29, 2011, Brisbane.

[5] Emerson Nafziger (2008). Nitrogen Deficiency in corn after pollination. The Bulleting integrated pest management, University of Illinois, Crop science Dept. Illinois Natural History survey.

[6] Fageria, N.K., Filho, M.P. Barbasa Moreira, A Guimaraes, C. M. (2009). "Foliar fertilization of crop plants." Journal of plant nutrients. 33 (6) 1044-1064.

[7] Kiiya, W.W., Mureithi, J.M. and Kiama, J.M. (2006). Improving production of irish potatoes in Kenya. Development and up scaling of Green Manure Technologies.

[8] Kjeldahl, J. (1993) "A new method for the estimation of Nitrogen in Organic compounds," Anal. Chem., 22, 366.

[9] Ling Fan and Moshe silberbush 2007. Journalof plant nutrition 10. 1081/PLN-120014698:2007, 2333-2342 first published 14th Feb 2007.

[10] Mahmoodi P. Yamla M. Amiirnia R. and Khorshidi M.B. 2011. African Journal of Agriculture Research. Vol. 6 (29), pp. 6226-6231, 5 December, 2011. ISSN 1991-637X.

[11] Makhanu, F. N. Kiptarus E and Kiongera F., (2012) "Impact of specialization and Diversification reengineering strategies on farm and off farm activities for sustainable food security in Kenya" CDMHA/ADMCRK 18th-20th July 2012 Conference proceedings. 2012.

[12] Oborn, I., Andrist-Rangel, Y., Askekaard, M., Grant, C.A., Watson, C.A. aand Edwards, A.C. (2005). Critical Aspects of potassium management in Agricultural systems. Soil use and management, 21: 102-112.

[13] Okaleb, J.R. Gathua, K.W. and Woomer, P.L (2002) Laboratory methods of soil and plant analysis. Aworking manual, 2rd e.d. TSBF-C.AT and SACRED Africa, Nairobi, Kenya pp128.

[14] Olielo, T. (2013). Food Security Problems in Various Income Groups of Kenya, African Journal of Food, Agriculture, Nutrition and Development, 13(4): 1-13.

[15] Renuka R, Yoncong L., Herbert H.B., Steward T.R and Florence D.A 2002 Assessment of foliar spray to alleviate flooding injury in corn zea mays L. Proc Fla. State Hort soc 115: 208-211.

[16] Romaniuk, R, Beitran M, Brutti L, Constantini A, Bacigaluppos and Sainz-Rozas H (2018) Soil Organic Carbon, Macro- and Micronutrient changes in soil fractions with different lability in response to crop intensification soil tillage Res (181: 136-143.

[17] Saidou. A, Janssen B, Temminghoff EJM (2012) Effect of soil properties on maize yields and nutrients budgets on ferratilic soils in Southern Benin. Agric Ecol, Environ 100: 265-273.

[18] Syers, J.K., (2001). Soil plant potassium in agriculture proceeding No. 411, The international fertilizer society, Newyork.

[19] Taiz, L and Zeiger E., (2006). Plant defences, surface protectants and secondary metabolites in plant physiology, sinnauer Associates, Sunderland M.A.

[20] Wiebold, B. and Scharf P, (2006). Potassium deficiency symptoms in stressed crops, plant stress resistance and impact of potassium application South China. Agronomy Journal 98, 1254-1357.

[21] Wortmann, C.S., Dobermann, A., Ferguson R.B., Hergert,

G.W., Shapiro, C.A., Tarkalson, D.D., Walters, D.T., 2009. High-yielding corn response to applied Phosphorous, Potassium and Sulfur in Nebraska, Agron. J. 101. 546-555.

[22] Yuncai Bur, Hucs Z. and Schmidhali U. 2008. Journal of Botany. 1747-1765.