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Effects of Blended Fertilizers on Leaf Nutrients Content of Mature Clonal Tea in Kenya

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ABSTRACT

Fertilizer studies in Kenya tea industry have focused predominantly on compound NPK. These fertilizers cannot be easily manipulated for specific soils and tea clones. In this respect, Athi River Mining limited has produced Mavuno blended NPK fertilizers with calcium (Ca) and magnesium (Mg). However, their application rates that would result in optimal nutrients uptake are lacking. This is the knowledge gap that this study sought to address. Therefore, the fertilizer blends were assessed for their effects on nutrients uptake at different rate in two sites. The sites were selected purposefully, one in the eastern and the other in the western tea growing areas. Randomized complete block design (RCBD) were used to select 36 trial plots in the two areas which were treated with three fertilizer types where one type was control, and four fertilizer application rates with one rate being a control. The trial was replicated three times. Leaf samples were collected and analyzed for nutrients content. The data were then subjected to the analysis of variance (ANOVA) using Mstat C computer software package. Two leaves and a bud had higher nitrogen content (Timbilil 4.84%; Kagochi 4.53%) compared to deficient levels in mature leaf (Timbilil 2.26%; Kagochi 2.95%). This study has shown that supplementing the soil applied NPK fertilizers with calcium, magnesium and micronutrients resulted in better nutrients uptake.

Keywords: Blended fertilizers, clonal tea, seasons

INTRODUCTION

Fertilizers are applied to fields to attain desired soil fertility levels for crops grown (Virk et al. 2013). The available nutrients content and their degree of accessibility and availability is very dynamic because of the various inorganic and biochemical processes in the soils (Baligar et al. 2001). These include temperature, water content, soil reaction, nutrient input, uptake and losses. Most of these nutrient forms (in solution, adsorbed, fixed, and sparingly soluble) are in a dynamic equilibrium. External applications only cause temporary changes in the relation between different fractions, but the basic nature of the equilibrium remains intact over time (Roy et al. 2006). A decrease in pH from the neutral range results in a smaller proportion of exchangeable Calcium (Ca) and Magnesium (Mg). In the case of phosphate, there is initially a greater mobilization of calcium phosphate, but later a strong immobilization or even fixation into aluminium and iron phosphates (Hansen et al. 2004). The dynamics of phosphate in soil present special problems because of the low solubility of most P compounds (Turner et al. 2006). The availability of some micronutrients, especially of Iron (Fe), Manganese (Mn) and Zinc (Zn), is increased strongly, and can even reach toxic levels (Roy et al. 2006). An increase in pH by liming can reverse the situation. Nitrogen (N) is a critical nutrient for tea production (Zentner et al. 2003), but it is difficult to optimize nitrogen (N) fertilizer applications because of the dynamic nature over the growing season (Sitienei et al. 2013). Potassium is an important macronutrient for plants which, with N and P, plays an important role in plant development (Zhang et al. 2010). Among the major cations, K^+ is absorbed by plants in the largest amount

(Bahmanyar and Mashaee, 2010). Potassium deficiency results in a decrease in net photosynthetic rate and dramatic decrease in crop yield (Ding et al. 2006). The behavior of K in soil, release, absorption, fixation and leaching, is also strongly dependent on the clay content and types of clay minerals present (Sparks, 2000). The Sulphur (S) content of soils is usually lower than that of Ca or Mg (Roy et al. 2006). Calcium (Ca) is essential macronutrient for energy metabolism, photosynthesis, and membrane transport of plants (Osono and Takeda, 2004). An exchange complex dominated by Ca and adequately provided with Mg and K is a favourable precondition for good crop yields (Sato et al, 2008). Magnesium rate of release is too slow for optimal plant growth (Barlog, 2001). Soil micronutrients are elements that are essential to plant growth, but are utilized in minimum quantities and may be harmful when added to the soils in high quantities (Bibiso et al. 2015). Micronutrient status in soils can be affected by long-term fertilization and intensive cropping (Li et al. 2010). The main sources of micronutrients in plants are their growth media, agro inputs and soil (Subbiah et al. 2007). Plants take up the elements from the soil and under certain conditions; high levels can be accumulated in the leaves (Lasheen et al. 2008). Nutrient status is an unseen factor in plant growth, except when imbalances become so severe that visual symptoms appear on the plant (Flynn et al. 2004). Measurement of the fertility of an agricultural soil tells much about the productive potential. Fortunately, producers can control fertility by managing the plant's nutritional status (Flynn et al. 2004). This study was meant to provide better insight on potential of blended fertilizers in providing required nutrition to tea crop.

MATERIAL AND METHOD

Study sites

The study was conducted at Tea Research Institute, Timbilil Estate in Kericho and KTDA, Kagochi farm in Nyeri; which represented the geographically different major tea growing regions in Kenya (East and West of the Great Rift Valley). Timbilil Tea Estate is located at 35 21' East longitude and 0 22' South latitude with altitude of 2200 m above the sea level. It has mean annual temperature and rainfall of 16.6^{0}C and 2175mm respectively. Kagochi Tea Farm is situated at an elevation of 2005 m above the sea level, latitude of 0 25' 43" South and longitude of 37 7' 41" East. It has mean annual temperature and rainfall of 15.4^{0}C and 2040mm respectively.

Leaf sampling and analyses

Leaf samples (approximately 100g of two leaves and a bud and mature) were plucked in each plot and taken to the laboratory. The samples were oven-dried at temperature of 105^{0}C for 72 hours before milling. Total nitrogen was determined by Kjeldahl method (Jones, 1991). Phosphorus, potassium, calcium, magnesium, manganese and trace elements (Zn, Cu, Pb, and Fe) concentration in the leaves were determined using Inductively Coupled Plasma Emission (ICPE) spectroscopy (Wolf and Beegle, 2011; Kalra, 1998). Nutrient element contents of tea plants were evaluated according to critical values (Adiloglu & Adiloglu, 2006; Kamau et al. 2005; Kwach et al. 2012).

Data analysis

Effect of treatments application on soil properties and leaf nutrients uptake data of mature tea clone BBK 35 in Timbilil and TRFK 6/8 in Kagochi were subjected to the analysis of variance (ANOVA) using the Mstat C computer software package (Russel, 1995). The Least Significant Difference (LSD) procedure was then used to separate differences among the treatment means.

RESULTS AND DISCUSSION

Effect of fertilizer types and rates on Leaf nutrient contents

Leaf analysis is routinely used in the

determination of nutrients availability to plants (Kamau et al. 2005; Venkatesan et al. 2004) and also elucidates how much of the available nutrients are taken up by the plant (Owuor et al. 2011). Thus, chemical analysis details the potential of plant nutrients in the soil and the ability of plant to extract those nutrients (Kamau, 2008). However, even when planted in one ?eld, different tea genotypes have varying ability to extract nutrients from the soil resulting in variations in leaf nutrients content of different clones grown at the same site (Owuor et al. 2011) even when the agronomic practices are similar (Njogu et al. 2015). The levels of nutrients in different parts of tea bushes also vary (Owuor et al. 2011; Sitienei et al. 2013). This suggests that nutrients removal from the soil by tea plant is dependent on both genotypes and harvesting management which could lead to variations in amounts of fertilizer needed to optimize yields and quality (Owuor et al. 2011) and high yields are only obtained where all nutrients are in the optimal supply ranges. Nath (2013) stated that the total metal components in tea plants depend on primarily the age of the tea leaves but also the soil conditions, rainfall, altitude and genetic makeup of the plant. Nutrients concentrations of two leaves and a bud and mature leaves were determined and their results are given in tables 1 & 2.

Nitrogen content in green tea leaves

Tables 1 and 2 show the leaf nitrogen content of mature leaf and two leaves and a bud at Timbilil and Kagochi respectively. As expected, two leaves and a bud had higher nitrogen content ranging from 4.51 - 5.05% in Timbilil and 4.33 - 4.85% in Kagochi compared to mature leaves which had lower values of % N content (Timbilil 2.09 - 2.48%; Kagochi 2.14 - 3.22%) respectively. This reflects the fact that nitrogen is highly mobile and is often translocated from old leaves to young leaves (Sitienei et al. 2013; Yemane et al. 2008; Marschner, 1995). Nitrogen is classified as deficient, when leaf content is less than 3% (Tabu et al. 2015). The higher site means of mature leaf content for Kagochi could be attributed to clonal differences of clone TRFK 6/8 compared to clone BBK 35 in Timbilil. The fertilizer types and rates did not influence leaf nitrogen content in Timbilil. However, at Kagochi the two leaves and a bud N levels were significantly (P=0.05) affected by fertilizer types with Blend “B” showing highest N content (4.61%) followed by NPK standard (4.50%) then Blend “A” (4.47%). Tabu et al. (2015) found that N content in mature leaf were affected significantly by fertilizer types. Hamid et al. (2002) found the response of nitrogen at any level depends on the availability of other nutrients. Nitrogen still remains one of the main nutrients required for plant growth and yield (Tshivhandekano et al. 2013).

Plant Phosphorus content of green tea leaves

The effect of fertilizer types and rates on percent leaf P content in the two sites is shown in Tables 1 and 2. Two leaves and a bud had a higher P content than the mature leaves ranging between 0.46 -0.54 % Timbilil while in Kagochi % P in two leaves and a bud were 0.44-0.52%. This could be attributed to nutrient translocation in from the mature to young leaves during the growing period. This has been reported in other studies and is attributed to mobility of P in tea plant tissue (Kwach et al., 2012, 2014, Yemane et al., 2008; Marschner, 1995). The higher site means for mature leaf content in Kagochi was attributed to clonal differences as for the case of N. The fertilizer types and rates did not significantly ($P<0.05$) influence leaf P content in both sites.

Table 1: Effects of different rates of Mavuno tea formulations fertilizers on mature and two leaves and a bud nutrients in Timbilil

Fertilizer type	Fertilizer Rate (kg N/ ha/year)	% N Mature leave	% N 2L+B	% P Mature	% P 2L+B	%K Mature	%K 2L+B	Ca Mature	Ca 2L+B	Mg Mature	Mg 2L+B
Blend "A"	0	2.09	4.51	0.18	0.46	0.76	2.22	0.90	0.43	0.14	0.22
	75	2.17	4.67	0.18	0.48	0.72	2.30	0.89	0.41	0.15	0.25
	150	2.22	4.90	0.17	0.50	0.73	2.47	0.89	0.41	0.18	0.27
	225	2.14	4.80	0.18	0.53	0.68	2.34	0.85	0.39	0.15	0.26
Mean		*2.16*	*4.72*	*0.18*	*0.49*	*0.72*	*2.33*	*0.88*	*0.41*	*0.16*	*0.25*
Blend "B"	0	2.23	4.51	0.18	0.46	0.80	2.05	0.85	0.43	0.13	0.23
	75	2.48	4.95	0.18	0.48	0.69	2.25	0.98	0.43	0.16	0.26
	150	2.29	4.91	0.18	0.45	0.68	2.16	0.84	0.41	0.15	0.25
	225	2.42	5.14	0.18	0.54	0.61	2.65	0.84	0.39	0.17	0.33
Mean		*2.36*	*4.88*	*0.18*	*0.48*	*0.70*	*2.28*	*0.88*	*0.42*	*0.15*	*0.27*
Std NPK	0	2.31	5.00	0.17	0.47	0.76	2.17	0.78	0.44	0.16	0.23
	75	2.19	4.90	0.17	0.47	0.70	2.33	0.80	0.43	0.14	0.25
	150	2.34	5.09	0.17	0.49	0.75	2.30	0.84	0.37	0.18	0.26
	225	2.30	4.65	0.17	0.46	0.71	2.23	0.90	0.44	0.15	0.25
Mean		*2.29*	*4.91*	*0.17*	*0.47*	*0.73*	*2.26*	*0.83*	*0.42*	*0.16*	*0.25*
CV (%)	*Fertilizer type*	*8.74*	*9.42*	*10.20*	*5.00*	*9.06*	*9.79*	*8.79*	*11.00*	*15.56*	*8.45*
	Rate	*8.74*	*9.42*	*10.20*	*5.00*	*9.06*	*9.79*	*8.79*	*11.00*	*15.56*	*8.45*
LSD, P=0.05		*NS*	*NS*	*NS*	*NS*	*0.07*	*NS*	*NS*	*NS*	*NS*	*0.023*

2L+B means 2 leaves and a bud

Table 2: Effects of different rates of Mavuno tea formulations fertilizers on mature and two leaves and a bud nutrients in Kagochi

Fertilizer type	Fertilizer Rate (kg N/ ha/year)	% N Mature leave	% N 2L+B	% P Mature	% P 2L+B	%K Mature	%K 2L+B	Ca Mature	Ca 2L+B	Mg Mature	Mg 2L+B
Blend "A"	0	3.20	4.50	0.36	0.51	1.16	2.32	0.92	0.32	0.15	0.16
	75	3.13	4.33	0.51	0.50	1.53	2.47	1.24	0.32	0.22	0.16
	150	3.21	4.48	0.34	0.47	1.13	2.47	0.85	0.30	0.15	0.16
	225	2.14	4.42	0.35	0.44	1.22	2.28	0.77	0.28	0.13	0.15
Mean		*2.92*	*4.43*	*0.39*	*0.48*	*1.26*	*2.39*	*0.95*	*0.31*	*0.16*	*0.16*
Blend "B"	0	2.48	4.39	0.34	0.46	1.24	2.19	0.95	0.28	0.15	0.15
	75	2.99	4.47	0.49	0.48	1.56	2.29	1.05	0.3	0.2	0.15
	150	3.42	4.30	0.45	0.48	1.3	2.19	1.06	0.27	0.22	0.15
	225	3.22	4.68	0.32	0.46	1.1	2.23	0.84	0.28	0.13	0.15
Mean		*3.03*	*4.46*	*0.40*	*0.47*	*1.30*	*2.23*	*0.98*	*0.28*	*0.18*	*0.15*
Std NPK	0	2.53	4.69	0.33	0.52	1.21	2.44	1.03	0.3	0.13	0.16
	75	2.40	4.51	0.35	0.47	1.23	2.31	0.94	0.29	0.14	0.15
	150	3.00	4.85	0.31	0.42	1.34	2.13	0.81	0.22	0.12	0.14
	225	2.86	4.72	0.32	0.47	1.11	2.29	0.94	0.29	0.14	0.15
Mean		*2.70*	*4.69*	*0.33*	*0.47*	*1.22*	*2.29*	*0.93*	*0.28*	*0.13*	*0.15*
CV (%)	*Fertilizer type*	*20.38*	*5.19*	*30.3*	*10.67*	*17.6*	*9.58*	*26.39*	*11.94*	*36.1*	*6.79*
	Rate	*20.38*	*5.19*	*30.3*	*10.67*	*17.6*	*9.58*	*26.39*	*11.94*	*36.1*	*6.79*
LSD, P=0.05		*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*

2L+B means 2 leaves and a bud

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Potassium content in tea leaves

The fertilizer types and rates effect on percent leaf K content in the two sites is shown in Tables 1 and 2. Two leaves and a bud (Timbilil 2.29%; Kagochi 2.30%) content were higher than mature leaf (Timbilil 0.72%; Kagochi 1.26%). Similar patterns have been reported in other studies and attributed to K mobility in tea plant tissue (Sitienei et al. 2013; Kwach et al. 2012). Potassium ions are the most mobile within plants since most are not assimilated in organic compounds. Potassium has the property of high phloem mobility and, as a result, a high degree of reutilization by re-translocation via the phloem (Zhang et al. 2010). Yemane et al. (2008) and Dang (2005) reported that plant nutrient concentrations in the tea plant are highest in the young leaves and buds with concentration ranges for the K (20.9–23.6 mg/g). These ranges are highly consistent with the levels obtained in the current study. The higher site means of mature leaf K content for Kagochi was attributed to clonal differences. The fertilizer types and rates did not significantly ($P<0.05$) influence leaf K content in both sites.

Calcium and magnesium content in tea leaves

Tables 1 and 2 also show effect of fertilizer types and rates on percent Ca content in Timbilil and Kagochi. Mature leaf Ca content (Timbilil 0.86 %; Kagochi 0.95%) were higher than two leaves and a bud (Timbilil 0.42%; Kagochi 0.29%) in both sites. This is due to lower mobility of calcium in tea plant tissue. There were no significant differences ($P=0.05$) due to fertilizer types and rates in both sites. This has been reported in other studies and is attributed to the lower mobility of Ca ions and competition with the K ions during uptake (Kwach et al. 2012). Yemane et al. (2008) and Dang (2005) found that Ca concentrations ranges from 4.4–4.7 mg/g. These ranges are highly consistent with the levels obtained in this study.

In Timbilil, two leaves and a bud Mg mean content was higher (0.26%) than mature leaf mean content (0.16%). Yemane et al. (2008) and Dang (2005) reported that plant nutrient concentrations in the tea plant are highest in the young leaves and buds with concentration ranges for the Mg (2.0– 2.3 mg/g). The higher levels of Mg in the 2L+B according to Yemane et al. (2008) and Marschner (1995) was due to the fact that nutrient elements such as N, P, K, S and Mg are highly mobile in the tea plant tissue and are translocated from old leaves to young leaves. The ranges of values by Dang, (2005) are higher than the levels obtained. However, this was different in Kagochi where mean mature leaf Mg content was 0.16% compared to two leaves and a bud, 0.15%. The patterns observed in Mg content in Kagochi are different from what has been reported in most trials. However, the same trend was reported by Kwach et al. (2012) in studies carried out in both East and West of Rift valley in Kenya. This pattern at Kagochi could be attributed to age of tea bush and year after prune.

Different clones have varying abilities to absorb nutrients from the soil (Omwoyo et al. 2014; Yemane et al. 2008) leading to clonal variation in nutrient levels. In both sites, there were no significant differences ($P=0.05$) due to fertilizer types and rates for Mg content.

Zinc and Copper leave contents

Figure 1 show the effects of fertilizer types and rates on Zn & Cu in Timbilil and Kagochi. Two leaves and a bud recorded higher mean levels of Zn (69.8 ppm) and Cu (34.5 ppm) compared to mature leaf (26.5 ppm) and (29.1 ppm) in Timbilil. The same trend was observed in earlier studies (Kwach et al. 2012, Yemane et al. 2008, Gupta, 1995). However, in Kagochi the reverse trend in two leaves and a bud of Zn (18.2 ppm) and Cu (26.7 ppm) and (20.8 ppm) and (29.6 ppm) for mature leaf was observed. Copper level in both sites were within the range reported by Karak and Bhagat (2010) as observed in made tea of South India and China. The two elements did not show significant differences ($P=0.05$) due to fertilizer types and rates. For Fe, mature leaf content (Timbilil 237 ppm; Kagochi 118 ppm) were higher than two leaves and a bud (Timbilil 108 ppm; Kagochi 94 ppm) in both sites. The same levels in two leaves and a bud were reported by Yemane et al., 2008. Kwach et al. (2012) reported the same patterns. No significant ($p<0.05$) differences due to fertilizer types and rates were observed in both sites. Yemane et al. (2008) and AL-Oud (2003) reported Fe, Zn and Cu ranges in the tea leaf to be 123.9– 513.0 mg/kg, 26.69–53.89 mg/kg, and 22.12–40.66 mg/kg, respectively. According to Nath (2013), Fe, Cu and Zn contents of two leaves and a bud ranged from 212.85 to 546.42; 14.34 to 29.78 and 24.82 to 58.26 mg/kg respectively. However, different clones have varying abilities to absorb nutrients from the soil (Omwoyo et al. 2014; Yemane et al. 2008) leading to clonal variation in nutrient levels. The results differ with those of Nath, (2013) who found that higher pH limits the micronutrient uptake by tea plants. In this study, it was found that the contents of micronutrient in tea leaves were sufficient and trends to excessive level according to Nath (2013) guidelines.

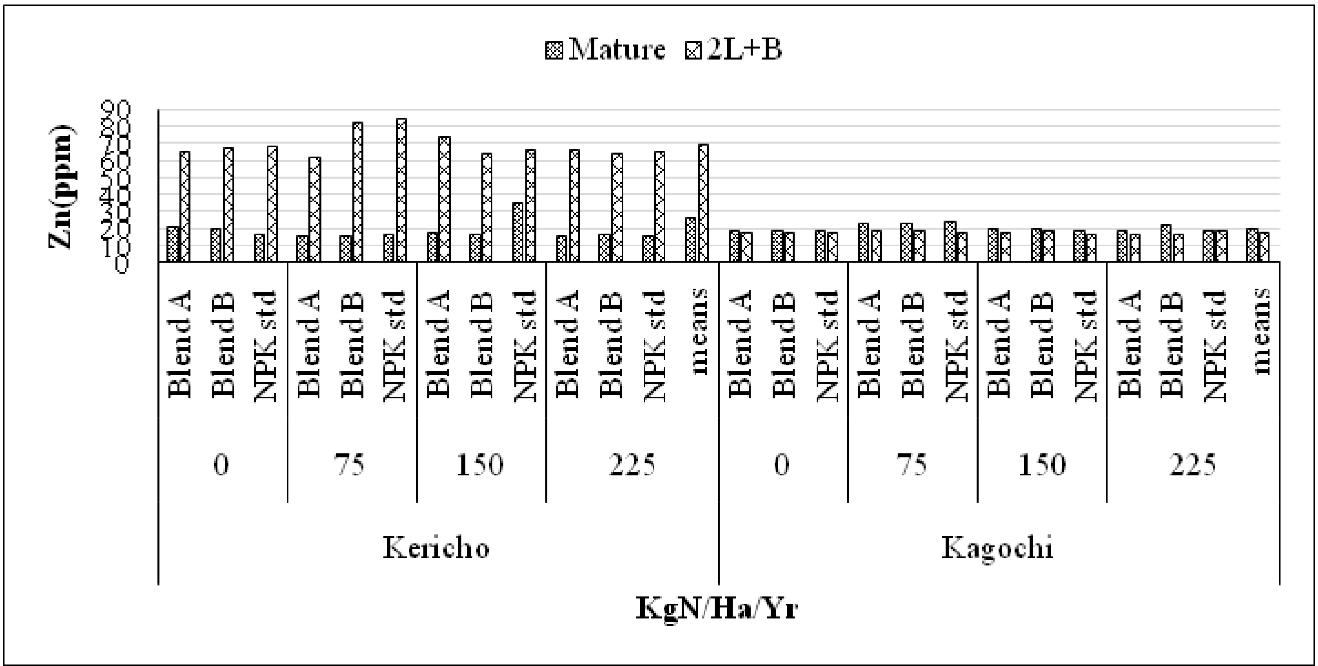

Figure 1: Effect of fertilizer types and rates on contents of Zinc and Copper in young and mature tea leaves

Boron and molybdenum leave contents

The fertilizer types and rates effects on leaf Boron and molybdenum in the two sites is shown in Figure 2. Mean mature leaf content (37.2 ppm) were slightly higher than two leaves and a bud (36.1ppm) in Timbilil. However, the reverse was observed in Kagochi where mean of two leaves and a bud (29.2 ppm) were higher than that of mature leaf content (25.3 ppm). There were no significance differences (P=0.05) due to fertilizer types and rates in both sites. Molybdenum content of mature and two leaves and a bud were higher in Kagochi than Timbilil. Mature leaf content (Timbilil 2.97 ppm; Kagochi 40.2) were higher than two leaves and a bud (Timbilil 1.89 ppm; Kagochi 34.0 ppm) in both sites. There were no significance differences (P=0.05) in Mo contents due to fertilizer types and rates in both sites. Similar patterns of boron and molybdenum contents in tea leaves was reported by Kwach *et al.*, 2012; Turner *et al.*, 2016). However, clonal variation in nutrient levels could be due to varying abilities of different clones to absorb nutrients from the soil (Omwoyo *et al.*, 2014; Yemane *et al.*, 2008). The results show similarity with the Nath (2013) findings that higher pH limits the Mo metal uptake by tea plants (Kabata-Pendias, (2011).

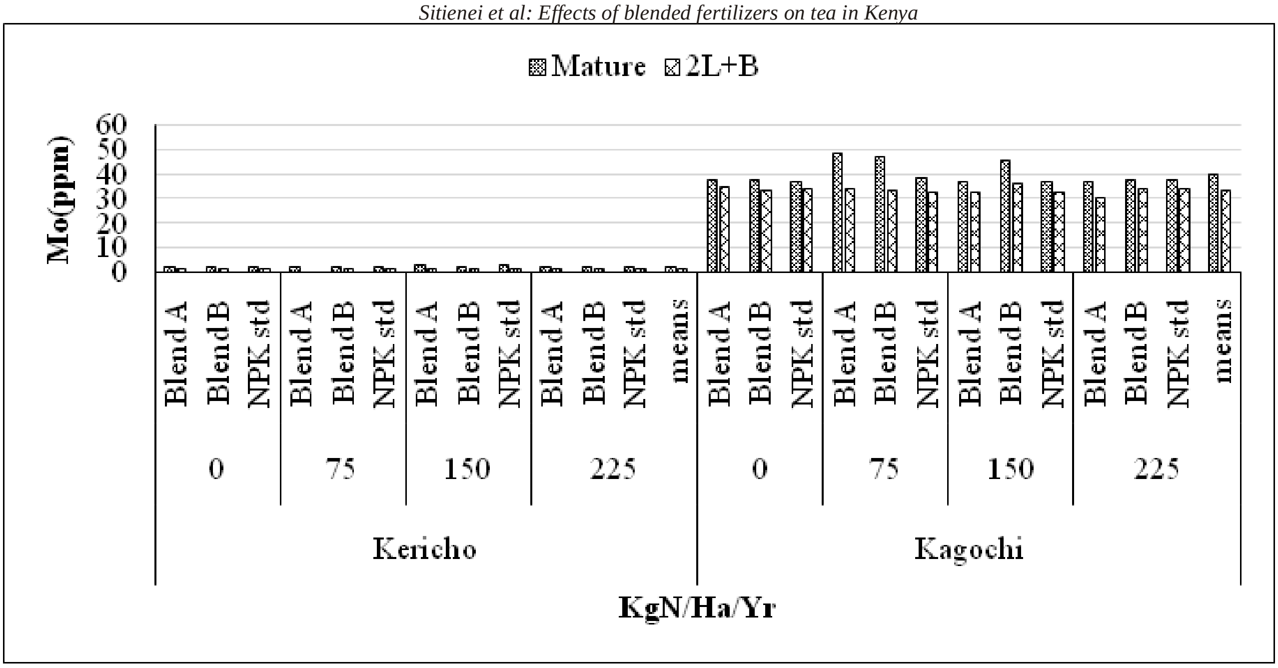

Figure 2: Effect of fertilizer types and rates on Boron and molybdenum content of tea leaves.

Conclusion

This study has shown that supplementing the soil applied NPK fertilizers with calcium, magnesium and micronutrients resulted in improved soil quality and better nutrients uptake hence environmental quality. The calcium and magnesium in the blends also contributed to the stabilization of soil acidity, which is desirable for tea cultivation.

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