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Effects of Foliar Fertilizer Application on Quality of Tea (*Camellia sinensis*) Grown in the Kenyan Highlands

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Abstract

In Kenya, foliar fertilizers have not found use in tea production despite their numerous advantages as exhibited in other crops. A fertilizer trial test was established in three sites of the major tea growing regions, with 36 plots per site to determine the effects of foliar fertilizer application on tea quality. Two foliar fertilizers were tested; foliar fertilizer 1 (FF1) and foliar fertilizer 2 (FF2), with a positive control of soil fertilizer (SF) and a blank. Two leaves and a bud tea samples were collected every two weeks after each foliar fertilizer application. These were then analyzed for tea quality (total polyphenols, TP), nutrient residues for the different clones and geographical locations. The TP contents for clone TRFK 31/8 were as follows: FF1 = 17.8%, FF2 = 17.9%, SF = 16.56% and Zero = 17.4%. Tukey-Kramer pair wise comparison test results between the foliar fertilizers and SF showed that the FF1 (HSD = 4.78) and FF2 (HSD = 5.27) fertilizers had significantly ($P < 0.05$) higher levels of TP content as compared to control SF fertilizer. Nutrients analyzed had average means as follows: N = 4% - 5%, P = 0.25% - 0.28%, K = 1.35% - 1.69%, Ca = 0.3 - 0.5 ppm, Mg = 0.19 - 0.27 ppm, Mn = 0.05 - 0.13 ppm, Zn = 25 - 40.5 ppm, Cu = 11 - 17 ppm and Fe = 72 - 122 ppm. The nutrient residue levels had non-significantly statistical differences at $P < 0.05$ level between pairs of zero applied plots and the FF1, FF2 and SF applied plots respectively. It was concluded that the foliar fertilizers increased the TP content in tested tea samples and the nutrients analyzed were all within the dietary reference intake (DRI) levels for SF, FF1 and FF2. Overall, the foliar fertilizer increased the quality of the tested tea samples.

Keywords

Tea, Total Polyphenols, Nutrient Residue, Foliar Fertilizer

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1. Introduction

Tea (*Camellia sinensis* (L.) O. Kuntze) is grown as a perennial monoculture and fertilizer application plays a vital role for its economic production [1]. Fertilizers improve the nutritional status of plants and soil for the plants. Tea is grown on recommended optimal soil conditions that are described as deep soils, well aerated with pH tending toward acidic (4.5 - 5.6 pH levels). Fertilizer application is an important part of the normal intensive production of tea [2], and one of the regular field management practices with significant bearing on both yield and quality of tea [3].

Foliar application of fertilizers is becoming increasingly the most effective way to increase yield and plant health. Experiments have shown that foliar feeding can increase yield from 12 to 25 percent when compared to conventional soil fertilizer application [1]. Foliar fertilizers widely used in vegetable and fruit crops, contain various macro and micronutrients essential for proper growth and yield [1] [4]. Foliar applications are best suited for new flush as the young leaves readily absorb nutrients [5]. The leaves are green factories where the complex chemical processes of photosynthesis produce the compounds, needed for plant growth. Foliar fertilizers are absorbed right at the site where these are used as quite fast acting, whereas much of soil fertilizers may never go to plants [1]. Despite the advantages of foliar fertilizers exhibited in other, it has not yet found extensive use in tea production in Kenya, except to correct Cu and Zn nutrient deficiencies in Malawi and Kenya respectively [6] and Mg in Nigeria [7], where they successfully reduced nutritional stress on tea plants.

The major chemical compounds present in the green leaf are carbohydrates, proteins, amino acids, lipids, polyphenols, caffeine, minerals and fiber. Young tea shoots are rich in polyphenolic compounds, the largest group being the catechins. These phenolic compounds are known to be one of the main factors in determining the quality of the resulting tea drink [8], hence total polyphenol contents are currently being used as indicators of black/green tea quality [9]. The polyphenols are primarily responsible for the beneficial healthful properties of tea [10]. The quality of tea mainly depends on the standard of the green leaf, and this is affected by agronomic practices among other factors. In Kenya, tea is grown free of agrochemicals to guarantee the consumer, safe and quality tea drink. There is hence the need to establish the effects of application of foliar fertilizer on total polyphenol content and nutrient residue levels in order not to comprise on quality of tea produced. Therefore, the aim of this study was to investigate foliar fertilizer Nitrogen, Phosphorus and potassium (NPK) uptake in different tea varieties in Kenya and determine its effects on tea quality changes and the levels of nutrient residues in tea leaf after foliar fertilizer application.

2. Methodology

2.1. Experimental Sites

The trial comprising of three experimental sites which represent the major tea growing regions in Kenya (East and West of the Great Rift Valley)—Timbilil estate, Tea Research Foundation of Kenya (TRFK), Kericho, clone TRFK 31/8; Kenya Tea Development Authority (KTDA)—Kangaita farm, Kirinyaga, clone TRFK 6/8; Michimikuru Ltd., Co. farm, Meru, clone EPK D99/10—was established in September 2010. Each site comprised of 36 plots and the trial was set up in a randomized complete block design with three replications of three fertilizer types; two NPK foliar fertilizers (FF1 and FF2) and the convectional NPK soil applied fertilizer (SF).

2.2. Fertilizers and Their Application Rates

Two foliar fertilizers and one soil applied fertilizer were used in the fertilizer trial; *Maj Tea foliar* fertilizer, a water soluble formulation with the elemental composition; NPK 24:24:18 + Trace elements 0.9 MgO, 0.1625 Fe (EDTA), 0.16 Cu, 0.08 Zn, 0.0325 B, 0.0012 Mo, and 0.08 Mn (EDTA). The pH of a 10% solution was 3 - 4, with a density of 1.40; *T-foliar* SPS fertilizer and plant booster containing NPK 20:5:5 + S + MgO + Trace Elements and the soil fertilizer containing NPK 25:5:5. The fertilizers were coded as Foliar Fertilizer 1 (FF1) for Maj Tea foliar, Foliar Fertilizer 2 (FF2) for T-foliar and Soil Fertilizer (SF) for NPK 25:5:5. FF1 was applied every 2 months, FF2 was applied every 3 months and SF was applied one per year.

Application rates used were Nil, Half rate, Full rate and Double rates. The specific fertilizers were coded as, $FF1_0$, $FF1_{½}$, $FF1_1$, $FF1_2$, and $FF2_0$, $FF2_{½}$, $FF2_1$, $FF2_2$, for Maj and T foliar fertilizer respectively and 0, 75, 150, and 225 Kg N/ha/year for soil applied fertilizer (SF) which was treated as the positive control. The amount of fertilizers to be applied, both foliar and soil, were calculated based on the number of bushes per plot and the spacing of the tea bushes. The average amounts applied per plot for each fertilizer type are shown (**Table 1**).

Table 1. Application rates and amounts of fertilizer applied.

Fertilizers	Rates	Amount of Fert. applied (g)	Total amount applied (g) (6 months)
FF1	Half	11.4	34.2
	Full	23	69
	Double	45.8	137.4
FF2	Half	24.3	48.6
	Full	49	98
	Double	98.3	196.6
SF	Half	437	437
	Full	873	873
	Double	1309	1309

Spraying of foliar fertilizers was done after plucking to allow 14-day interval before next plucking of samples which would be analyzed. A 15-liter hand-operated knapsack sprayer was used and spraying was done such that each plot of the three replicates of the same fertilizer and rate of application would be sprayed with 5 liters of the 15 liters foliar fertilizer. Spraying was done such that the sprayer was a few inches from direct contact with the upper side of the leaves and then it was brushed just below the plucking surface to spray the lower side of the leaves. All fertilizer applications were done early in the morning.

2.3. Laboratory Analysis for Total Polyphenols and Nutrient Residues

2.3.1. Sampling and Sample Processing

A plucking round length of 10 - 14 days was applied throughout the experiment period and samples of two leaves and a bud shoots were collected every successive plucking day from each plot in each site for chemical analyses, with a total of hundred and eight samples collected in total for each plucking round. The plant sample (leaf) was dried immediately in an oven at 105˚C for 24 hours to stop enzymatic activity. The material was then mechanically ground to a fine powder (using a coffee miller) to obtain a homogeneous sample from which a representative sample was taken.

2.3.2. Analysis of Total Polyphenols and Nutrient Residues

1) Treatment of Samples for Total Polyphenol analysis

Two grams of the milled samples were placed on pre-weighed moisture free dish and left for 16 hours at 103˚C in the oven to dry. The ground leaf samples (0.2 g) were extracted with five milliliter of 70% hot methanol/water mixture. Heating of the extraction tube continued in the water bath for 10 minutes with mixing in the vortex mixer after every 5 minutes. The extraction tubes were removed from the water bath, allowed to cool to room temperature and stoppers removed. Centrifuging was done for 10 minutes at 3500 revolutions per minute (rpm). The supernatant was carefully decanted into graduated tubes. Extraction steps were repeated; the extracts combined and made up to 10 ml with cold methanol/water mixture. The contents were finally mixed using a vortex. The Folin-Ciocalteu phenol reagent method was used to determine total polyphenols as described by [11].

2) Nutrient Residue analysis

Samples were subjected to N, P, K, Ca, Mg, Mn, Fe, Zn, and Cu chemical analysis. Total Nitrogen analysis was done using Kjeldahl method, Phosphorus analysis using Colorimetric/Spectrophotometric method, with UV-Vis Spectrophotometer UV-1800, Shimadzu, ENG240V, Potassium analysis using Corning 400 Flame Photometry and Ca, Mg, Mn, Cu, Zn, and Fe were analyzed using Atomic Absorption Spectrometer (AAS) Model SpectrAA-30 Varian.

2.4. Statistical Analysis

All the determinations were carried out in triplicate and the data were subjected to one-way analysis of variance

(ANOVA) whereby analysis for each variable separately *i.e.* by fertilizer type (zero, FF1, FF2, SF) and by rates of application (zero, half, full and double) was done. This was followed by the Tukey-Kramer range test to establish the honest significant difference (HSD) in means between the various group means at $P < 0.05$ confidence level. HSD is minimum distance between two group means that must exist before the difference between the two groups is considered statistically significant.

3. Results

The results for total tea polyphenol contents of the 2 leaves and a bud for a period of six months (September 2010 to June 2011) are given below (**Table 2**). Pair wise comparison test for the fertilizers types showed that the FF1 (HSD = 4.78) and FF2 (HSD = 5.27) fertilizers produced tea leaves with significantly ($P < 0.05$) higher levels of total polyphenol content as compared to control SF fertilizer. The comparison by rates showed a significant increase between half and double rates (HSD = 4.04).

The results for nutrient residue levels are given such that the leaf nutrient sampling conducted during this project allowed comparisons of actual leaf nutrient residue levels on the three sites with the dietary reference intake (DRI) values for food safety. Pair wise comparisons were done between the results of the zero applied plots and the FF1, FF2 and SF applied plots respectively, to establish the changes in nutrients level in. In Kericho site results (**Table 3**) from the pair wise comparisons, the nutrient levels analyzed were obtained not significantly different at $P < 0.05$ after both foliar and soil fertilizer (with the exception of N, HSD = 10.5, $P < 0.05$ for SF) at the different application rates. However, all the elements analyzed were within acceptable daily uptake levels for consumption as indicated in **Table 2**. In Kirinyaga site (**Table 4**), the levels of N were significantly higher for SF (HSD = 6.25) and iron (Fe) for FF2 fertilizer (HSD = 4.07) as compared to zero treatments. From rates of application pair wise comparison, on Fe showed a significant change in full rates (HSD = 5.24) from zero rates, showing that Fe was absorbed effectively at full rates of FF2. However, for P, K, Ca, Mg, Mn, Zn, and Cu there were no statistically significant differences for the treatments and their application rates. The levels of all nutrients analyzed were within the DRI levels (**Table 5**). In Meru site (**Table 4**), the pair wise comparison by fertilizer showed that for SF had significantly higher levels than zero fertilizers of N (HSD = 5.0), P (HSD = 4.1) and Zn (HSD = 5.10) at $P < 0.05$. FF2 had significantly higher levels than zero treatments of P (HSD = 4.05), Mg (HSD = 7.0), Zn (HSD = 4.7) and Fe (HSD = 4.8) at $P < 0.05$. FF1had significantly higher levels of mg

Table 2. Analysis for total polyphenols in Kericho site.

Grp ($\bar{Y}_1$) vs. Grp ($\bar{Y}_2$)	Group means		Mean dif	HSD
BY FERTILIZER	$\bar{Y}_1$	$\bar{Y}_2$	($\bar{Y}_2 - \bar{Y}_1$)	
Zero vs. FF1	17.39	17.78	0.39	1.52
Zero vs. FF2	17.39	17.9	0.51	2
Zero vs. SF	17.39	16.56	−0.83	3.27
FF1 vs. FF2	17.78	17.9	0.12	0.49
FF1 vs. SF	17.78	16.56	−1.22	4.7810*
FF2 vs. SF	17.9	16.56	−1.34	5.2661*
BY RATE				
Zero vs. Half	17.39	16.96	−0.43	1.55
Zero vs. Full	17.39	17.2	−0.19	0.7
Zero vs. Double	17.39	18.08	0.69	2.48
Half vs. Full	16.96	17.2	0.24	0.86
Half vs. Double	16.96	18.08	1.12	4.0359*
Full vs. Double	17.2	18.08	0.88	3.18

Starred values *represent significant differences at $P < 0.05$.

Table 3. Elemental analysis by fertilizer type for 2 + B samples in Kericho site.

	Element	Grp ($\bar{Y}_1$) vs. Grp ($\bar{Y}_2$)	Group means $\bar{Y}_1$ $\bar{Y}_2$		Mean dif ($\bar{Y}_2 - \bar{Y}_1$)	HSD
Kericho	N %	Zero vs. FF1	3.89	4.04	0.15	2.95
		Zero vs. FF2	3.89	4	0.11	2.13
		Zero vs. SF	3.89	4.43	0.54	10.5491*
	P %	Zero vs. FF1	0.25	0.26	0.01	1.45
		Zero vs. FF2	0.25	0.26	0.01	1.71
		Zero vs. SF	0.25	0.26	0.01	1.61
	K %	Zero vs. FF1	1.42	1.38	−0.04	0.91
		Zero vs. FF2	1.42	1.37	−0.05	1.21
		Zero vs. SF	1.42	1.35	−0.07	1.92
	Ca ppm	Zero vs. FF1	0.36	0.39	0.03	0.97
		Zero vs. FF2	0.36	0.35	−0.01	0.53
		Zero vs. SF	0.36	0.33	−0.03	1.11
	Mg ppm	Zero vs. FF1	0.21	0.23	0.02	1.38
		Zero vs. FF2	0.21	0.21	0	0.34
		Zero vs. SF	0.21	0.2	−0.01	0.5
	Mn ppm	Zero vs. FF1	0.1	0.13	0.03	2.69
		Zero vs. FF2	0.1	0.11	0.01	0.87
		Zero vs. SF	0.1	0.11	0.01	0.63
	Zn ppm	Zero vs. FF1	31	33.61	2.61	1.37
		Zero vs. FF2	31	32.95	1.95	1.02
		Zero vs. SF	31	33.51	2.51	1.32
	Cu ppm	Zero vs. FF1	15.3	15.7	0.4	0.39
		Zero vs. FF2	15.3	16.96	1.66	1.64
		Zero vs. SF	15.3	17.07	1.77	1.75
	Fe ppm	Zero vs. FF1	73	77.35	4.35	1.84
		Zero vs. FF2	73	72.42	−0.58	0.25
		Zero vs. SF	73	75.17	2.17	0.92

Starred values *represent significant differences at $P < 0.05$.

(HSD = 3.85) as compared to zero treatment at $P < 0.05$.

Pair wise comparison by rates showed that for P, full (HSD = 4.7) and double (HSD = 4.4) rates of application led to a significant increase in the levels of nutrient in the sample from zero rate. For Mg, half (HSD = 4.0) and double (HSD = 5.3) rates led to significantly higher levels of Mg as compared to zero rates while for Zn, full rates (HSD = 5.7) had significantly higher levels than zero applied plots. All nutrients analyzed were within the DRI levels (**Table 6**) in this site.

4. Discussion

In this study, the foliar fertilizers (FF1 and FF2) had significant higher total polyphenol (TP) levels than SF

Table 4. Elemental analysis for 2 + B samples in Kirinyaga site.

	Element	Grp ($\bar{Y}_1$) vs. Grp ($\bar{Y}_2$)	Group means $\bar{Y}_1$ $\bar{Y}_2$		Mean dif ($\bar{Y}_2 - \bar{Y}_1$)	HSD
Kirinyaga	N %	Zero vs. FF1	4.45	4.43	−0.02	0.30
		Zero vs. FF2	4.45	4.40	−0.05	0.72
		Zero vs. SF	4.45	4.88	0.43	6.2496*
	P %	Zero vs. FF1	0.25	0.26	0.01	1.67
		Zero vs. FF2	0.25	0.26	0.01	0.90
		Zero vs. SF	0.25	0.26	0.01	2.22
	K %	Zero vs. FF1	1.46	1.50	0.04	1.04
		Zero vs. FF2	1.46	1.41	−0.05	1.32
		Zero vs. SF	1.46	1.51	0.05	1.25
	Ca ppm	Zero vs. FF1	0.30	0.33	0.03	2.65
		Zero vs. FF2	0.30	0.34	0.04	3.57
		Zero vs. SF	0.30	0.34	0.04	2.92
	Mg ppm	Zero vs. FF1	0.19	0.20	0.01	1.08
		Zero vs. FF2	0.19	0.21	0.02	1.79
		Zero vs. SF	0.19	0.19	0.00	0.26
	Mn ppm	Zero vs. FF1	0.06	0.05	−0.01	2.35
		Zero vs. FF2	0.06	0.05	−0.01	1.51
		Zero vs. SF	0.06	0.05	−0.01	2.14
	Zn ppm	Zero vs. FF1	35.00	37.10	2.10	1.07
		Zero vs. FF2	35.00	40.52	5.52	2.79
		Zero vs. SF	35.00	36.36	1.36	0.69
	Cu ppm	Zero vs. FF1	11.00	11.50	0.50	1.60
		Zero vs. FF2	11.00	11.33	0.33	1.07
		Zero vs. SF	11.00	10.85	−0.15	0.47
	Fe ppm	Zero vs. FF1	110.00	117.14	7.14	2.28
		Zero vs. FF2	110.00	122.77	12.77	4.0718*
		Zero vs. SF	110.00	120.48	10.48	3.34

Starred values *represent significant differences at $P < 0.05$.

which was indicative of improved the quality of tested tea samples. This is because tea total polyphenols have gained predominance in determination of tea quality, hence used as primary markers of quality in tea [9] [12]. These results were achieved not withstanding the considerable lower amounts of foliar fertilizers applied as compared to the control SF by a factor of 1:5:107 (FF1:FF2:SF) per hectare. This is because application of nutrients on leaves increases the activity of the leaves since these nutrients are applied right on the sites where they are needed *i.e.* the green factories of the plant where photosynthesis takes place hence these nutrients can be quickly converted into compounds need for plant growth, unlike in soil applied fertilizers where most of the nutrients may never go to the plant due to loses through leaching, volatilization, denitrification etc. Previous studies revealed that total leaf polyphenols increased as a result of foliar fertilizer application, which was attributed to the presence of micronutrients in the foliar fertilizers [13]. However, existence of seasonal variations in qual-

Table 5. Elemental analysis for 2 + B samples in Meru site.

	Element	Grp ($\bar{Y}_1$) vs. Grp ($\bar{Y}_2$)	Group means $\bar{Y}_1$ $\bar{Y}_2$		Mean dif ($\bar{Y}_2 - \bar{Y}_1$)	HSD
Meru	N %	Zero vs. FF1	4.10	4.15	0.05	0.76
		Zero vs. FF2	4.10	4.18	0.08	1.21
		Zero vs. SF	4.10	4.43	0.33	5.0107*
	P %	Zero vs. FF1	0.25	0.28	0.03	3.51
		Zero vs. FF2	0.25	0.28	0.03	4.0460*
		Zero vs. SF	0.25	0.28	0.03	4.0905*
	K %	Zero vs. FF1	1.60	1.69	0.09	2.47
		Zero vs. FF2	1.60	1.69	0.09	2.28
		Zero vs. SF	1.60	1.62	0.02	0.64
	Ca ppm	Zero vs. FF1	0.45	0.46	0.01	0.28
		Zero vs. FF2	0.45	0.51	0.06	2.80
		Zero vs. SF	0.45	0.44	0.01	0.30
	Mg ppm	Zero vs. FF1	0.20	0.24	0.04	3.8494*
		Zero vs. FF2	0.20	0.27	0.07	6.9746*
		Zero vs. SF	0.20	0.22	0.02	2.55
	Mn ppm	Zero vs. FF1	0.07	0.06	0.01	1.02
		Zero vs. FF2	0.07	0.08	0.01	1.79
		Zero vs. SF	0.07	0.05	0.01	2.03
	Zn ppm	Zero vs. FF1	25.00	27.97	2.97	2.54
		Zero vs. FF2	25.00	30.45	5.45	4.6693*
		Zero vs. SF	25.00	30.91	5.91	5.0633*
	Cu ppm	Zero vs. FF1	14.00	15.56	1.56	1.75
		Zero vs. FF2	14.00	14.98	0.98	1.10
		Zero vs. SF	14.00	16.07	2.07	2.33
	Fe ppm	Zero vs. FF1	90.80	97.73	6.93	1.78
		Zero vs. FF2	90.80	109.53	18.73	4.8034*
		Zero vs. SF	90.80	95.24	4.44	1.14

Starred values *represent significant differences at $P < 0.05$.

ity of made tea has been reported [14] [15] and studies have also shown that tea quality parameters, quality precursors and yields changed with geographical area of production within East Africa [16].

The three sites, each having a different clone responded differently to the nutrients from the applied fertilizers. This is indicative of the different nutritional status in different tea clones and in different geographical locations. It was observed that clone EPK D99/10 had the most significantly increased levels of P (HSD = 4.05, 4.1 for FF1 and FF2), Mg (HSD = 3.85, 7 for FF1 and FF2), Zn (HSD = 5.1 for FF2), and Fe (HSD = 4.8 for FF2) resulting from the foliar fertilizer applications (FF1 and FF2), while for clone TRFK 31/8 and clone TRFK 6/8 only N was significantly increased by the SF fertilizer. This was corroborated by studies that have shown that the differences in the total elemental contents could be influenced by many aspects: primarily the age of the tea leaves, but also the genetic make-up of the plant, soil conditions, rainfall, and altitude [17]. In India, levels of

Table 6. Recommended Dietary Reference Intakes (DRI): Elements.

NUTRIENT	RDA/AI's (mg/d)	UL (mg/d)	ADVERSE EFFECTS OF EXCESSIVE CONSUMPTION
P	700	4000	Metastatic calcification, skeletal porosity
Mg	420 (M), 320 (F)	350	None from naturally occurring Mg in foods, but from supplemental intakes
Ca	1,000	2500	Kidney stones, hypocalcaemia, milk alkali syndrome, renal insufficiency
Mn	2.3 (M), 1.8 (F)	11	Elevated blood concentration and neurotoxicity
Cu	900 (µg/d)	10,000 (µg/d)	Gastrointestinal distress, liver damage
Fe	8(M), 18(F)	45	Gastrointestinal distress
Zn	11 (M), 8(F)	40	Reduced Cu status
F	4	10	Enamel and skeletal fluorosis
I	150	1100	Elevated thyroid stimulating hormone (TSH) conc

Source: DRI reports—The National Academy of Sciences (2001). M = males; F = females; RDA = recommended dietary allowances; UL = tolerable upper intake level; AI = adequate intake.

micronutrients in teas change with locations [16]. The amounts of macronutrient removed via plucking vary with the type of cultivator and geographical location hence the uptake of the nutrients will also differ hence the differences in nutrient levels observed across the sites. Tea bush is known to accumulate trace elements. Several studies have reported that teas from various countries have Ca, Na, Mg, K, and Mn present in tea at mg/g while Cr, Fe, Co, Ni, Cu, Zn and Cd occurred at low level of µg/g range [16]. Studies have shown that drinking tea can be used as a major source of dietary Mn [18] [19], Zn and Al [20]. Copper contamination in tea remains a concern and practices should be used to ensure food safety from excessive Cu [18].

After foliar fertilizer application, it was pivotal to compare the actual nutrients after chemical analyses with the theoretical recommended nutrient dietary levels, to assess the amount of possible uptake of some of the elements through drinking of tea. Dietary reference intake (DRI) is a set of reference values used to plan and assess nutrient intakes of healthy people and is provided by the regulatory agencies to define intake, supplementation and toxicity. Results could be a source of information with regard to quality and standards, medicine, nutrition and pollution [19] [21].

In all the three sites, the nutrients were within the recommended DRI levels (**Table 6**) for both the foliar fertilizers and the soil fertilizer. This was because despite the direct application of the foliar fertilizers on the leaves, the amounts therein were very small as compared to the soil fertilizers as seen in **Table 1**.

5. Conclusions

Tea total polyphenol contents average means for clone TRFK 31/8 was FF1 = 17.8%, FF2 = 17.9%, SF = 16.56%. Pair wise comparison between the foliar fertilizers and soil fertilizer showed that the FF1 and FF2 had significantly higher levels of TP content than SF with FF1, HSD = 4.78 and FF2, HSD = 5.27. This was indicative of improved quality by the foliar fertilizers more than that by the soil fertilizer. It is worth noting that the quantities of foliar fertilizer applied were very lower compared to the soil fertilizer application by a factor of 1:5:107 (FF1:FF2:SF) per hectare. This demonstrated high efficiency in foliar fertilizer uptake since the low amounts applied led to significant changes in TP levels. Therefore, the foliar fertilizers had significant positive effect on the overall quality of tea leaves picked.

The residue nutrients analyzed were N, P, K, Ca, Mg, Mn, Zn, Cu and Fe and had average means as follows: N = 4% - 5%, P = 0.25% - 0.28%, K = 1.35% - 1.69%, Ca = 0.3 - 0.5 ppm, Mg = 0.19 - 0.27 ppm, Mn = 0.05 - 0.13 ppm, Zn = 25 - 40.5 ppm, Cu = 11 - 17 ppm and Fe = 72 - 122 ppm for the trial fertilizers. These were compared with the theoretical DRI values which showed that no residues resulted when two leaves and a bud samples were picked two weeks after foliar fertilizer application. All the nutrients analyzed were within the DRI levels for SF, FF1 and FF2 applications. The study also demonstrated that the nutritional requirements for tea are dependent on the type of clone and the geographical location. In Meru site, clone EPK D99/10, significant increases were recorded for FF2 fertilizer in P, Mg, Zn and Fe nutrients as compared to zero applied plots, with

HSD of 4.05, 7.00, 4.67 and 5.24 respectively at $P < 0.05$. Moreover, FF1 levels of Mg were significantly higher than that for zero applied plots (HSD = 3.85).

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References

[1] Woldegebriel, D. (2007) Levels of Essential and Non-Essential Metals in Commercially Available Ethiopian Black Teas. MSc Thesis, Addis Ababa University, Ethiopia.

[2] Drinnan, E. (2008) Fertilizer Strategies for Mechanical Tea Production. RIRDC Publication No. 08/030.

[3] Anonymous (2002) Tea Growers Hand Book. 5th Edition, Tea Research Foundation of Kenya, Elizer Services Publishers, Times Printing Services, Nairobi.

[4] Karak, T. and Bhagat, R. (2010) Trace Elements in Tea Leaves, Made Tea and Tea Infusions: A Review. *Food Research International*, **43**, 2234-2252. http://dx.doi.org/10.1016/j.foodres.2010.08.010

[5] Bonheure, D. and Willson, K. (1992) Mineral Nutrition and Fertilizers. In: Willson, K. and Clifford, M., Eds., *Tea*: *Cultivation to Consumption*, Chapman and Hal, London, 269-329. http://dx.doi.org/10.1007/978-94-011-2326-6_9

[6] Cheruiyot, E., Mumera, L., Ng'etich, W., Hasanali, A. and Wachira, F. (2009) High Fertilizer Rates Increase Susceptibility of Tea to Water Stress. *Journal of Plant Nutrition*, **33**, 115-129. http://dx.doi.org/10.1080/01904160903392659

[7] Kuepper, G. (2003) Foliar Fertilization. NCAT Agriculture Specialist. ATTRA Publication#CT13.

[8] Hara, Y., Luo, S., Wickremashinghe, R.L. and Yamanishi, T. (1995) Special Issue on Tea. *Food Reviews International*, **11**, 371-545.

[9] Achudum, A. and Owoeye, D. (2010) Quantitative Assessment of Heavy Metals in Some Tea Marketed in Nigeria-Bioaccumulation of Heavy Meals in Tea. *Health*, **2**, 1097-1100. http://dx.doi.org/10.4236/health.2010.29162

[10] Kottur, G., Venkatesan, S., Kumar, R. and Murugesan, S. (2010) Influence of Seasons on Biochemical Parameters of Green Shoots and Quality Parameters of Made Tea under South Indian Conditions. *Journal of Bioscience Research*, **1**, 74-82.

[11] Islam, S., Qamar-uz-Zaman, A.S., Ahmad, F., Hussain, S. and Hamid, F.S. (2012) Effect of Foliar Spray of Varying Nitrogen Levels on Mature Tea Yield under Different Agroecological Conditions. *Journal of Agricultural Research*, **50**, 485-492.

[12] Sharangi, A.B. (2009) Medicinal and Therapeutic Potentialities of Tea (*Camellia sinensis* L.)—A Review. *Food Research International*, **42**, 529-535. http://dx.doi.org/10.1016/j.foodres.2009.01.007

[13] 13Obatolu, C.R. (1999) Correction of Magnesium Deficiency in Tea Plants through Foliar Applications. *Communications in Soil Science and Plant Analysis*, **30**, 1649-1655. http://dx.doi.org/10.1080/00103629909370317

[14] Cherotich, L., Kamunya, S., Alakonya, A., Msomba, S., Uwimana, M., Wanyoko, J., *et al.* (2013) Variation in Catechin Composition of Popularly Cultivated Tea Clones in East Africa (Kenya). *American Journal of Plant Sciences*, **4**, 628-640. http://dx.doi.org/10.4236/ajps.2013.43081

[15] Ertur, Y., Ercisli, A., Sengul, M., Eser, Z., Haznedar, A. and Turan, M. (2010) Seasonal Variation of Total Phenolic, Antioxidant Activity and Minerals in Fresh Tea Shoots (*Camellia sinensis* Var. Sinensis). *Pakistan Journal of Pharmaceutical Science*, **23**, 69.

[16] Omwonyo, W., Owour, P., Ongeri, D., Kamau, D., Kwach, B., Munyao, P. and Otieno, M.O. (2013) Availability of Some Inorganic Micronutrients and Effects of Grading on Their Levels in East Africa Black Teas and Infusions. *Asian Journal of Biological and Life Sciences*, **2**, 42-49.

[17] Kamunya, S. and Wachira, F. (2006) Two New Clones (TRFK 371/3 and TRFK 430/90) Released for Commercial Use. *Tea*, **27**, 4-16.

[18] Jayaganesh, S. and Venkatesan, S. (2010) Impact of Magnesium Sulphate on Biochemical and Quality Constituents of Black Tea. *American Journal of Food Technology*, **5**, 31-39. http://dx.doi.org/10.3923/ajft.2010.31.39

[19] Pourmorad, F., Husseinimehr, S. and Shahabimajd, N. (2006) Antioxidant, Phenol and Flavanoid Contents of Some Selected Iranian Medicinal Plants. *African Journal of Biotechnology*, **5**, 1142-1145.

[20] Street, R., Száková, J., Drábek, O. and Mládková, L. (2006) The Status of Micronutrients (Cu, Fe, Mn, Zn) in Tea and Tea Infusions in Selected Samples Imported to the Czech Republic. *Czech Journal of Food Science*, **24**, 62-71.

[21] Yemane, M., Chandravanshi, B. and Wondimu, T. (2008) Levels of Essential and Non-Essential Metals in Leaves of the Tea Plant (*Camellia sinensis* L.) and Soil of Wushwush Farms, Ethiopia. *Food Chemistry*, **107**, 1236-1243.

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