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Evaluation of foliar analysis as a diagnostic tool of predicting nutrients deficiencies of clonal tea in Kenya

Bowa O. Kwach[a], P. Okinda Owuor[a]*, David M. Kamau[b], John K. Wanyoko[b]

[a]Department of Chemistry, Maseno University, P. O. Box 333 40105, Maseno, Kenya
[b]Department of Chemistry, Tea Research Foundation of Kenya, P.O. Box 820 20200, Kericho, Kenya

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Abstract

Tea is a high value cash crop grown in countries with varying environmental conditions. High demand for the commodity led to development of high yielding varieties leading to nutrients loss with harvested crop. For continuous high production, replenishment of lost nutrients is mandatory, hence the need for a reliable nutrients diagnostic tool to predict nutrients demand. Although such a tool was developed for seedling tea, clonal tea varieties which now dominate the tea grown in Kenya adopted the set limits without re-evaluation. It is not known if these limits are suitable for clonal tea grown in different environments or if clonal tea partitions the leaf nutrients differently. This study assessed these factors and results showed that leaf nutrients varied ($P \leq 0.05$) with clones and locations with significant ($P \leq 0.05$) interaction effects between clones and location of production. The level of nutrients obtained in the clonal leaf did not concur with set limits in seedling tea, demonstrating the limits set for seedling tea are unsuitable for clonal tea. No relationship existed between nutrients in different leaves or clones in different locations. It is necessary to generate more data on tissue nutrients levels of clonal tea for use in producing region and clonal specific foliar diagnostic guidelines.

INTRODUCTION

Tea, (*Camellia sinensis* (L.)) is an important commodity crop grown in many countries for the processing of various tea beverages. Successful commercial tea production has been reported from 49°N, Outer Carpathians, to 33°S, Natal, South Africa [1], and altitudes ranging from sea level in Japan and Sri Lanka [2] to around to 2,700 m above mean sea level (amsl) in Kenya and Rwanda [3]. In Kenya tea is grown on the foothills of the Aberdare ranges and Mount Kenya in the East of the Great Rift Valley and the Mau ranges, Nandi, Kisii and Kakamega Hills in the West of the Great Rift Valley of Kenya at altitudes ranging from 1300m amsl [2]. The plant is adaptable to geographical areas with differences in environmental factors affecting growth, nutrients availability and uptake, leading to yields [5, 6] and quality variations [5, 7].

Tea beverages are very popular and it has been claimed the tea beverages are the most widely consumed fluids after water [8]. Arising from the high demand, emphasis is put on high production and yields as high as 10,995 kg made tea per hectare has been reported under commercial production technologies [9]. Continuous cropping together with leaching, surface run off and fixation diminish the soil nutrients supply, thus reducing plant growth and profitable yields [10]. It therefore becomes necessary to supplement the nutrients available to the plant for sustainable continuous high production. Clones can be specific to environments, with pronounced yield and quality responses to environmental heterogeneity [11]. Clones also differ widely from seedling plants which fit wide range of environments because of genetic heterogeneity, show minimal effects to soil and environmental heterogeneity, but have marked yield fluctuations [12]. The differences in these characteristics suggest that the nutrients uptake by clonal tea and seedling tea are likely to be different and therefore the critical levels of leaf nutrients set for seedling tea may not be applicable to clonal tea plants or same clonal tea plants grown in different regions.

The extent of variations in nutrients partitioning in different tea clones has not been documented, especially when grown under different environments. However, different clones have varying abilities to absorb nutrients from the soil [13] leading to clonal variations in mature leaf nutrients levels [14]. These differences may be made worse by Environment x Genotype interactions [6]. Indeed, it was recently shown that same clone grown in different regions but receiving same agronomic inputs, produce varying yields [5, 15] and quality [5, 7, 15] and has different mature leaf nutrient contents [16], indicating that clones may need different tissue analysis guidelines for fertilizer use efficiency to maximise yields and quality.

Use of tissue analysis has been advocated as a reliable way of predicting possible deficiencies in tea production [17-19]. With proper and timely monitoring of the tea plants nutrients status, remedial applications of nutrient elements can successfully alleviate the deficiencies and prevent yield losses. Different countries and regions use different types of leaves to predict the tea bush nutritional status [10]. For tea in Kenya, the first mature leaf type analysis has been adopted for tissue analysis advisory system to assess the problems in nutrients management [17, 18, 20]. But the method was based on mature seedling tea. With the expansion of tea, the amount of clonal tea is now large [21]. There is need to assess the suitability of seedling tea foliar diagnostic system for clonal tea.

The objectives of the study were to assess the variations in mature leaf nutrients of different popular clones grown in different major tea growing areas in Kenya to establish if the recommendations for mature seedling tea leaf can be used in clonal tea; to assess the leaf age that is stable and can be used to guide foliar analysis advisory system for clonal tea; to assess if leaf nutrients levels in clones at different locations or of different ages are related.

MATERIALS AND METHODS

Leaf was obtained from 20 popular clonal teas planted by Department of Botany, Tea Research Foundation of Kenya planted in a Randomised Complete Block design replicated three times in Timbilil Estate (latitude 0° 22'S, longitude 35° 21'E and altitude 2180m above mean sea level (amsl)) in Kericho, Magura Estate (latitude 0° 39'S, longitude 35° 02'E and altitude 1800m amsl) of Kipkebe Tea Company in Sotik, and Kangaita Tea Farm (latitude 0° 30'S, longitude 37° 16'E and altitude 2100m amsl) [6, 7]. The clones were TRFK 1/26, TRFK 6/8, TRFK 7/9, TRFK 54/40, TRFK 56/89, TRFK 12/12, TRFK 12/19, TRFK 31/27, TRFK 31/8, TRFK 7/3, EPK TN14-3, AHP S15/10, BBK35, TRFK 2x1/4, TRFK 303/1199, TRFK 303/259, TRFK 303/577, TRFK 303/999, TRFK 57/15 and STC 5/3. These clones were subjected to same agronomic inputs including application of NPKS 25:5:5:5 at 150 kg N ha^{-1} $year^{-1}$. Mature leaf, third leaf and two leaves and a bud leaf samples (100gm) were taken from each plot and oven dried at 80°C. Sampling was done in April 2010 during wet and cold period when soil moisture deficit was not expected to limit nutrients uptake. Each plot at the three sites was sampled. The dried leaves from each plot were milled to powdery form. A portion of the milled sample (0.5gm) was ashed for AAS analysis of Ca, Mg, Mn, Zn, Cu and Fe, UV-Vis analysis of P and flame photometer analysis of K. A further 1gm of the milled samples was digested for micro-Kjeldahl N analysis [22].

RESULTS AND DISCUSSION

Tea plants in these trials received the recommended fertiliser rates 150kgN ha^{-1} $year^{-1}$ [18] and did not show any visual signs of deficiency [12]. Consequently, any nutrients levels observed below the set limits [10, 17, 18, 20] could only demonstrate the poor suitability of the method for use to guide fertiliser use tissue analysis diagnosis. Nutrients levels observed were below the set limits [10, 17, 18, 20] and this therefore could only demonstrate the poor suitability of the seedling tea-based tissue analysis diagnosis method to guide fertiliser use in clonal tea. Plant tissue analysis has been claimed to be a more direct and unique method of assessing soil fertility by use of the growing plants [23, 24], especially tea soils [25-28]. However for use as diagnostic method, the age of the leaf must be clearly defined [29]. Consequently, norms to guide use of mature [17, 18] and third [10] leaf were set as shown in Tables 1 and 2. The first mature leaf was thought to be more stable [17, 18] and was adopted for setting nutrients norms in Kenya. However, the recommended plucking standard is two leaves and a bud [18]. The nutrients in the two leaves and a bud therefore are fair estimates of the amounts of nutrients harvested with crop.

N, P and K are the most critical nutrients in the fertilization programme of tea [10]. The variations in these major nutrients are presented in Tables 3, 4 and 5, respectively. For first mature leaf, 3rd leaf and 2 leaves and a bud, there were significant ($P \leq 0.05$) variations in all the three nutrients with clones and locations despite the fact that all the tea plants were receiving same amount recommended fertiliser rate [4, 10, 18]. The mean site values for mature leaf N at all the sites were at what was considered borderline in the foliar analysis advisory service [17, 18]. The mean clonal mature leaf levels were only within the adequate levels for clones TRFK 303/259 and TRFK 57/15, while clone AHP S15/10 was within the deficient level and seventeen clones were within the borderline deficiency limit. Levels of mature leaf N were generally borderline to adequate supply limits at Timbilil and Kipkebe, but at Kangaita, except for clone TRFK 303/259 that had adequate leaf nitrogen, six clones fell within the deficient limits while thirteen clones showed borderline deficiency. The significant ($P \leq 0.05$) interactions between leaf N in clones and locations indicated that the pattern of change in clonal leaf N was not uniform. These results demonstrated that the N limits guidelines being used [17, 18, 20] were not suitable on clonal tea plantations in all three locations.

The levels (Table 3) of N in the 3rd leaf did not reach the 5% content suggested as adequate supply (Table 2) [10], for all clones and in all locations. Although no suggested limit has been published for the nutrients in two leaves and a bud, this is the recommended leaf for harvesting [18]. At all sites and in all clones higher levels of N were recorded in younger leaves than older leaves, showing that tea partitions more nitrogen to the young leaves. Data presented show that for tea with high yields as had been demonstrated for these clones [6], substantial amounts of N nutrient is harvested with crop. The noted variations in mature leaf N were replicated in the 3rd leaf and 2 leaves and a bud, indicating the unique ability of individual tea clones to absorb N from the soil. Irrespective of the leaf that is used in foliar analysis, there were significant ($P \leq 0.05$) variations in leaf N with clone/cultivar and location of production, suggesting that limits to guide foliar analysis advisory system should be different for individual clones and to also depend on location of production.

The changes in the levels of leaf P with locations and clones are presented in Table 4. There were significant ($P \leq 0.05$)

Table 1: Critical levels of nutrients in the uppermost mature tea leaf in East Africa.

Nutrient	Deficient	Borderline	Adequate
Nitrogen	Below 3.0%	3.0 to 3,5%	Above 3.5%
Phosphorous	Below 0.15%	0.15 to 0.17%	Above 0.17%
Potassium	Below 1.20%	1.20 to 1.50%	Above 1.50%
Magnesium	Below 0.10%	0.10 to 0.13%	Above 0.13%
Zinc	Below 10 ppm		

Source: Owuor and Wanyoko, 1983

Table 2: Critical levels of nutrients in the third leaf of tea shoot

	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Mn (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)
Deficient	3.00	0.35	1.60	0/05	0.05	50	60	20	20
Subnormal	4.00	0.40	2.00	0.10	0.10	100	100	25	15
Normal	5.00	0.50	3.00	0.35	0.30	5000	500	50	30

Source: Bonheure and Willson, 1992

Table 3: Effects location of production and cultivars on lean nitrogen levels

Clone	Mature leaf				3rd Leaf				2 leaves and a bud			
	Timb	Kipk	Kang	Mean clone	Timb	Kipk	Kanga	Mean clone	Timb	Kipk	Kang	Mean clone
TRFK7/9	3.62	3.45	3.25	3.44	3.66	3.68	3.33	3.56	4.76	4.70	5.51	4.66
TRFK303/259	3.62	3.67	3.55	3.61	3.68	3.64	3.30	3.54	5.17	4.63	4.68	4.83
TRFK303/1199	3.18	3.28	2.67	3.04	3.29	3.35	3.10	3.25	4.45	4.46	4.39	4.44
TRFK54/40	3.42	3.51	2.97	3.30	3.25	3.50	3.08	3.28	4.52	4.61	4.34	4.49
TRFK31/8	3.11	3.62	2.76	3.16	3.52	3.85	2.92	3.43	4.51	4.68	4.48	4.56
BB35	3.10	3.31	2.91	3.11	3.61	3.63	3.09	3.44	4.97	5.06	4.40	4.81
TRFK6/8	3.55	3.64	3.15	3.44	3.38	3.36	2.97	3.24	3.83	4.38	4.11	4.11
TRFK31/27	3.54	3.40	3.30	3.41	3.58	3.50	3.36	3.48	5.62	5.15	5.15	5.31
TRFK12/12	3.44	3.46	3.39	3.43	3.62	3.77	3.37	3.59	4.71	4.43	5.23	4.79
TRFK303/999	3.26	3.32	3.19	3.26	3.26	3.57	3.00	3.28	4.35	4.28	4.21	4.28
AHPS15/10	3.30	3.66	2.73	2.89	3.57	3.39	2.72	3.23	4.38	4.33	4.06	4.26
TRFK57/15	3.74	3.65	3.28	3.56	3.83	3.60	3.42	3.62	4.73	4.84	4.54	4.70
TRFK56/89	3.25	3.32	3.30	3.29	3.58	3.50	2.89	3.32	4.85	5.14	4.42	4.80
TRFK12/19	3.39	3.34	3.21	3.32	3.36	3.61	3.30	3.42	454	4.51	4.78	4.61
TRFK11/26	3.57	3.39	3.40	3.46	3.30	3.45	3.29	3.35	4.39	4.39	4.49	4.42
STC5/3	3.68	3.58	2.89	3.38	3.21	3.42	2.97	3.20	4.61	4.35	4.21	4.39
TRFK7/3	3.16	3.25	3.25	3.22	3.60	3.40	3.42	3.47	4.77	4.80	4.54	4.70
TRFK303/577	3.41	3.49	3.04	3.32	3.35	3.18	2.91	3.15	3.69	3.75	4.09	3.85
EPKTN14-3	3.64	3.10	3.17	3.30	3.60	3.82	3.21	354	4.64	4.75	4.45	4.55
TRFK2xI/4	3.43	2.80	3.26	3.17	3.45	3.45	3.40	344	4.31	4.40	4.47	4.39
Mean site	3.41	3.36	3.13		3.48	3.53	3.15		4.59	4.57	4.48	
C.V. (%)		6.28				6.22				4.66		
LSD, P<0.05												
Clone		0.21				0.21				0.21		
Site		0.17				0.17				0.17		
Interactions		0.35				NS				0.35		

Timb = Timbilil, Kipk = Kipkebe, Kang = Kangaita

Table 4: Effects location of production and cultivars on leaf phosphorus levels (%)

Clone	Mature leaf				3rd Leaf				2 leaves and a bud			
	Timb	Kipk	Kang	Mean clone	Timb	Kipk	Kanga	Mean clone	Timb	Kipk	Kang	Mean clone
TRFK7/9	0.17	0.18	0.17	0.17	0.20	0.26	0.20	0.22	0.23	0.28	0.19	0.24
TRFK303/259	0.19	0.23	0.24	0.22	0.22	0.24	0.21	0.22	0.32	0.25	0.20	0.26
TRFK303/1199	0.19	027	0.26	0.24	0.20	0.26	0.20	0.22	0.31	0.28	0.22	0.27
TRFK54/40	0.18	0.28	0.28	0.25	0.22	0.29	0.19	0.23	0.28	0.25	0.19	0.24
TRFK31/8	0.17	0.22	0.25	0.21	0.20	0.26	0.23	0.23	0.22	0.29	0.20	0.24
BBK35	0.15	0.23	0.24	0.21	0.21	0.29	0.19	0.23	0.25	0.22	0.24	0.23
TRFK6/8	0.19	0.21	0.22	0.21	0.20	0.20	0.18	0.19	0.23	0.21	0.24	0.23
TRFK31/27	0.17	0.21	0.21	0.20	0.21	0.24	0.20	0.22	0.37	0.26	0.21	0.28
TRFK12/12	0.19	0.29	0.28	0.25	0.22	0.27	0.22	0.24	0.23	0.34	0.22	0.26
TRFK303/999	0.14	0.24	0.23	0.21	0.20	0.28	0.20	0.23	0.28	0.22	0.21	0.23
AHPS15/10	0.17	0.27	0.26	0.23	0.23	0.29	0.22	0.25	0.29	0.31	0.21	0.27
TRFK57/15	0.20	0.15	0.25	0.20	0.22	0.29	0.25	0.25	0.39	0.23	0.30	0.30
TRFK56/89	0.15	0.20	0.21	0.19	0.22	0.25	0.24	0.24	0.26	0.24	0.22	0.24
TRFK12/19	0.18	0.20	0.20	0.19	0.23	0.28	0.20	0.24	0.31	0.26	0.19	0.25
TRFK11/26	0.15	0.22	0.20	0.19	0.20	0.23	0.19	0.21	0.28	0.26	0.19	0.24
STC5/3	0.19	0.21	0.32	0.24	0.21	0.22	0.18	0.20	0.24	0.20	0.17	0.20
TRFK7/3	0.16	0.19	0.21	0.19	0.21	0.28	0.21	0.23	0.28	0.27	0.16	0.24
TRFK303/577	0.19	0.18	0.20	0.19	0.22	0.24	0.21	0.22	0.23	0.26	0.21	0.23
EPKTN14-3	0.19	0.22	0.24	0.22	0.21	0.25	0.25	0.24	0.34	0.24	0.18	0.26
TRFK2xI/4	0.19	0.20	0.23	021	0.21	0.26	0.24	0.23	0.31	0.28	0.23	0.27
Mean site	0.18	0.22	0.23		0.21	0.26	0.21		0.28	0.26	0.21	
C.V. (%)		9.64				8.62				8.17		
LSD, P <0.05												
Clone		0.02				0.02				0.02		
Site		0.02				0.02				0.02		
Interactions		0.03				0.03				0.03		

Timb = Timbilil, Kipk = Kipkebe, Kang = Kangaita

variations in the leaf P levels with location of production and clones. Indeed the mean data for clones showed that only clone TRFK 7/9 had borderline mature leaf P level. At all locations and in every clone the mean data revealed that P supply was adequate. However, a closer scrutiny of the data revealed that in one clone grown in the three different locations, the variations can be very large. A total of eight clones in Timbilil and one clone in Kipkebe had borderline mature leaf P content. The results demonstrated that use of mature leaf to evaluate deficiency of the nutrient in clonal tea may work well in Kipkebe and Kangaita, but performs very poorly in Timbilil. However, for the 3rd leaf, no clone had P level that could be considered adequate. The diagnostic level set [10], is therefore unrealistically high for clonal tea in Kenya. Like N, there was a general rise in leaf P in younger tea leaves.

The average mature leaf K was borderline for clonal tea in Kangaita, while adequate for both Timbilil and Kipkebe clonal tea (Table 5). There were two clones with mean values below 1.20% considered deficient, while seven clones had borderline deficiency and eleven clones had adequate levels [17, 18, 20]. At Kangaita, except for clones TRFK 303/259 and EPK TN 14-3, other clones had either borderline K deficiency (fifteen clones) or deficiency (three clones), while in Kipkebe, K in mature leaf was adequate except in four clones where there was mild deficiency, and in Timbilil four clones showed deficiency, five clones were borderline and eleven clones had adequate K levels. There were large variations in mature leaf K with locations and clones. As a result, the guidelines based on mature leaf K levels may not be appropriate for clonal tea and at different locations. For the 3rd leaf, no clone at any location had adequate level of K. The suggested guidelines [10], was therefore not suitable for clonal tea. There was rise in K levels as the leaves became younger. High amount of K is therefore harvested with two leaves and a bud.

The other macronutrients essential for tea are Ca [30] and Mg [31]. There are no recommended diagnostic levels set for Ca, but Mg is considered deficient when mature leaf levels are below 0.10% [18, 20]. The variations in leaf Ca with age of leaf, location and clones are presented in Table 6. The clones exhibited significantly ($P \leq 0.05$) different abilities to absorb calcium from the soil and this also varied ($P \leq 0.05$) with locations. The large variations demonstrated possible difficulties in setting single diagnostic levels that can be used in all clones at different locations. In the third leaf, all samples had Ca levels higher than 0.35% the suggested optimal level [10]. These results suggest that the Ca levels in Kenya tea soils are either adequate, or the clones used in this study were efficient in Ca extraction from the soil. The observations may also offer an explanation as to why Ca fertilisers are not normally applied to tea in Kenya. Unlike N, P and K (Tables 3, 4, 5), there was increase in Ca levels as the leaf matured.

Mg levels also varied significantly ($P \leq 0.05$) in tea leaves type due to clones and location of production (Table 7). Using mature leaf as a guide, on the average, all clones at all locations extracted adequate amounts of Mg from the soil. However, significant ($P \leq 0.05$) variations in Mg levels with location and clones were observed (Table 7), suggesting differences in the ability of the plants to extract the nutrient from the soil. Bonheure and Willson [10] had suggested 0.30% as level of Mg in the third leaf considered adequate (Table 2). There was no clone at any site with

Table 5: Effects location of production and cultivars on leaf potassium levels (%)

	Mature leaf				3rd Leaf				2 leaves and a bud			
Clone	Timb	Kipk	Kang	Mean clone	Timb	Kipk	Kanga	Mean clone	Timb	Kipk	Kang	Mean clone
TRFK7/9	1.43	1.26	1.31	1.33	1.58	2.26	1.30	1.72	1.89	2.41	1.80	2.03
TRFK303/259	1.80	1.66	1.61	1.69	1.74	2.79	1.67	2.07	2.07	2.60	1.74	2.13
TRFK303/1199	1.66	1.59	1.32	1.52	1.79	2.50	1.46	1.92	1.98	2.65	1.84	2.16
TRFK54/40	1.19	1.94	1.18	1.44	1.51	2.32	1.33	1.72	1.90	2.48	1.75	2.05
TRFK31/8	1.46	2.14	1.27	1.62	1.80	2.31	158	1.90	2.05	2.40	1.73	2.06
BBK35	1.09	1.46	1.02	1.19	1.73	2.19	1.38	1.77	1.93	2.43	1.62	1.99
TRFK6/8	1.64	1.62	1.31	1.52	1.82	2.34	1.32	1.83	2.03	2.56	1.77	2.12
TRFK31/27	1.65	2.18	1.30	1.71	1.79	2.41	1.62	1.94	2.15	2.46	1.88	2.17
TRFK12/12	1.52	2.11	1.43	1.69	1.78	2.49	1.73	2.00	1.94	2.38	1.83	2.05
TRFK303/999	1.63	2.10	1.36	1.70	2.11	2.24	1.55	1.97	2.27	2.68	1.72	2.22
AHPS15/10	1.74	2.21	1.46	1.80	2.02	2.69	1.58	2.10	2.04	2.90	1.70	2.21
TRFK57/15	1.55	1.46	1.34	1.45	1.95	2.59	1.70	2.08	2.15	2.63	2.02	2.27
TRFK56/89	1.12	1.57	1.25	1.31	1.66	2.24	1.69	1.86	2.00	2.68	2.04	2.24
TRFK12/19	1.37	1.59	1.37	1.45	1.67	2.47	1.53	1.89	2.01	2.66	1.68	2.12
TRFK11/26	1.39	1.35	1.29	1.34	1.86	2.26	1.59	1.90	2.02	2.55	1.78	2.12
STC5/3	1.14	1.26	1.18	1.19	1.35	2.04	1.40	1.60	1.90	2.41	1.67	1.99
TRFK7/3	1.42	1.57	1.40	1.46	1.76	2.68	1.58	2.01	2.11	2.69	1.78	2.19
TRFK303/577	1.91	1.50	1.25	1.55	2.12	2.43	1.79	2.11	2.02	2.60	1.94	2.19
EPKTN14-3	1.58	1.80	1.56	1.64	1.60	2.06	1.51	1.72	1.91	2.31	1.68	1.97
TRFK2xI/4	2.00	1.81	1.34	1.72	1.82	2.48	1.90	2.07	2.14	267	2.02	2.28
Mean site	1.52	1.71	1.33		1.77	2.39	1.56		2.02	2.56	1.80	
C.V. (%)		11.00				7.48				7.06		
LSD, P <0.05												
Clone		0.16				0.14				0.15		
Site		0.13				0.11				0.12		
Interactions		0.28				0.24				NS		

Timb = Timbilil, Kipk = Kipkebe, Kang = Kangaita

Table 6: Effects location of production and cultivars on leaf calcium levels (%)

	Mature leaf				3rd Leaf				2 leaves and a bud			
Clone	Timb	Kipk	Kang	Mean clone	Timb	Kipk	Kanga	Mean clone	Timb	Kipk	Kang	Mean clone
TRFK7/9	0.95	0.98	0.89	0.94	0.46	0.57	0.53	0.52	0.39	0.47	0.35	0.40
TRFK303/259	0.88	1.26	0.93	1.02	0.49	0.54	0.39	0.47	0.38	0.36	0.30	0.34
TRFK303/1199	1.11	1.12	1.07	1.10	0.51	0.68	0.39	0.53	0.34	0.55	0.35	0.41
TRFK54/40	0.89	0.68	0.85	0.81	0.52	0.58	0.45	0.52	0.37	0.50	0.35	0.40
TRFK31/8	1.45	0.75	1.54	1.25	0.48	0.58	0.70	0.58	0.28	0.41	0.29	0.33
BBK35	0.87	0.62	0.99	0.83	0.36	0.53	0.38	0.42	0.23	0.25	0.24	0.24
TRFK6/8	0.70	0.93	1.07	0.90	0.38	0.44	0.54	0.46	0.29	0.40	0.32	0.34
TRFK31/27	1.12	1.06	1.16	1.11	0.60	0.66	0.55	0.60	0.40	0.46	0.31	0.39
TRFK12/12	1.04	1.24	1.02	1.10	0.47	0.58	0.50	0.51	0.30	0.39	0.29	0.33
TRFK303/999	1.04	0.98	1.11	1.04	0.57	0.59	0.54	0.57	0.34	0.40	0.35	0.36
AHPS15/10	1.06	1.18	1.34	1.19	0.46	0.57	0.58	0.54	0.31	0.41	0.45	0.39
TRFK57/15	1.02	1.33	1.10	1.15	0.44	0.51	0.54	0.50	0.21	0.43	0.30	0.31
TRFK56/89	1.42	1.13	1.16	1.24	0.44	0.49	0.53	0.49	0.34	0.40	0.39	0.38
TRFK12/19	1.19	1.25	1.01	1.14	0.55	0.58	0.53	0.55	0.31	0.43	0.29	0.34
TRFK11/26	0.94	1.08	1.04	1.02	0.51	0.60	0.50	0.54	0.37	0.46	0.35	0.39
STC5/3	0.94	1.12	1.10	1.06	0.49	0.59	0.40	0.50	0.27	0.42	0.35	0.35
TRFK7/3	1.14	1.34	0.90	1.13	0.50	0.46	0.56	0.51	0.34	0.41	0.36	0.37
TRFK303/577	0.79	0.86	1.19	0.95	0.60	0.42	0.46	0.49	0.31	0.34	0.36	0.34
EPKTN14-3	0.86	0.95	0.83	0.88	0.40	0.43	0.54	0.46	0.26	0.36	0.28	0.30
TRFK2xI/4	1.14	1.19	1.47	1.27	0.63	0.75	0.81	0.73	0.36	0.42	0.44	0.41
Mean site	1.03	1.05	1.09		0.49	0.56	0.56		0.32	0.41	0.34	
C.V. (%)			12.44			3.36				9.02		
LSD, P <0.05												
Clone			0.13			0.04				0.03		
Site			0.10			0.03				0.02		
Interactions			0.22			0.06				0.05		

Timb = Timbilil, Kipk = Kipkebe, Kang = Kangaita

Table 7: Effects location of production and cultivars on leaf magnesium levels (%)

	Mature leaf				3rd Leaf				2 leaves and a bud			
Clone	Timb	Kipk	Kang	Mean clone	Timb	Kipk	Kanga	Mean clone	Timb	Kipk	Kang	Mean clone
TRFK7/9	0.09	0.13	0.08	0.10	0.12	0.18	0.08	0.13	0.20	0.21	0.15	0.19
TRFK303/259	0.11	0.16	0.10	0.12	0.18	0.17	0.12	0.15	0.25	0.22	0.18	022
TRFK303/1199	0.07	0.18	0.10	0.12	0.18	0.18	0.12	0.16	0.23	0.22	0.17	0.21
TRFK54/40	0.06	0.13	0.10	0.10	0.10	0.15	0.10	0.11	0.15	0.19	0.17	0.17
TRFK31/8	0.13	0.18	0.14	0.15	0.14	0.21	0.12	0.16	0.19	0.23	016	0.19
BBK35	0.14	0.16	0.12	0.14	0.12	0.18	0.11	0.14	0.20	0.21	0.15	0.19
TRFK6/8	0.11	0.15	0.10	0.12	0.17	0.16	0.11	0.15	0.20	0.21	0.16	0.19
TRFK31/27	0.07	0.17	0.12	0.12	0.15	0.19	0.12	0.15	0.21	0.23	0.18	0.21
TRFK12/12	0.12	0.25	0.13	0.17	0.17	0.20	0.12	0.16	0.19	0.19	0.16	0.18
TRFK303/999	0.12	0.23	0.13	0.16	0.15	0.18	0.13	0.15	0.22	0.22	0.17	0.20
AHPS15/10	0.14	0.21	0.16	0.17	0.19	0.21	0.16	019	0.23	0.30	0.19	0.24
TRFK57/15	0.15	0.27	0.13	0.18	0.18	0.20	0.17	0.18	0.23	0.23	0.19	0.22
TRFK56/89	0.12	0.17	0.10	0.13	0.12	0.17	0.11	0.13	0.19	0.22	016	0.19
TRFK12/19	0.17	0.19	0.12	0.16	015	0.22	0.13	017	0.21	0.26	0.17	0.21
TRFK11/26	0.07	0.14	0.13	0.11	011	0.17	0.13	0.14	0.18	0.21	0.17	0.19
STC5/3	0.11	0.15	0.11	0.13	0.15	0.18	0.13	0.16	0.22	0.22	0.16	0.20
TRFK7/3	0.11	0.17	0.13	0.14	0.16	0.19	014	0.17	0.27	0.24	0.17	0.23
TRFK303/577	0.20	0.17	0.14	0.17	0.22	0.20	0.15	0.19	0.25	0.23	0.19	0.23
EPKTN14-3	0.13	0.14	0.13	0.13	0.15	0.17	0.13	0.15	0.18	0.20	0.17	0.18
TRFK2xI/4	0.18	0.19	0.16	0.18	0.16	0.21	0.17	0.18	0.21	0.22	0.19	0.21
Mean site	0.12	0.18	0.12		0.15	0.19	0.13		0.21	0.22	0.17	
C.V. (%)		12.31				10.75				11.65		
LSD, P <0.05												
Clone		0.02				0.02				0.02		
Site		0.01				0.01				0.02		
Interactions		0.03				0.03				NS		

Timb = Timbilil, Kipk = Kipkebe, Kang = Kangaita

Table 8: Effects location of production and cultivars on leaf manganese levels (%)

Clone	Mature leaf				3rd Leaf				2 leaves and a bud			
	Timb	Kipk	Kang	Mean clone	Timb	Kipk	Kanga	Mean clone	Timb	Kipk	Kang	Mean clone
TRFK7/9	0.47	0.48	0.21	0.39	0.19	0.28	0.12	0.20	0.19	0.21	0.07	0.17
TRFK303/259	0.61	0.51	0.14	0.42	0.22	0.22	0.07	017	0.13	0.17	0.06	0.12
TRFK303/1199	0.49	0.45	0.22	0.39	0.21	0.30	0.08	0.20	0.10	0.17	0.07	0.12
TRFK54/40	0.38	0.40	0.16	0.35	0.22	0.26	0.04	0.17	0.14	0.19	0.06	0.13
TRFK31/8	0.57	0.36	0.34	0.42	0.18	0.26	0.12	0.19	0.12	0.20	0.06	0.13
BBK35	0.50	0.53	0.17	0.40	0.19	0.22	0.05	0.15	0.14	0.20	0.04	0.13
TRFK6/8	0.30	0.43	0.20	0.32	0.22	0.25	0.07	0.18	0.15	0.19	0.06	0.14
TRFK31/27	0.46	0.31	0.22	0.33	0.22	0.30	0.10	0.20	0.13	0.25	0.05	0.14
TRFK12/12	0.52	0.54	0.23	0.43	0.15	0.29	0.09	0.18	0.16	0.17	0.06	0.13
TRFK303/999	0.43	0.42	0.20	0.35	0.18	0.26	0.14	0.19	0.16	0.21	0.07	0.14
AHPS15/10	0.52	0.53	0.23	0.43	0.17	0.28	0.10	0.19	0.13	0.23	0.07	0.14
TRFK57/15	0.44	0.61	0.22	0.42	0.15	0.31	0.10	0.18	0.19	0.22	0.06	0.16
TRFK56/89	0.60	0.40	0.12	0.37	0.17	0.20	0.06	0.15	0.15	0.22	0.05	0.14
TRFK12/19	0.41	0.66	0.11	0.39	0.14	0.31	0.09	0.18	0.15	0.22	0.05	0.14
TRFK11/26	0.43	0.46	0.23	0.37	0.22	0.34	0.12	0.22	0.19	0.28	0.08	0.18
STC5/3	0.51	0.48	0.33	0.44	0.21	0.22	0.08	0.17	0.17	014	0.07	0.13
TRFK7/3	0.42	0.61	0.24	0.41	0.16	0.28	0.10	0.18	0.09	0.22	0.05	0.12
TRFK303/577	0.39	0.55	0.29	0.41	0.19	0.27	0.10	0.18	0.17	0.21	0.07	0.15
EPKTN14-3	0.45	0.45	0.27	0.39	0.13	0.25	0.12	0.16	0.16	0.16	0.07	0.13
TRFK2xI/4	0.48	0.51	0.23	0.40	0.15	0.24	0.12	0.17	0.15	0.17	0.07	0.13
Mean site	0.47	0.48	0.22		0.18	0.27	0.09		0.15	0.20	0.06	
C.V. (%)		7.24				8.49				7.48		
LSD, P <0.05												
Clone		0.03				0.02				0.01		
Site		0.02				0.01				0.01		
Interactions		0.05				0.03				0.02		

Timb = Timbilil, Kipk = Kipkebe, Kang = Kangaita

Table 9: Effects location of production and cultivars on leaf zinc levels (ppm)

Clone	Mature leaf				3rd Leaf				2 leaves and a bud			
	Timb	Kipk	Kang	Mean clone	Timb	Kipk	Kanga	Mean clone	Timb	Kipk	Kang	Mean clone
TRFK7/9	16	10	9	12	18	10	9	12	24	21	15	20
TRFK303/259	17	10	8	12	18	13	12	14	57	41	29	42
TRFK303/1199	13	13	9	12	28	16	12	19	48	32	28	36
TRFK54/40	13	15	9	12	20	24	8	17	46	44	22	37
TRFK31/8	11	10	7	9	22	13	12	16	43	21	22	29
BBK35	11	10	7	9	18	13	13	15	44	33	24	34
TRFK6/8	11	10	7	9	13	12	12	12	28	24	20	24
TRFK31/27	11	13	7	10	17	16	14	16	53	35	26	38
TRFK12/12	15	15	9	13	22	15	12	16	28	33	23	28
TRFK303/999	14	12	8	11	17	14	10	14	43	27	19	30
AHPS15/10	11	12	6	10	25	14	11	17	51	27	25	34
TRFK57/15	15	13	9	12	21	24	14	20	61	31	18	37
TRFK56/89	11	9	7	9	15	11	8	11	30	23	18	24
TRFK12/19	11	10	7	9	16	16	10	14	45	27	25	32
TRFK11/26	10	3	6	8	17	11	10	13	35	27	17	26
STC5/3	9	9	6	8	11	9	10	10	23	23	12	20
TRFK7/3	11	10	7	9	17	12	11	14	45	30	18	31
TRFK303/577	16	14	10	13	27	17	13	19	49	30	28	34
EPKTN14-3	10	10	9	9	16	13	10	13	44	27	20	30
TRFK2xI/4	11	11	11	11	17	13	10	13	26	28	18	23
Mean site	12	11	8		18	14	11		41	29	21	
C.V. (%)		12.89				11.11				7.35		
LSD, P <0.05												
Clone		1				2				2		
Site		1				1				2		
Interactions		2				3				4		

Timb = Timbilil, Kipk = Kipkebe, Kang = Kangaita

Table 10: Effects location of production and cultivars on leaf copper levels (ppm)

	Mature leaf				3rd Leaf				2 leaves and a bud			
Clone	Timb	Kipk	Kang	Mean clone	Timb	Kipk	Kanga	Mean clone	Timb	Kipk	Kang	Mean clone
TRFK7/9	8	10	8	9	9	10	7	9	10	12	10	11
TRFK303/259	8	20	7	12	10	11	5	9	14	14	10	13
TRFK303/1199	8	9	9	9	10	11	8	10	13	16	11	13
TRFK	9	10	8	9	8	11	5	8	12	15	10	12
TRFK31/8	6	10	16	11	8	12	7	9	12	13	11	12
BBK35	7	9	6	7	9	11	4	8	12	14	10	12
TRFK6/8	6	6	8	7	6	9	5	7	8	11	8	9
TRFK31/27	8	10	7	8	8	11	5	8	12	15	9	12
TRFK12/12	6	11	6	8	8	10	7	8	10	12	9	10
TRFK303/999	6	11	6	8	8	11	9	9	13	13	8	11
AHPS15/10	7	10	6	7	8	10	10	9	14	16	10	13
TRFK57/15	6	11	7	8	6	9	9	8	11	14	9	11
TRFK56/89	6	8	5	6	9	9	9	9	15	15	10	13
TRFK12/19	8	13	7	10	9	16	9	11	15	15	11	14
TRFK11/26	7	12	6	8	11	12	9	10	13	15	9	12
STC5/3	7	6	8	7	7	9	8	8	11	14	9	11
TRFK7/3	7	6	6	6	8	10	7	9	10	13	7	10
TRFK303/577	9	7	6	8	12	10	9	10	10	13	9	11
EPKTN14-3	7	8	6	7	7	10	8	8	9	11	8	9
TRFK2xI/4	9	7	6	7	10	10	8	9	10	12	7	10
Mean site	7	10	7		9	11	7		12	14	9	
C.V. (%)		15.83				12.43				12.92		
LSD, P <0.05												
Clone		1				1				1		
Site		1				1				1		
Interactions		2				2				NS		

Timb = Timbilil, Kipk = Kipkebe, Kang = Kangaita

Table 11: Effects location of production and cultivars on leaf iron levels (ppm)

	Mature leaf				3rd Leaf				2 leaves and a bud			
Clone	Timb	Kipk	Kang	Mean clone	Timb	Kipk	Kanga	Mean clone	Timb	Kipk	Kang	Mean clone
TRFK7/9	67	102	76	81	36	70	56	54	50	70	42	54
TRFK303/259	95	141	74	103	40	68	59	56	46	70	51	56
TRFK303/1199	73	78	71	74	44	69	57	56	58	70	84	71
TRFK54/40	80	101	67	83	41	65	56	54	55	72	64	64
TRFK31/8	90	80	103	91	38	66	61	55	49	70	57	59
BBK35	95	100	89	94	37	67	46	50	37	61	68	55
TRFK6/8	57	109	90	85	36	69	49	51	42	71	63	59
TRFK31/27	66	72	90	76	41	72	68	60	72	69	74	72
TRFK12/12	75	89	95	86	34	61	50	48	40	67	65	57
TRFK303/999	108	96	101	102	50	76	58	61	47	65	58	57
AHPS15/10	78	68	96	81	41	76	52	57	52	68	48	56
TRFK57/15	77	103	65	82	48	71	57	58	44	60	63	56
TRFK56/89	94	92	73	86	41	57	48	49	48	73	53	58
TRFK12/19	96	103	73	91	47	75	54	59	46	66	59	57
TRFK11/26	83	99	75	86	60	74	58	64	44	82	46	57
STC5/3	79	107	66	84	41	53	45	46	51	65	66	60
TRFK7/3	98	130	84	104	39	62	53	51	43	66	61	56
TRFK303/577	79	103	98	93	57	62	57	58	44	63	62	56
EPKTN14-3	94	109	88	97	45	68	61	58	43	65	64	58
TRFK2xI/4	74	104	85	88	52	65	52	56	42	62	64	56
Mean site	83	99	83		43	67	55		48	68	60	
C.V. (%)		5.03				4.84				4.61		
LSD, P <0.05												
Clone		4				3				3		
Site		3				2				3		
Interactions		7				4				4		

Timb = Timbilil, Kipk = Kipkebe, Kang = Kangaita

Table 12: Regression coefficients (r^2) of linear regression analyses between same nutrients in leaves from different regions.

			Mature leaf					
		Timbilil	Kipkebe	Kangaita		Timbilil	Kipkebe	Kangaita
N	Timbilil	1.000			P	1.000		
	Kipkebe	0.046	1.000			0.133	1.000	
	Kangaita	0.240	0.019	1.000		0.004	0.293	1.000
K	Timbilil	1.000			Ca	1.000		
	Kipkebe	0.106	1.000			0.059	1.000	
	Kangaita	0.320	0.091	1.000		0.274	0.000	1.000
Mg	Timbilil	1.000			Mn	1.000		
	Kipkebe	0.155	1.000			0.018	1.000	
	Kangaita	0.342	0.227	1.000		0.000	0.027	1.000
Cu	Timbilil	1.000			Zn	1.000		
	Kipkebe	0.004	1.000			0.233	1.000	
	Kangaita	0.016	0.000	1.00		0.304	0.296	1.000
Fe	Timbilil	1.000						
	Kipkebe	0.097	1.000					
	Kangaita	0.010	0.100	1.000				
			Third leaf					
N	Timbilil	1.000			P	1.000		
	Kipkebe	0.222	1.000			0.158	1.000	
	Kangaita	0.149	0.084	1.000		0.080	0.086	1.000
K	Timbilil	1.000			Ca	1.000		
	Kipkebe	0.185	1.000			0.288	1.000	
	Kangaita	0.253	0.195	1.000		0.096	0.078	1.000
Mg	Timbilil	1.000			Mn	1.000		
	Kipkebe	0.203	1.000			0.003	1.000	
	Kangaita	0.356	0.345	1.000		0.134	0.167	1.000
Cu	Timbilil	1.000			Zn	1.000		
	Kipkebe	0.098	1.000			0.209	1.000	
	Kangaita	0.028	0.001	1.000		0.133	0.065	1.000
Fe	Timbilil	1.000						
	Kipkebe	0.066	1.000					
	Kangaita	0.074	0.249	1.000				
			Two leaves and a bud					
N	Timbilil	1.000			P	1.000		
	Kipkebe	0.661	1.000			0.012	1.000	

this level of Mg in the third leaf (Table 7), although the plants did not have any visual signs of Mg deficiency [10]. Kamau [32] reported similar observations and findings on magnesium levels in clonal tea. The norms set for third leaf Mg levels are therefore unrealistic for Kenyan clonal tea plantations. The levels of Mg decreased as the leaf became older.

The essential micronutrients for tea include Mn, Zn, Cu and Fe [10]. The changes in leaf Mn levels due to locations and clones are presented in Table 8. The clones showed significant ($P \leq 0.05$) variations in mature leaf Mn. Such variations differed ($P \leq 0.05$) with locations. The level of Mn in the third leaf of all clones and at all sites were above 0.005% (50ppm) considered optimal [10]. With continuous application of nitrogenous fertilisers, there are normally increases in soil pH which in turn increases soil available Mn [33]. Since N fertilisation forms the basis of tea nutrition, it is unlikely Mn deficiency will be prevalent in Kenya tea soils. There was decline in Mn levels in younger leaves compared to older leaves. However, the change from mature uppermost leaf to the third leaf was more drastic than the change from third leaf to two leaves and a bud.

Zn is an important micronutrient in tea, and where deficiency is detected, this is usually corrected through foliar application of zinc oxide [18]. In mature leaf, level of Zn significantly ($P \leq 0.05$) changed with clones and location. Although the zinc levels appeared within the accepted range [18, 20] for all clones in Timbilil, except in STC 5/3, and in Kipkebe, except in clones TRFK 56/89, TRFK 11/26 and STC 5/3, and only clone TRFK 303/577 showed adequate Zn levels in Kangaita (Table 9). The levels recorded in the third leaf were much lower than the 50 ppm considered adequate [10] for optimal growth. High amount of zinc was harvested with crop in two leaves and a bud.

Cu is also an important micronutrient in tea, and low levels have detrimental effects on black tea quality. Polyphenol oxidase responsible for fermentation process is a copper-protein

Table 13: Regression coefficients (r^2) of linear regression analyses between nutrients in different leaves of clonal tea

		Timbilil			Kipkebe			Kangaita		
		Mature	3rd leaf	2 + bud	Mature	3rd leaf	2 + bud	Mature	3rd leaf	2 + bud
N	Mature	1.000			1.000			1.000		
	3rd leaf	0.020	1.000		0.000	1.000		0.441	1.000	
	2 + bud	0.006	0.277	1.000	0.012	0.209	1.000	0.243	0.461	1.000
P	Mature	1.000			1.000			1.000		
	3rd leaf	0.068	1.000		0.043	1.000		0.001	1.000	
	2 + bud	0.053	0.062	1.000	0.159	0.100	1.000	0.001	0.102	1.000
K	Mature	1.000			1.000			1.000		
	3rd leaf	0.396	1.000		0.051	1.000		0.010	1.000	
	2 + bud	0.254	0.470	1.000	0.010	0.381	1.000	0.064	0.417	1.000
Ca	Mature	1.000			1.000			1.000		
	3rd leaf	0.047	1.000		0.020	1.000		0.430	1.000	
	2 + bud	0.012	0.047	1.000	0.060	0.266	1.000	0.171	0.155	1.000
Mg	Mature	1.000			1.000			1.000		
	3rd leaf	0.268	1.000		0.343	1.000		0.670	1.000	
	2 + bud	0.158	0.525	1.000	0.083	0.395	1.000	0.349	0.661	1.000
Mn	Mature	1.000			1.000			1.000		
	3rd leaf	0.007	1.000		0.048	1.000		0.224	1.000	
	2 + bud	0.039	0.007	1.000	0.001	0.324	1.000	0.215	0.299	1.000
Cu	Mature	1.000			1.000			1.000		
	3rd leaf	0.340	1.000		0.213	1.000		0.035	1.000	
	2 + bud	0.000	0.100	1.000	0.085	0.110	1.000	0.205	0.000	1.000
Fe	Mature	1.000			1.000			1.000		
	3rd leaf	0.024	1.000		0.062	1.000		0.030	1.000	
	2 + bud	0.105	0.009	1.000	0.015	0.018	1.000	0.001	0.002	1.000
Zn	Mature	1.000			1.000			1.000		
	3rd leaf	0.219	1.000		0.437	1.000		0.000	1.000	
	2 + bud	0.081	0.230	1.000	0.224	0.381	1.000	0.020	0.238	1.000

Table 14: Regression coefficients (r^2) analyses between different nutrients in clonal tea leaves of the same age

	Timbilil								
	N	P	K	Ca	Mg	Mn	Cu	Fe	Zn
N	1.00								
P	0.28	1.00							
K	0.03	0.17	1.00						
Ca	0.25	0.10	0.03	1.00					
Mg	0.01	0.05	0.13	0.00	1.00				
Mn	0.04	0.02	0.29	0.29	0.01	1.00			
Cu	0.01	0.08	0.10	0.06	0.00	0.03	1.00		
Fe	0.17	0.26	0.07	0.09	0.05	0.09	0.04	1.00	
Zn	0.03	0.07	0.14	0.06	0.01	0.01	0.04	0.00	1.00
N	1.00								
P	0.06	1.00							
K	0.01	0.00	1.00						
Ca	0.16	0.01	0.08	1.00					
Mg	0.02	0.09	0.32	0.04	1.00				
Mn	0.16	0.14	0.01	0.00	0.03	1.00			
Cu	0.06	0.00	0.06	0.24	0.08	0.04	1.00		
Fe	0.15	0.00	0.21	0.30	0.19	0.00	0.28	1.00	
Zn	0.01	0.03	0.28	0.04	0.03	0.00	0.16	0.02	1.00
N	1.00								
P	0.20	1.00							
K	0.00	0.18	1.00						
Ca	0.04	0.00	0.02	1.00					
Mg	0.00	0.03	0.24	0.00	1.00				
Mn	0.05	0.00	0.02	0.03	0.10	1.00			
Cu	0.16	0.04	0.02	0.06	0.00	0.04	1.00		
Fe	0.00	0.12	0.01	0.25	0.00	0.08	0.08	1.00	
Zn	0.01	0.40	0.14	0.01	0.14	0.10	0.11	0.07	1.00

	Kipkebe								
	N	P	K	Ca	Mg	Mn	Cu	Fe	Zn
N	1.00								
P	0.01	1.00							
K	0.00	0.31	1.00						
Ca	0.00	0.04	0.01	1.00					
Mg	0.01	0.00	0.14	0.23	1.00				
Mn	0.00	0.07	0.25	0.25	0.13	1.00			
Cu	0.11	0.00	0.02	0.05	0.02	0.01	1.00		
Fe	0.00	0.08	0.25	0.04	0.07	0.18	0.04	1.00	
Zn	0.01	0.03	0.24	0.00	0.19	0.00	0.00	0.07	1.00
N	1.00								
P	0.07	1.00							
K	0.04	0.09	1.00						
Ca	0.00	0.02	0.01	1.00					
Mg	0.01	0.13	0.15	0.07	1.00				
Mn	0.01	0.03	0.08	0.04	0.10	1.00			
Cu	0.05	0.06	0.01	0.08	0.11	0.16	1.00		
Fe	0.01	0.07	0.06	0.04	0.03	0.33	0.24	1.00	
Zn	0.00	0.25	0.10	0.00	0.00	0.12	0.01	0.05	1.00
N	1.00								
P	0.02	1.00							
K	0.05	0.01	1.00						
Ca	0.00	0.06	0.02	1.00					
Mg	0.02	0.05	0.52	0.00	1.00				
Mn	0.03	0.01	0.12	0.02	0.13	1.00			
Cu	0.02	0.00	0.06	0.14	0.21	0.00	1.00		
Fe	0.00	0.02	0.07	0.22	0.02	0.02	0.08	1.00	
Zn	0.01	0.00	0.00	0.00	0.05	0.06	0.09	0.00	1.00

	Kangaita								
	N	P	K	Ca	Mg	Mn	Cu	Fe	Zn
N	1.00								
P	0.19	1.00							
K	0.17	0.01	1.00						
Ca	0.12	0.01	0.02	1.00					
Mg	0.02	0.01	0.00	0.38	1.00				
Mn	0.16	0.10	0.00	0.16	0.17	1.00			
Cu	0.23	0.04	0.02	0.16	0.01	0.20	1.00		
Fe	0.03	0.02	0.01	0.19	0.30	0.13	0.02	1.00	
Zn	0.02	0.00	0.02	0.00	0.01	0.00	0.01	0.00	1.00
N	1.00								
P	0.02	1.00							
K	0.05	0.41	1.00						
Ca	0.02	0.28	0.20	1.00					
Mg	0.00	0.24	0.46	0.17	1.00				
Mn	0.04	0.11	0.11	0.33	0.13	1.00			
Cu	0.04	0.16	0.00	0.07	0.00	0.27	1.00		
Fe	0.08	0.04	0.07	0.03	0.01	0.22	0.00	1.00	
Zn	0.02	0.00	0.02	0.01	0.00	0.00	0.06	0.07	1.00
N	1.00								
P	0.01	1.00							
K	0.01	0.02	1.00						
Ca	0.09	0.06	0.16	1.00					
Mg	0.08	0.03	0.19	0.19	1.00				
Mn	0.04	0.02	0.00	0.21	0.08	1.00			
Cu	0.02	0.00	0.05	0.06	0.12	0.03	1.00		
Fe	0.02	0.05	0.01	0.07	0.04	0.06	0.00	1.00	
Zn	0.00	0.02	0.00	0.04	0.01	0.06	0.18	0.10	1.00

compound, and teas grown on Cu deficient soils do not ferment [34, 35]. There were significant ($P \leq 0.05$) variations in leaf Cu levels in different clones and at different locations (Table 10). The levels of Cu in mature leaf to guide foliar analysis advisory system have not been set. However, for clones grown in the same location, large variations were observed suggesting that setting a single level for all clones may not be accurate limit. For third leaf, most clones had lower than the 15 ppm content considered borderline deficiency and none reached the 30 ppm considered adequate [10]. But these clones did not have any Cu deficiency problem and fermented very well [7]. Levels of copper were generally higher in younger leaves than older leaves.

Significant ($P \leq 0.05$) differences were observed in Fe levels due to location of production and clones (Table 11). Although there are no set norms to guide diagnostic mature leaf Fe levels, the large variations demonstrate that setting such level in mature leaf to serve as a guide for many clones in different locations can be problematic. In the third leaf, there were either deficient (less than 60 ppm) or borderline (less than 100 ppm) levels and no clone reached the adequate (500 ppm) level [0]. Thus although there were no visible signs of Fe deficiency, the third leaf could not be diagnostic to delineate demand for corrective measure in clonal tea at all locations.

The results presented herein demonstrated that the foliar nutrients norms set to guide the tissue analysis advisory service for seedling tea is East Africa using the uppermost mature leaf [17, 18, 20] or third leaf [10] are not useful to guide tissue analysis advisory system for clonal teas grown in single or different locations. Earlier large variations had been shown in mature leaf nutrients contents grown at the same location and that the nutrients contents were not related to yields [14]. Recently, clone BBK 35 was shown to have different mature leaf nutrients levels when grown in different regions in Kenya under same agronomic inputs [16]. The earlier results together with data presented herein demonstrate clear evidence that there is need to generate additional data on widely grown clones in different locations to help in setting realistic nutrients norms to guide foliar analysis advisory system for clonal teas.

Except for third leaf N, two leaves and a bud P, Mg and Cu levels, there were significant ($P \leq 0.05$) interactions effects between the leaf nutrient levels of clones and locations. These results demonstrated that the patterns of nutrients uptake and partitioning varied with clones and in individual clones the extent or rate of variations were not uniform. Indeed the regression coefficients (r^2) between the levels of same nutrient in different locations were low and not significant (Table 12) further demonstrating that there were variations in the patterns of nutrients` uptake and partitioning with location of production. The regression coefficients (r^2) between same nutrient contents in leaf of different age in same clones at individual locations were not significant (Table 13), implying the clones partitioned nutrients differently even in same location. Similarly, the regression coefficients (r^2) between different nutrients in leaves of same age in same location were also not significant (Table 14), an indication that clones partition different nutrients differently in their leaves even in the same location. Although several studies have reported dry matter partitioning in different clones [36, 37], no study has reported nutrient partitioning in clonal teas. Results presented here demonstrated that such variations can be large in clones or even in same clone grown in different locations. Similar variations were recently observed in the plain tea quality parameters [7]. It is necessary that clonal and locational specific foliar diagnostic systems are developed. These results further demonstrated the difficulties encountered in the use of tissues analysis to guide fertiliser use recommendations. Indeed, despite the wide use of the tissue analysis, there are no recommendations in many major tea growing countries including Sri Lanka [38], South India [39] and Papua New Guinea [40]. For more definitive and accurate tissue analysis diagnostic system, collection of more data from clonal tea that are widely grown is necessary. The recommendations based on seedling tea [17, 18, 20] are unreliable and inaccurate to guide foliar analysis advisory system for clonal tea.

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