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EFFECT OF SOIL MICRONUTRIENT STATUS ON THE FERMENTATION CHARACTERISTICS AND ORGANOLEPTIC QUALITY OF NIGERIAN TEA

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ABSTRACT

The status of micronutrients (Cu^{2+}, Zn^{2+}, Fe^{2+} and Mn^{2+}) in soils and foliage of three commercial tea clones 68, 143 and 35 collected from the Ardo-Gore tea estates of the Mambilla Plateau in Gongola State of Nigeria was evaluated. Leaf samples were also batch-processed and examined for fermentation characteristics including average fermentation time and organoleptic cup quality, and analytical quality indices, namely total phenol and tannin. Results showed that while Cu and Mn contents are adequate, Fe and Zn are marginal. A high negative correlation was obtained for soil Fe and leaf Cu (r = 0.98) and Zn (r = 1.00) probably due to substitution ability of these essential nutrients which could have limiting consequences on the fermentation process. Leaf Cu showed a significant positive relationship with total phenol and tannin contents of the samples (r = 0.77 and 0.73, respectively) while the relationship between leaf Zn and total phenol (r = 0.64) was statistically insignificant. Sensory evaluation of the samples from the three clones showed that clone 35 had the least fermenting ability and poorest cup quality. This trend was in agreement with the levels of leaf Cu, Zn, total phenol and tannin of the samples, indicating high variability in clonal requirements of micronutrients for physiological and processing functions.

***Key Words*: Fermentation time, micronutrients, organoleptic**

RÉSUMÉ

La situation des microélements (Cu^{2+}, Zn^{2+}, Fe^{2+} et Mn^{2+}) dans le sol et dans le feuillage de 3 clones commerciaux de thé (68, 143 et 35) collectés dans la zone theièŕe du Plateau de Mambilla dans l'Etat de Gongola au Nigéria est évalué. Les échantillons de feuilles sont collectés par groupe et étudiés pour les caractéristiques de fermentation comportant le temps moyen de fermentation, la qualité morganoleptique, les indices de qualité analytique (Phenol total et tannin). Les résultats montrent que les teneurs en Cu et Mn sont adéquates, tandis que celles du Fe et du Zn sont marginales. Une corrélation hautement négative est observée entre la teneur en Fe du sol et celle des feuilles en Cu (r = 0.98) et en Zn (r = 1.00). Cela est probablement lié à la possibilité de substitution de ces élements nutritifs essentiels qui ne peuvent pas limiter les conséquences du processus de fermentation. Le Cu foliaire a une relation hautement significative avec la teneur en phénol total et en tannin des échantillons (r = 0.77 et 0.73 respectivement). La relation entre le taux de Zn folaire et le phénol total (r = 0.64) est significative. Une évaluation sensorielle des échantillons obtenus des trois clones ont montré que le clone 35 avait le plus inférieur abilité de fermentation et qualité buvable. Cette tendance était en accord avec les niveaux de Cu, Zn, phenol et tannin totals dans les feuilles des échantillons, indiquant une haute variabilité de besoin clonal en microélements pour les fonctions phsiologiques et ceux de traitement.

***Mots Clés*: Micronutrients, organoteptique, temps de fermentation**

INTRODUCTION

The ultimate aim in tea manufacture is to obtain a product of good 'cup quality'. However, variations in yield and processing quality potential of harvested leaves from tea bushes may be due to several factors including clonal differences, environmental conditions, soil nutrient status and plant uptake.

Previous study (Ogunmoyela and Obatolu, 1984) highlighted the inadequancy of macronutrients (N, P, K, Ca and Mg) in both the soils and tea foliage from the Mambilla Plateau of Gongola State in Nigeria where tea cultivation was recently established. Whereas macronutrient problems are readily manifested in poor growth and yield of tea bushes, micronutrient problems in contrast, are manifested in often obscure physiological conditions which not only affect yield and quality but cause processing problems. Thus, for instance, Cu deficiency is often indicated by the lack of normal turgor in plant tissue as well as abnormal or pale pigmentation (Eden, 1976). Zinc deficiency on the other hand, may produce leaf mottling as well as crowding of leaves on the shoot, which reduce the quality of the harvested leaves and cause difficulty in processing. The result is reduced organoleptic quality (Ogunmoyela, 1982; 1987).

Yet, to date, the micronutrient status of Mambilla tea has not been evaluated. The objectives of the present study, therefore, were to examine the status of micronutrients in Mambilla soils and tea foliage; the clonal variations in Cu, Zn, Mn and Fe, and their possible effects on both physiological efficiency and processing quality of the tea bushes; as well as the relationship between leaf micronutrients and quality of the infusions, with a view to improving the organoleptic quality of the tea produced when different clones are batch-processed.

MATERIALS AND METHODS

Collection and analyses of soil and leaf Samples. Soil samples (0-15 cm, 15-30 cm depth) were collected from hilltop and valley sites on the Ardo-Gore Tea Estate in the Mambilla Plateau, Gongola State of Nigeria. The samples were air-dried and sieved through a 2 mm sieve. Soil pH was determined in a 1:2 soil/0.01 M $CaCl_2$ suspension. Five gram samples were extracted for available Cu^{2+}, Mn^{2+}, and Fe^{2+} using 50 ml 1.0 N EDTA. Micronutrient (Cu, Zn, Fe and Mn) contents of the extracts were determined using SP 900 spectro-photometer at appropriate wavelengths.

Leaf samples (two apical leaves and the bud) were collected from the same plots as the soil samples. The samples were obtained from three of the important commercial clones imported from Kenya, namely 68, 35 and 143. These were oven-dried to constant weight at 65°C and ground using a mortar and pestle prior to storage and analysis. The samples were dry-ashed and Cu, Zn, Fe and Mn availability determinined on an Hitachi Atomic Absorphoi spectrometer.

Total phenol was determined spectrophotometrically using the method based on oxidation of Folin-Ciocalteau reagent, followed by estimation of the resulting blue complex at 765 nm (AOAC, 1960) with gallic acid as standard. Tannin was also determined spectrophotometrically using the Folin-Denis Reagent method (AOAC, 1984) with tannic acid as standard at 760 nm.

Batch-processing of tea leaves. Processing was carried out in the laboratory scale miniature factory at Ardo-Gorre, Mambilla Plateau (Hainsworth, 1981). Fresh leaves plucked from the tea clones were withered by spreading on wire mesh racks overnight for moisture reduction. The withered leaves were transferred into a Kenwood mixer and thoroughly churned up for cell disruption. The material was subsequently fermented by spreading in thin layers, about 3–5 cm thick, on aluminium trays at an average dry bulb temperaure of 26°C. Drying was carried out at 100–5°C for about 27 minutes to a moisture content of about 3%. Infusions were subsequently prepared from the black tea thus obtained for organoleptic assessment.

Sensory evaluation. Infusions obtained from samples of the three clones were coded and ranked for overall cup characteristics (briskness, quality, strength and flavour) by eight fairly experienced tea tasters. Judgements were replicated twice with a different order of presentation and each of the cup characteristics clearly defined[1]. The rank scores were pooled together and three clones ranked A, B and C where A = best cup quality, B = moderate and C = poorest. Tasters were also asked to describe the 'brightness' and preference in terms of these cup characters.

[1]Briskness = fresh astringent taste at the tip of the tongue; strength = full and positive response by the taste buds at the back of the tongue, near the throat, where bitterness is most experienced; quality = pleasant satisfying taste on the central region of the tongue; and flavour = delicate fragrance spreading over the whole palate.

RESULTS AND DISCUSSION

Micronutrient status of Mambilla tea soils and foliate and their inter-relationships. The results of soil analyses outlined in Table 1 show that the soil is acidic with a pH range of 4.3–5.1. The low pH is conducive to availability of Fe, Cu and Mn. In general, slight but insignificant differences (P=0.05) were found between the values of these nutrients both with respect to location and between clones. The values of Cu and Mn are much higher than the limiting values of 0.2 mg Kg^{-1} and 1:00 ppm respectively (Cottenie *et al.*, 1981). Iron is marginally deficient based on the limiting value of 2.5 mg Kg^{-1}, while Zn contents are much lower than the limiting value of 0.5 ppm (Cottenie *et al.*, 1981). This confirms the Zn deficiency symptoms earlier suspected on the tea estate in Mambilla (Ogunmoyela and Obatolu, 1984; Ogunmoyela, 1987). The limiting values listed above are, however, not absolute values since they are site and crop specific. For instance, Agboola (1979) observed Cu deficiency symptoms in Cote d'Ivoire soils with Cu content of about 0.2 mg kg^{-1}. As already indicated, the present results indicate no significant location effect (P=0.05). This agrees with the observation of Cottenie *et al.* (1981) that there is no appreciable mobility of these micro nutrients within the soils.

Foliar analyses (Table 2) show that Mambilla tea is adequate in Fe with values of 97–114 ppm compared with 70–75 mg kg^{-1} recorded for East Africa and Sri Lanka tea leaves (Van Dierein-donck, 1959). This suggests that although the Fe content of the soil is marginal there is adequate

TABLE 1. pH and micro-nutrient availability of Nigerian tea soils in relation to site of growth and soil depth

Location	Clones on soil	Depth (cm)	pH in $CaCl_2$	cmol kg^{-1} (ETDA–Extractable) Fe^{2+}	Cu^{2+}	Zn^{2+}	Mn^{2+}
	35	0–15	4.6	7.14×10^{-3}	0.0125	7.07×10^{-3}	6.55×10^{-3}
		15–30	5.1	9.43×10^{-3}	0.0137	9.18×10^{-4}	6.84×10^{-3}
Hill top	68	0–15	4.3	9.29×10^{-3}	0.0142	7.10×10^{-3}	3.90×10^{-3}
		15–30	4.8	6.11×10^{-3}	0.0154	1.04×10^{-3}	1.09×10^{-2}
	143	0–15	4.7	5.50×10^{-3}	0.0152	7.67×10^{-3}	7.24×10^{-3}
		15–30	5.1	5.61×10^{-3}	0.0113	1.10×10^{-1}	1.33×10^{-2}
	35	0–15	4.6	6.26×10^{-3}	0.0121	2.45×10^{-4}	4.88×10^{-3}
		15–30	5.2	4.00×10^{-3}	0.0133	3.37×10^{-4}	5.75×10^{-3}
Valley	68	0–15	4.9	1.54×10^{-3}	0.0140	21.48×10^{-3}	5.75×10^{-3}
		15–30	4.8	3.82×10^{-3}	0.0107	8.57×10^{-4}	8.30×10^{-3}
	143	0–15	4.8	8.71×10^{-3}	0.0107	9.18×10^{-5}	6.77×10^{-3}
		15–30	4.7	1.30×10^{-2}	0.0138	6.12×10^{-5}	8.34×10^{-3}

[a]Data are means of two replicates and varietal differences between clones and location effect were not significant ($P > 0.05$).

TABLE 2. Average micronutrient contents of Nigerian tea leaves in relation to site of growth and variety

Location	Clones	mg kg^{-1} (leaf dry matter) Fe	Cu	Zn	Mn
Hill top	35	95	62	39	458
	68	106	68	41	413
	143	90	72	45	600
Slope	35	128	40	25	360
	68	121	59	34	492
	143	78	65	40	350
Valley	35	120	46	29	425
	68	110	65	27	477
	143	123	68	48	718

[a]Data are means of two replicates and varietal and location effects were not significant ($P > 0.05$).

uptake of the nutrient, hence it may not create any deficiency problem. This is consistent with the observation of Ahn (1970) that it is unlikely that Fe deficiencies occur in acid West African soils. Although soil Mn levels appear adequate, leaf values are considerably lower than the 900–1900 mg kg^{-1} obtained in Malawi or the 590–2500 mg kg^{-1} in Kenya (Eden, 1976). The increased uptake of Mn in this study thus suggests a possible Fe-Mn interaction. However, the high correlation (r = 0.97) in Table 3 between soil Mn and leaf Fe suggests that there was no antagonism between Fe and Mn.

The Cu levels of the tea leaves are higher than the 15–25 mg kg^{-1} recorded in East Africa and Sri Lanka (Van Diereindonck, 1959; Eden, 1976) while the Zn levels compare favourably with the 26–42 mg kg^{-1} reported in the same areas (Eden, 1976) in contrast with the low soil Zn values. This suggests greater Zn uptake efficiency from the Mambilla soil. It is also indicative of the variable Zn requirements in different tea-growing areas in view of the observed visual Zn deficiency symptoms in the tea leaves. In addition, highly significant but negative relationships were found between soil Fe and leaf Cu (r = 0.98) and Zn (r =1.00) (Table 3), suggesting a possible antagonism of uptake of Cu and Zn by soil Fe, which could have the consequence of limiting the availability of these essential nutrients for the fermentation process.

Leaf micronutrient levels in relation to tea fermentation and quality. The total phenol and tannin contents of the processed tea (Table 4) show insignificant differences between clones 68 and 143 but a significant difference (P = 0.05) between these two and clone 35. There was, however, no significant effect of location on the total phenol or tannin contents.

Total phenol and tannin levels of the tea samples are important indices of leaf quality and suitability of the clones for processing. This is principally due to the influence of the polyphenol oxidase system on the fermentation rate and quality of the tea leaf during tea manufacture. According to Hilton (1975), this enzymic oxidation in the presence of atmospheric oxygen is the most important feature of fermentation. But since the system is not homogenous, the availability and activity of the enzyme system of which both Cu and Zn are essential components, as well as the degree of contact between enzyme and substrate, are important to the overall development of flavour quality (Eden, 1976). Hence, correlation analysis was used to determine if any relationships exist

TABLE 4. Average total phenol and tannin contents of processed black tea leaves in relation to site of growth and varieties

Location	Clones	% total phenol (on DM basis)	% total (on DM basis)
Hill top	35	1.6	1.4
	68	2.6	2.4
	143	2.9	1.4
Slope	35	1.7	1.4
	68	2.6	2.4
	143	3.0	2.0
Valley	35	1.6	1.3
	68	2.5	2.4
	143	3.0	2.0

Differences between clones significant at P = 0.05, location effect not significant (P > 0.05); Means of two replications are presented.

TABLE 3. Coefficients of relationship (r) between micronutrient levels in Mambilla soils and tea leaves

	Soil			
Leaf	Fe	Cu	Zn	Mn
Fe	0.77 ns	-0.03 ns	0.92 ns	0.97*
Cu	-0.98**	-0.74 ns	0.30 ns	-0.46 ns
Zn	-1.00**	-0.57 ns	-0.50 ns	-0.64 ns
Mn	-0.39 ns	-0.97*	0.64 ns	0.50 ns

[a]Astericks indicate statistical significance,
* = $P \leq 0.05$;
** = $P \leq 0.01$;
ns = not significant.

TABLE 5. Correlation matrix between micronutrient levels, total phenol and tannin contents of Mambilla tea

	Cu	Zn	Fe	Mn	Tp
Zn	0.78*[b]				
Fe	-0.59	-0.45			
Mn	0.52	0.62	0.18		
Tpa	0.77*	0.64	-0.35	0.46	
Tna	0.73*	0.38	-0.20	0.31	0.85**

[b]Tp = Total phenol and Tn = Tannin
*Asterisks indicate significance: *P = 0.05 and **P = 0.01 respectively.

TABLE 6. Fermenting characteristics and organoleptic qualities of Mambilla tea clones

Clones	Average Fermenting ability and characteristics	Organoleptic fermentation time (min)	quality (cup characteristics)
35	Very troublesome with colour changes. May require ball-breaking twice or reduction in dhool quantity for rapid fermentation	up to 120	Rank = c 'Average' bright, flavoury liquors
68	Fairly good, changes from green to dark brown easily	60–90	rank = a 'Full' bright, flavoury liquors
143	Fairly troublesome with colour changes but much better than clone 35. May require ball-breaking twice	90–100	Rank = b 'Thin' bright, flavoury liquors

[a]Ranks: A = best cup quality; B = moderate; and C = poor cup quality.

between the micronutrient contents of the leaf and the total phenol and tannin contents (Table 5). Only leaf Cu showed significant positive relationships with total phenol and tannin content of the tea samples (r = 0.77 and 0.73, respectively). The relationship between leaf Zn and total phenol, although statistically insignificant, is positive enough to the extent that as much as 40% variation (R^2 = 0.41) in total phenol content could be explained by the leaf Zn content. This, therefore, makes Cu and Zn important factors in determining the fermenting characteristics of the leaf and subsequent quality of the product.

The lower values of leaf Zn, Cu, total phenol and tannin for clone 35, compared to the other two clones (Tables 2 and 4) as already highlighted, suggest that commercial tea clones have variable micronutrient requirements for physiological and processing functions. This would probably explain why clone 35 poses the greatest problem in the fermentation process and gives a product of cup quality judged to be the poorest (Table 6).

It is conceivable, therefore, that the combined effects of interaction between Fe, Cu and Zn as well as the effects of these micronutrients on the total phenol and tannin contents of the Cu and Zn for fermentation may be responsible for the observed variations in the fermenting ability of the tea clones and the organopletic quality of the products. Thus, the solution might be a regular return to the soil of such amounts of the micronutrients that have been taken out by harvest, especially for clone 35 which showed the least fermenting ability and poorest cup quality relative to 68 and 143.

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