

ASSESSMENT OF TEA PLOTS ACROSS AGRO-ECOLOGIES IN NIGERIA FOR CULTIVATION EXPANSION

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ABSTRACT

Tea production across agro-ecological areas is the main thrust in Nigeria to resolve limited land for tea plantation expansion. Soils under tea cultivation and tea leaves from three commercial tea growing areas in Kusuku, Ngoroje, Kakara (highland agro-ecology) and three adaptive trial centers in Mayo-Selbe, Ikom and Ibadan (Lowland agro-ecology) were assessed for nutrient contents for proper nutrient management and possible tea cultivation expansion. Ten tea plants per location were tagged and their leaf samples collected while soil samples at 0–30cm were collected at the same points. The soils and tea leaves were analyzed for N, P, K, Ca, Mg and Zn contents in addition to soil pH and organic C. The Ikom soil was strongly acidic while the other locations were slightly acidic. The soil organic C was below critical value of 30.0g kg⁻¹ soil for the lowland locations but higher than critical for the highland areas. The 0.8g N kg⁻¹ for Mayo-Selbe, 9.82mg P kg⁻¹ for Ngoroje, and 0.2cmol K.kg⁻¹ for Kakara were below their critical values of 1.0g N, 10mg P and 0.3cmol K kg⁻¹ soil respectively while the Ca and Mg contents were higher than critical levels. Foliar nutrient composition in Ca, Mg and Zn contents did not differ significantly across the agro-ecological areas but there were significant differences in N, P and K contents. Generally, the tea nutrient contents for the lowland ecology compared favorably with the highland areas. This suggests that tea cultivation could be advised for all the locations. However, there is need for tea from the different ecologies to be processed as a unique tea blend. Profitable tea production in the lowland locations would need sustained improvement in the soil OC and N contents while, Kakara and Ikom locations should be supplied 78.2kg K and 8.72kg P at Ngoroje.

Keywords: Agro-ecology; soil fertility management; sustainable tea production

INTRODUCTION

Tea (*Camellia Sinesis* (L) Kuntze) is a major beverage commodity crop grown in 58 countries across 5 continents of the world with a global annual production of 5 million tonnes of tea leaves (Kaisan and Margarita, 2015; FAOSTAT, 2016; Mukhopadhyay and Mondal, 2017). Commercial tea cultivation was pioneered by Nigerian Beverage Company in Nigeria in 1982 on the Mambilla Plateau. Productions covered about 450 ha in Kakara village and environ (Obatolu and Ipinmoroti, 2001). Many farmers have since adopted the art of tea cultivation either on very small or medium-scaled plots ranging between 0.5 and 5.0 ha (Ipinmoroti, *et al.*, 2018). Expansion of tea cultivation has been becomes constrained by scarcity of suitable land due to competition with other enterprises on the Mambilla Plateau (Ipinmoroti and Adeoye,

2007). To stem this problem, the possibility of extending tea cultivation to other agro-ecologies of Nigeria especially the lowland areas was initiated through adaptive trials in 1996 (Esan, 1996; Obatolu and Ipinmoroti, 2001). Trial sites included Mayo-Selbe (North Eastern Nigeria), Ajassor and Akwete (South Eastern Nigeria); Uhonmora and Iyanomon (Southern Nigeria); Ikorodu and Ibadan (South Western Nigeria).

Though tea is the most important beverage crop globally, its cultivation is vulnerable to climate change (Wermer, *et al.*, 2017). Hence, its successful cultivation is highly dependent on agro climatic conditions which includes specific threshold of temperature, rainfall, humidity and solar radiation that influences tea leaf yields and quality (Wijeratne, 1996). Globally, in the past six decades, there has been unfavourable changes in average climate

conditions which involves global warming and increase in biannual variability of temperatures and precipitation (Swert, *et al*, 2005, IIPCC 2014), which had increased anthropogenic greenhouse gas emission that are recognized to influence agricultural systems, including tea production (Chang and Brattoff, 2015).

Shifts in rainfall and solar radiation have adversely influenced tea yields (Boehm *et al*, 2016). Irreparable tea yield losses could be recorded due to droughts, while heavy rains can cause water logging, cause extensive leaching of essential soil nutrients and could lead to eroding of top soil which eventually, affects tea quality indices, such as colour, aroma, visual appeal, taste and texture (Ahmed *et al*, 2014; Kawalsick *et al*, 2014). Tea quality is determined largely by nutrients, secondary metabolite and mineral profiles. The secondary metabolites are plant components that vary in concentration depending on genetic, environment and management inputs (Van Dan and Vrieling, 1994; Bjorkman *et al*, 2011; Ahmed *et al*, 2013).

Tea cultivation can be possible across the various agro-ecologies in Nigeria with more vigorous growth and dry matter yield in the lowland agro-ecologies with warm climatic conditions compared with the highland ecologies with cold climatic conditions (Ipinmoroti and Adeoye, 2007). However, the soil and tea flush (2-leaf + bud) nutrients content assessments to compare the quality of tea harvest across the various agro-ecologies have not been assessed. This is to help to know if there would be need to have different blends of tea from each agro-ecology or a mixture of the tea harvests from all the zones for a single tea blend in Nigeria. This study was conducted to assess tea leaves and soil samples across some selected tea plots in the various agro-ecologies in Nigeria for their nutritional quality and soil management needs.

MATERIALS AND METHODS

This study was conducted in six tea farm sites across the various agro-ecologies under which tea is presently cultivated in Nigeria (Fig. 1). There were three sites in the cold highland region at Kusuku, Kakara and Ngoroje on the Mambilla Plateau, while three sites were in the warm humid lowland regions at Mayo-selbe, Ajassor and Ibadan. In each location, the data on

temperature (Fig. 2) and rainfall (Fig. 3) were collected while, the tea plots were sectioned into three equal parts and soil samples from 0-30cm were collected at 10 points per section and mixed to form a composite sample per section for 3 composite samples per plot. Tea leaf was sampled by collecting the tea flush (2-leaf + bud) from four tea plants surrounding each soil sampling point. The harvested tea leaves per section of each tea plot were homogenized to form a composite tea sample for a total of three composite tea samples per plot. The soil samples were air dried and passed through 2mm sieve. The tea leaf samples were oven dried to constant weight at 70 °C for 72 hours milled for analysis.

The soil pH was measured electronically with glass electrode pH meter in soil/water ratio of 1:2.5 (Maclean, 1986). The soil organic carbon content was determined by wet dichromate oxidation method (Nelson and Sommers, 1982), while the total N was determined by the micro Kjeldahl digestion method (Bremmer, 1996). Available P was determined by Bray I method (Bray and Kurtz, 1945), while the exchangeable cations were actuated by leaching 5gm soil with 50ml of 1N NH₄OAC at pH=7 and the K, Na, Ca and Mg were measured by atomic spectrophotometer (AAS), (AOAC, 1990). Tea leaf samples were digested using nitric-perchloric-sulphuric acid mixture (AOAC, 1990). N content was determined by micro-Kjeldahl method and P by Vernadomolybdate colorimetry. The K was analyzed by flame photometer while the Ca, Mg and Zn were by AAS. Significant differences in the soil and tea leaf sample contents were determined by LSD at 5% probability.

RESULTS AND DISCUSSION

The average monthly temperature in the locations from 1984-2019 indicated that temperature was highest in the months of February and March with temperature ranging between 23.5-26.5 °C, while it was lowest in August and September with range of 20- 24.5 °C (Fig. 2). The highland areas on the Mambilla had the lowest temperature range throughout, while the lowland areas had higher temperature than the highland areas. Generally, temperature was highest at Ibadan and Ikom locations. The average annual rainfall differed with location (Fig. 3).

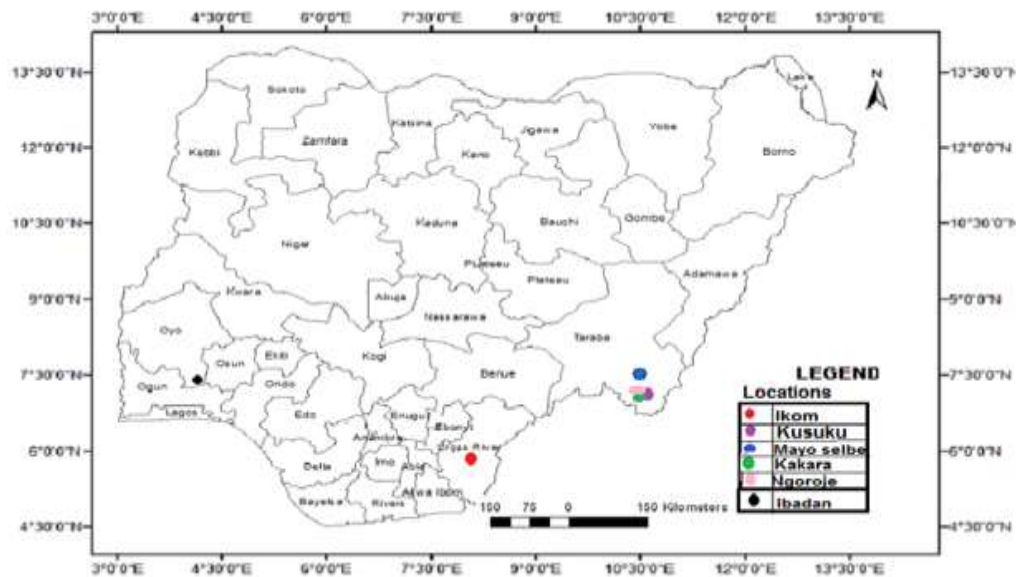


Fig. 1: Map of Nigeria showing the 6 locations where soil and tea samples were collected

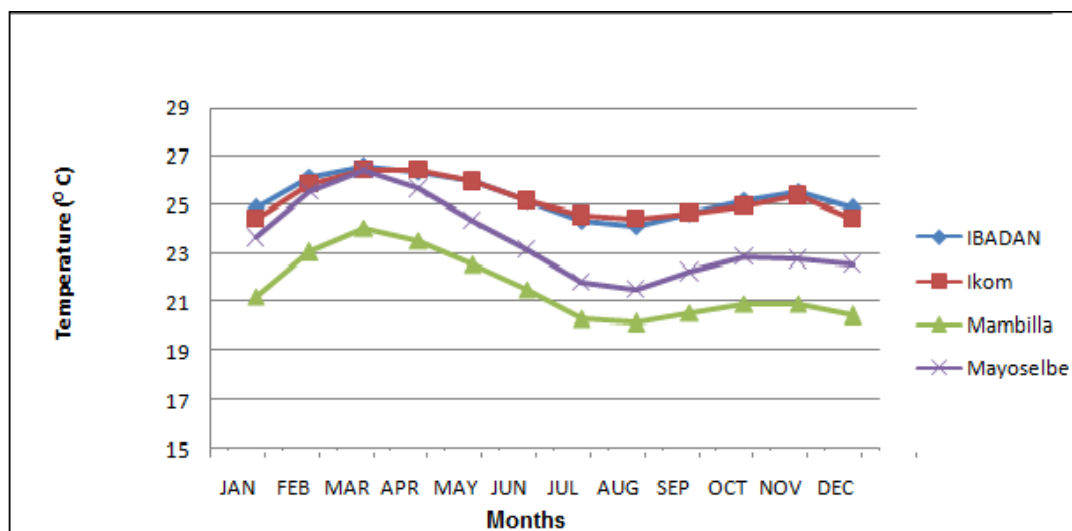


Fig. 2: Average Monthly Temperature Range in the Locations from 1984-2019.

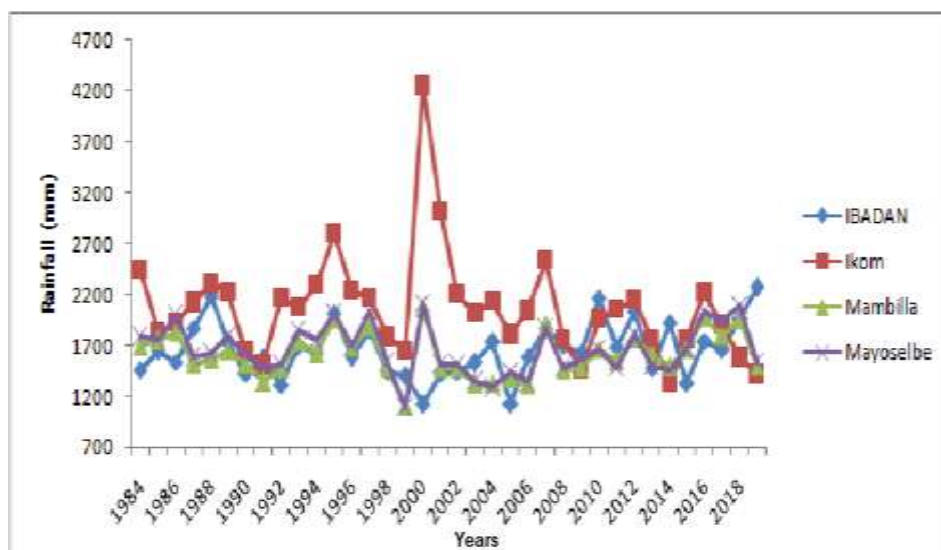


Fig. 3: Average Annual Rainfall in the Locations from 1984-2019.

The trend analysis indicated that rainfall in Ikom from 1984 to 2019 had a negative regression line equation of $Y = -12.37X + 229.8$. ($R^2 = 0.061$). The line of best fit suggests that rainfall gradually decreased over the last 35 years at the location. This may have negative effects on sustainable tea production in future and may require applying irrigation to sustain tea production in the most vulnerable months due to reduced rainfall. The other locations had strong positive line of best fits. At Ibadan trend was $Y = 5.767X + 1551$ and $R^2 = 0.048$. Mambilla was $Y = 1.165X + 1589$ ($R^2 = 0.003$) while Mayo-Selbe was $Y = 1.203X + 1680$ ($R^2 = 0.002$). The results of the coefficient of determination for Mambilla and Mayo-Selbe locations suggest a rainfall trend consistent with known trends (Swert, *et al*, 2005, IPCC, 2014). However, Ibadan indicated a slight increase in trend of rainfall. This slight increase noticed in Ibadan is not sufficient to dispense for tea production without irrigation during the long dry months in the region. Overall, the temperature of 19.8-27.3 ° C and rainfall of 800-4,300mm across the locations were within ranges suitable for tea cultivation

Soil pH varied across the tea growing agro-ecological zones in Nigeria (Table 1). The pH values were within the critical range of pH 4.50-6.50 for tea production (Ipinmoroti *et al*, 2007; Han, *et al.*, 2018). However, the Ikom soil pH required adjustments through the application of organic fertilizers that could serve as buffering materials to prevent the soils from being critically too acidic for tea production after long time of tea cultivation.

The soil organic carbon content ranged from 11.2 – 53.4 g kg⁻¹ soil, with Ibadan soil having the least value of 11.2g kg⁻¹ soil but highest at Kusuku with 53.4g kg⁻¹ soil (Table 1). Generally, the soil organic carbon levels were higher than the critical value of 30.0g kg⁻¹ soil in the cold highland area in Kusuku, Ngoroje and Kakara compared to the warm lowland area of Mayo-Selbe, Ikom and Ibadan where the values were lower than the critical level (Table 2) due to higher oxidation rate of organic materials in the warmer zones that results to lower accumulation of organic residues in the soils (Ashardiono and Cassin, 2014). To redress this the use of organic fertilizer is recommended in the Ikom, Mayo-Selbe and Ibadan locations (lowland areas).

Table 1: Soil particle size distribution of the locations

Location	Sand Silt Clay			Textural class
	←	(g.kg)	→	
Kusuku	500.00	160.00	340.00	Clay loam
Ngoroje	520.00	170.00	310.00	Clay loam
Kakara	516.00	164.00	320.00	Clay loam
Mayo-Selbe	610.00	170.00	220.00	Sandy clay loam
Ikom	570.20	222.80	174.80	Sandy clay loam
Ibadan	680.00	140.00	180.00	Sandy loam

The soil total N content ranged from 0.80-2.80 g kg⁻¹ soil across the various locations. The highland areas soil total N content was 2.30 – 2.80 g kg⁻¹ soil while it was 0.80-1.70 g kg⁻¹ soil for the lowland area. The highland areas thus, had much higher soil total N compared to the lowland areas. The trend followed similar pattern as obtained for the soil organic carbon contents. The highland areas had total soil N level that were higher than the critical level of 1.00g N kg⁻¹ soil (Table 2) while it was lower than the critical at Mayo-Selbe but marginally adequate at Ibadan. Since leaf is the main harvest of tea, there is need to have sustainable N supply to the soils as one of the major aspect of fertility management on the tea fields in the lowland areas especially, in the Mayo-Selbe and Ibadan axes. Nitrogen fertilizer supply forms about 50% of the input need of tea farms (Ipinmoroti *et al.*, 2007) hence, N supply through fertilizer application would be very important in the management of the tea farms for sustainable tea production in the lowland areas.

The soil available P value of 9.83-30.3 mg kg⁻¹ soil was above the critical level at all study sites except for Ngoroje. This suggests that climatic differences did not influence the level of the soil P content when compared with total soil N and soil organic C contents. However, more attention on the P nutrient management must be paid to the Ngoroje, Mayo-Selbe and Ibadan

areas due to their relatively lower soil available P levels when compared to the other locations. The soil exchangeable K content ranged from 0.20-0.43cmol kg⁻¹ soil. The value for Kakara area was lower than the soil critical level of 0.30cmol K kg⁻¹ soil and requires attention for fertilizer application.

The soil exchangeable Ca of 15.93–19.63cmol kg⁻¹ soil and Mg of 1.06-1.82cmol kg⁻¹ soil were higher than their respective critical levels of 5.00cmol kg⁻¹ soil for Ca and 0.08cmol kg soil for Mg respectively, indicating that these elements are in sufficient amounts for tea cultivation nonetheless, for long term cultivation, application of organic fertilizers either of plant or animal origin or a combination of both, would help to replenish the soil with the nutrients along with building the soil organic matter base, which was considered very low especially in the lowland areas. The organic fertilizers would help to replenish the soil Ca and Mg uptake by tea plants. Pruning materials have been adjudged to play this role in tea fields over the years (Babajide and Olla, 2014). The soil Na content range of 0.38 – 0.86cmol kg⁻¹ soil indicated that the amounts are not likely to pose a threat to tea cultivation. The Zn content was below values which could elicit toxicity in soil or impair food safety.

Table 2: Some soil chemical and nutrient contents across the six tea growing locations

Soil properties	Unit	← Kusuku	Ngoroje	Kakara	Mayo-Selbe	Ikom	Ibadan	LSD (5%)
		← Highland areas		→	← Lowland areas		→	
pH		5.20	5.17	5.10	5.40	4.80	6.50	0.11
OC	g/kg	53.4	52.1	39.9	13.5	25.8	11.2	4.70
N	g/kg	2.50	2.80	2.30	0.80	1.70	1.10	0.20
P	mg/kg	14.22	9.82	17.33	10.20	30.30	12.60	2.33
K	cmol/kg	0.35	0.43	0.20	0.43	0.40	0.37	0.03
Ca	„	18.51	19.63	17.61	17.78	15.93	16.20	1.21
Mg	„	1.79	1.34	1.06	1.82	1.52	1.61	0.24
Na	„	0.86	0.65	0.52	0.58	0.75	0.57	ns
Zn	mg/kg	3.53	2.79	2.53	3.38	4.45	3.02	ns

The tea leaf N, P and K composition differed significantly ($P \leq 0.05$) across the locations, but there were no significant differences in the Ca, Mg and Zn contents (Table 3). This suggests that at all trial locations soil content of Ca, Mg and Zn contents was sufficient and fertilizer regimes should focus more on N, P and K amendments. The N content was higher for Ikom, a warm lowland area and was followed by

value for Kusuku, a cold highland area. The Kakara, Ibadan and Ngoroje locations had similar N contents that did not differ significantly. The very low tea leaf N contents for the Mayo-Selbe location was a reflection of the very low soil N content of the area, which was below the soil critical level. This calls for conscientious attempt in the usage of N supplying fertilizers in the locality. The tea leaf P contents varied across the

locations with a range of 358.4 – 585.4mg kg⁻¹ soil. Tea leaves from Ngoroje on the highland area had the least amount of tea leaf P content. The low tea leaf P was a reflection of the low soil available P in the Ngoroje soils. It indicated the dare need for the usage of P supplying fertilizers at the Ngoroje location.

The tea leaf K contents ranged from 1.71–3.84cmol kg⁻¹ soil. The tea leaves for Kusuku had the highest K content followed by those of tea leaves for Ikom. The variation followed a similar trend as the P contents of the

leaf samples. The tea leaf Ca contents ranged from 3.44–4.16%, while the Mg content was 0.42–0.53%. The variation in the tea leaves for Ca and Mg contents were not significantly different ($P \leq 0.05$) across the various agro-ecological locations. This was in trend with the soil contents for Ca and Mg that were discussed earlier. The Zn content in the tea leaves ranged from 56.7 -67.5mg Kg⁻¹, the values were not high to cause man health hazard when the leaves are consumed.

Table 3: Soil nutrient critical levels for tea cultivation

Soil	OC	N	P	K	Ca	Mg
	— (g /kg) —		mg/kg		— (cmo/kg) —	
Value	30.0	1.00	10.0	0.30	9.50	0.85

Generally, ranking the tea leaves based on nutrient composition (Table 4) showed that there was not a clear line of divide between the tea leaves from the cold highland region and those from the warm lowland region. Teas from the lowland ranked favourably with those produced on the highland areas. This indicates that a special tea blend could be produced using tea leaves produced across the various agro-

ecological areas to get a unique tea blend in Nigeria. Expanding tea cultivation to those areas, will lead to more tea leaf production to meet the need of the various tea processing factories, rather than depending on continuous importation of tea leaves, with its attendant effects on the nation's foreign reserves.

Table 4: Tea leaf nutrient contents across tea growing agro-ecological areas of Nigeria

Nutrients	Kusuku	Ngoroje	Kakara	Mayo-Selbe	Ikom	Ibadan	LSD (5%)
	— Highland areas —		—	—	Lowland areas		
N (%)	1.59	1.23	1.38	0.46	1.65	1.31	0.25
P (mg/kg)	585.40	358.43	489.85	573.68	370.37	501.11	10.41
K (%)	3.84	2.56	2.13	1.71	3.24	2.25	0.64
Ca (%)	0.27	0.25	0.21	0.21	0.23	0.20	ns
Mg (%)	4.15	3.70	3.44	4.16	3.59	3/51	ns
Na (%)	0.53	0.47	0.45	0.51	0.48	0.42	ns
Zn (mg/kg)	56.67	63.68	67.54	63.35	61.63	57.22	ns

Table 5: Tea nutrient composition ranking table across agro-ecologies

Location	Tea leaf nutrient composition score						Total score	Ranked position
	N	P	K	Ca	Mg	Zn		
Kusuku	5	6	6	5	6	6	34	1 st
Ngoroje	1	1	4	4	3	2	15	5 th
Kakara	3	3	2	1	2	1	12	6 th
Mayo-Selbe	4	5	1	6	5	3	24	2 nd
Ikom	6	2	5	3	4	4	24	2 nd
Ibadan	5	4	3	2	1	5	17	4 th

CONCLUSION

Whereas the temperature and rainfall regimes in the localities generally suffice for tea production across the various agro-ecological areas, there

would be need for supplemental irrigation and mulching management practices during long dry spells, especially on juvenile tea plots. The soil management strategies should be location

specific. The variation in the tea quality across the locations could be turned to advantage by blending to produce a unique tea blend.

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