

## Variability analysis of some genotypes in Nigeria tea (*Camellia sinensis*) germplasm

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### Abstract

Thirty four tea clones were sourced from Cocoa Research Institute of Nigeria tea germplasm and raised through stem cuttings for 10 months in the nursery. The experiment was laid out in a randomized complete block design (RCBD) with 3 replications in 2016. Agronomic and yield data were collected and subjected to analysis of variance. Single linkage cluster analysis (SLCA), principal component analysis (PCA) and FATCLUS analysis were employed to analyse the data. ANOVA showed considerable significant variation  $p < 0.05$  among the 34 tea genotypes. The PCA showed that Plant Height (PH) 0.39, Number of Leaves (NL) 0.38, Number of Branches (NB) 0.37, Harvestable Points (HP) 0.31, Stem Diameter 0.39 and Leaf Breadth 0.30 accounted for most of the variations observed. Axes 1, 2 and 3 of the PCA accounted for 37.23%, 15.48% and 10.75% variability respectively with cumulative value of 63.47%. The genotypes were clustered into 7 groups by FASTCLUS Analysis. The dendrogram showed that the first cluster was observed between NGC29 and NGC 47 at 0.08 level of similarity. At 0.50 level of similarity the dendrogram revealed 5 distinct groups. Therefore, variation exists among the tea germplasm in Nigeria thereby suggests further presenting opportunities for further varietal development.

**Keywords:** Variability; Genotype; Tea; Germplasm and Analysis

### 1. Introduction

Tea (*Camellia sinensis*) was first cultivated in China over 2000 years ago and China remains the highest tea producer in the world [5]. It was introduced to Nigeria from Kenya in 1972 [10]. Tea is an ever green, perennial, and flowering plant belonging to the order of Thecales and family of Theaceae [21]. Commercial tea cultivars are recognized under three different taxons viz. *C. sinensis*, *C. Assamica* and *C. assamicasp. lasiocalyx*. Tea is a diploid ( $2n = 30$  chromosomes) but triploid and tetraploid have been reported or created [19]. It naturally grows as tall as 15 m, but is kept between 60 cm and 100 cm under cultivation for easy harvesting, with a life span of more than 100 years [12]. It is an important crop growing across the continents of the world and major source of revenue to countries like China, Kenya, Japan, Indonesia and Vietnam. It contributes up to 26% of the Kenya annual earning [15].

Tea germplasm is considered very important for further improvement and development of new tea varieties. In the past when farming activities were still at subsistence level, natural variability was explored but now that human population is increasing at a geometric progression, there is need to be more focused on how the growing population will be fed with fixed land resources. *Camellia sinensis* is of high economic importance to many developing countries of the world. The sustainability of the tea industries is important owing to the fact that tea production needs to be increased to meet up with the challenges of its demand susceptibility to pest or disease. Modern breeding strategies need to be adopted

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by the breeder to develop tea varieties that will combine high yielding, good cup quality and resistance to both biotic and abiotic factors to enhance its production [9].

Accurate assessment of genetic diversity of valuable crop species is a functional component of crop improvement programmes. It can also be of help for various purposes such as analysis of genetic variability of cultivars [22] and identification of diverse parental combinations to develop segregating progenies with maximum genetic variability for specific breeding purposes and further selection [6]. It is capable also for efficient germplasm management and prevention of duplicates.

The objective of the study was therefore to estimate the extent of genetic diversity and to group the 34 tea genotypes using agro-morphological characters.

## 2. Material and methods

Thirty four genotypes of tea (*Camellia sinensis*) were obtained from Cocoa Research Institute of Nigeria tea germplasm in Mambilla, Taraba State.

**Table 1** List of the tea accessions used in the experiment.

S/N	Genotype	Origin	S/N	Genotype	Origin	S/N	Genotype	Origin
1	NGC12	China	13	NGC32	China	25	NGC53	China
2	NGC13	China	14	NGC37	China	26	NGC54	China
3	NGC15	China	15	NGC38	China	27	NGC55	China
4	NGC17	China	16	NGC40	China	28	NGC6	China
5	NGC18	China	17	NGC41	China	29	NGC8	China
6	NGC22	China	18	NGC42	China	30	NGC19	China
7	NGC23	China	19	NGC46	China	31	NGC45	China
8	NGC24	China	20	NGC47	China	32	C143	Kenya
9	NGC25	China	21	NGC48	China	33	C318	Kenya
10	NGC26	China	22	NGC49	China	34	C357	Kenya
11	NGC27	China	23	NGC50	China			
12	NGC29	China	24	NGC51	China			

The experiment was carried out in Cocoa Research Institute of Nigeria Kusuku Mambilla sub-station, Taraba State. The plot was established in July, 2016 and Kusuku Mambilla is located on latitude 6o43' N and longitude 11o15' E. with the altitude of 1600 m above sea level. The type of rainfall in Mambilla is unimodal.

### 2.1. Land Preparation

The land area was cleared manually using hoe and cutlass.

Randomized Complete Block Design was used and experiment included three blocks, each containing 34 single-row plots, representing each of the tea genotypes.

Spacing of 0.6 m X 1.0 m within and between rows with plot size of 3.6 m<sup>2</sup>, making the total land area to be 489.6 m<sup>2</sup>.

The Weeding and other cultural maintenance practices were done as and when necessary.

## 2.2. Data collection

Data were collected on 9 plants per plot in 3 months interval for 2 years using meter rule, vernier caliper and electronic weighing balance.

## 2.3. Quantitative Characters Measured

Internodes length (cm), Length of mature leaf (cm), Width of mature leaf (cm), Plant height (cm), No of branches, Shoot weight (g), Stem diameter, Number of leaves, Number of flower buds.

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## 3. Results

### 3.1. Analysis of variance

Table 2 shows mean separation of the combined analysis of variance of 34 tea genotypes tested across 3 environments. The result showed that C143 was the tallest (96.62 cm) followed by NGC 25 (88.14) cm but not significantly different from each other. The least plant height was observed NGC 55 with average value of 34.26 cm and significantly different from 143 and NGC 25. NGC 38 recorded highest number of leaves 205 while the least number of leaves were observed for NGC 55 (43.18) and statistically different from each other. Number of branches and harvestable point were highest in C143 with value of 30.22 and 15.17 respectively while the least values for the two traits were observed in NGC55 with values of 6.29 and 2.40 respectively. Furthermore, C357 recorded highest stem diameter 16.83 mm and the least stem diameter was recorded for NGC 55 with average value of (9.28mm) and significantly different from each other. It was observed that NGC 53 recorded the longest internodes length (4.45) cm and is significantly different from NGC 48 with average of 2.73cm. The longest leaf length was observed in NGC 50 with average of 12.92cm followed by NGC 54 with value of 9.02 cm and statistically different from each other while the least was observed in NGC 55 (5.88cm). C357 has the largest leaf size (4.88cm) and is significantly different from NGC 38 with 2.79cm. Genotype with the highest number of flowers was C357 with average of 41.29 flowers while the genotype with the least flower was NGC 41 with 3.44 flowers. NGC 40 recorded the highest yield /plant with average value of 10.87g/plant while the least was recorded for NGC55 with average value of 0.9g/plant and significantly different from NGC40 above.

Table 3 described means among 34 tea genotypes for 3 proximate analyses viz protein, crude fibre and caffeine. The highest protein content observed was observed in NGC 38 (22.74%) The least protein content was recorded for NGC 8 value of 18.83%. The highest crude fibre content among 34 tea genotypes 10.16% recorded for NGC 40 while NGC 8 showed the least fibre content of 8.41% and significantly different from NGC40. Finally, 2.65% caffeine content was observed in NGC 40 which was the highest and significantly different from NGC 8 with the least value of 1.37%.

**Table 2** Mean performance of 34 tea genotypes evaluated for 10 agronomic characters in Mambilla

S/N	Genotypes	Plant Height	No. of Leaves	No. of Branches	Harvestable Point	Stem Diameter	Internodes Length	Leaf Length	Leaf Breadth	No. of Flower Bud	Yield/Plant(g)
1	C143	96.62 <sub>a</sub>	174.30 <sub>a-f</sub>	30.22 <sub>a</sub>	15.17 <sub>a</sub>	14.93 <sub>a-c</sub>	3.49 <sub>a-c</sub>	9.44 <sub>b</sub>	4.16 <sub>b</sub>	19.40 <sub>c</sub>	8.14 <sub>bc</sub>
2	NGC25	88.14 <sub>ab</sub>	203.62 <sub>a</sub>	22.09 <sub>b-d</sub>	7.79 <sub>e-i</sub>	15.66 <sub>ab</sub>	3.08 <sub>bc</sub>	8.79 <sub>b</sub>	3.93 <sub>bc</sub>	8.79 <sub>f-k</sub>	5.16 <sub>d-h</sub>
3	C357	87.04 <sub>a-c</sub>	183.88 <sub>a-d</sub>	21.06 <sub>b-e</sub>	11.47 <sub>bc</sub>	16.83 <sub>a</sub>	3.71 <sub>a-c</sub>	9.44 <sub>b</sub>	4.88 <sub>a</sub>	41.29 <sub>a</sub>	7.00 <sub>cd</sub>
4	NGC49	79.97 <sub>b-d</sub>	156.04 <sub>b-i</sub>	20.68 <sub>b-e</sub>	8.00 <sub>d-i</sub>	12.38 <sub>c-k</sub>	3.56 <sub>a-c</sub>	8.83 <sub>b</sub>	3.53 <sub>c-f</sub>	16.46 <sub>c-f</sub>	4.45 <sub>e-l</sub>
5	NGC19	77.34 <sub>b-e</sub>	206.15 <sub>a</sub>	24.12 <sub>b</sub>	11.50 <sub>bc</sub>	13.05 <sub>b-j</sub>	3.24 <sub>bc</sub>	8.89 <sub>b</sub>	3.33 <sub>d-g</sub>	18.24 <sub>cd</sub>	9.31 <sub>a-b</sub>
6	NGC18	75.82 <sub>c-f</sub>	168.48 <sub>a-g</sub>	23.50 <sub>bc</sub>	12.47 <sub>ab</sub>	12.69 <sub>c-j</sub>	3.39 <sub>bc</sub>	9.29 <sub>b</sub>	3.29 <sub>d-g</sub>	7.88 <sub>g-k</sub>	5.18 <sub>d-g</sub>
7	NGC27	75.40 <sub>c-g</sub>	141.95 <sub>e-j</sub>	17.91 <sub>c-h</sub>	7.67 <sub>e-i</sub>	14.12 <sub>b-g</sub>	3.86 <sub>ab</sub>	8.19 <sub>bc</sub>	3.28 <sub>d-h</sub>	14.33 <sub>c-h</sub>	2.69 <sub>j-o</sub>
8	NGC13	74.38 <sub>d-g</sub>	142.96 <sub>d-j</sub>	19.09 <sub>b-g</sub>	10.15 <sub>b-e</sub>	14.59 <sub>a-d</sub>	3.59 <sub>a-c</sub>	9.62 <sub>b</sub>	3.62 <sub>c-e</sub>	5.15 <sub>jk</sub>	3.89 <sub>f-m</sub>
9	NGC53	73.00 <sub>d-h</sub>	156.57 <sub>b-h</sub>	18.57 <sub>b-h</sub>	5.50 <sub>h-j</sub>	14.49 <sub>a-e</sub>	4.45 <sub>a</sub>	7.79 <sub>bc</sub>	3.37 <sub>d-g</sub>	11.57 <sub>d-j</sub>	3.30 <sub>g-n</sub>
10	NGC40	72.61 <sub>d-h</sub>	192.38 <sub>ab</sub>	20.08 <sub>b-f</sub>	11.21 <sub>b-d</sub>	14.33 <sub>a-f</sub>	3.05 <sub>bc</sub>	7.77 <sub>bc</sub>	3.34 <sub>d-g</sub>	6.20 <sub>i-k</sub>	10.87 <sub>a</sub>
11	NGC29	72.42 <sub>d-h</sub>	125.32 <sub>h-k</sub>	15.89 <sub>e-i</sub>	9.69 <sub>b-f</sub>	11.72 <sub>f-l</sub>	3.19 <sub>bc</sub>	8.92 <sub>b</sub>	3.25 <sub>d-h</sub>	6.19 <sub>i-k</sub>	3.18 <sub>g-n</sub>
12	NGC45	72.30 <sub>d-h</sub>	143.36 <sub>d-j</sub>	16.76 <sub>d-i</sub>	11.38 <sub>b-d</sub>	14.34 <sub>a-f</sub>	3.17 <sub>bc</sub>	8.29 <sub>bc</sub>	3.24 <sub>d-h</sub>	9.89 <sub>e-k</sub>	3.78 <sub>f-n</sub>
13	NGC26	71.73 <sub>d-i</sub>	136.45 <sub>f-k</sub>	11.91 <sub>i</sub>	6.00 <sub>g-j</sub>	13.45 <sub>b-i</sub>	3.22 <sub>bc</sub>	7.46 <sub>bc</sub>	3.19 <sub>e-h</sub>	7.33 <sub>g-k</sub>	2.93 <sub>i-n</sub>
14	NGC51	71.71 <sub>d-i</sub>	188.61 <sub>a-c</sub>	20.94 <sub>b-e</sub>	6.29 <sub>f-j</sub>	11.23 <sub>h-l</sub>	3.20 <sub>bc</sub>	8.35 <sub>bc</sub>	2.88 <sub>gh</sub>	7.76 <sub>g-k</sub>	2.01 <sub>m-o</sub>
15	NGC50	70.27 <sub>d-j</sub>	125.52 <sub>h-k</sub>	16.26 <sub>e-i</sub>	8.92 <sub>c-h</sub>	11.47 <sub>g-l</sub>	3.15 <sub>bc</sub>	12.92 <sub>a</sub>	3.36 <sub>d-g</sub>	11.00 <sub>d-k</sub>	3.10 <sub>h-n</sub>
16	NGC54	68.96 <sub>d-j</sub>	149.86 <sub>c-i</sub>	20.57 <sub>b-e</sub>	6.31 <sub>f-j</sub>	15.01 <sub>a-c</sub>	3.59 <sub>a-c</sub>	9.02 <sub>b</sub>	3.91 <sub>bc</sub>	6.83 <sub>h-k</sub>	4.03 <sub>f-m</sub>
17	NGC8	68.50 <sub>d-j</sub>	123.58 <sub>h-k</sub>	16.00 <sub>e-i</sub>	7.50 <sub>e-i</sub>	12.51 <sub>c-k</sub>	3.58 <sub>a-c</sub>	7.34 <sub>bc</sub>	3.00 <sub>g-h</sub>	5.75 <sub>i-k</sub>	1.77 <sub>no</sub>
18	NGC24	68.39 <sub>d-j</sub>	146.02 <sub>d-j</sub>	17.61 <sub>d-h</sub>	7.07 <sub>e-j</sub>	13.42 <sub>b-i</sub>	3.29 <sub>bc</sub>	8.42 <sub>bc</sub>	3.64 <sub>c-e</sub>	11.45 <sub>d-j</sub>	2.36 <sub>l-o</sub>

Means with the same letter along the column are not significantly different at 5% level of probability, using DMRT.

Plant Height (PH), Number of Leaf (NL), Number of Branches (NB), Harvestable Point (HP), Stem Diameter (SD), Internodes Length (IL), Leaf Length (LL), Leaf Breadth (LB), Number of Flower Bud (NFB) and Yield/plant

**Table 2** Mean performance of 34 tea genotypes evaluated for 10 agronomic characters in Mambilla continued....

S/N	Genotypes	Plant Height	No of Leaves	No of Branches	Harvestable Point	Stem Diameter	Internodes Length	Leaf Length	Leaf Breadth	No of Flower Bud	Yield/Plant(g)
19	C318	67.53 <sub>d-j</sub>	141.85 <sub>e-j</sub>	17.35 <sub>d-i</sub>	7.79 <sub>e-i</sub>	14.99 <sub>a-c</sub>	3.45 <sub>a-c</sub>	8.74 <sub>bc</sub>	3.97 <sub>bc</sub>	7.40 <sub>g-k</sub>	4.85 <sub>e-i</sub>
20	NGC12	66.51 <sub>e-j</sub>	113.85 <sub>i-k</sub>	14.81 <sub>f-i</sub>	3.95 <sub>jk</sub>	10.44 <sub>j-l</sub>	3.25 <sub>bc</sub>	8.06 <sub>bc</sub>	3.29 <sub>d-h</sub>	12.28 <sub>c-j</sub>	1.78 <sub>no</sub>
21	NGC42	66.48 <sub>e-j</sub>	113.76 <sub>i-k</sub>	15.96 <sub>e-i</sub>	9.53 <sub>b-f</sub>	12.37 <sub>c-k</sub>	3.42 <sub>bc</sub>	8.05 <sub>bc</sub>	3.59 <sub>c-e</sub>	13.44 <sub>c-i</sub>	5.54 <sub>d-f</sub>
22	NGC23	66.29 <sub>e-j</sub>	153.54 <sub>b-i</sub>	19.44 <sub>b-f</sub>	6.55 <sub>f-j</sub>	12.98 <sub>b-j</sub>	3.07 <sub>bc</sub>	8.10 <sub>bc</sub>	3.22 <sub>d-h</sub>	12.42 <sub>c-j</sub>	2.50 <sub>k-o</sub>
23	NGC37	63.98 <sub>f-k</sub>	181.54 <sub>a-e</sub>	21.28 <sub>b-e</sub>	9.47 <sub>b-g</sub>	12.17 <sub>d-k</sub>	3.16 <sub>bc</sub>	8.51 <sub>bc</sub>	3.18 <sub>e-h</sub>	30.90 <sub>b</sub>	4.63 <sub>e-j</sub>
24	NGC38	63.21 <sub>f-k</sub>	205.30 <sub>a</sub>	20.75 <sub>b-e</sub>	5.14 <sub>i-k</sub>	13.73 <sub>b-h</sub>	3.20 <sub>bc</sub>	7.88 <sub>bc</sub>	2.79 <sub>h</sub>	31.72 <sub>b</sub>	2.36 <sub>l-o</sub>
25	NGC15	62.73 <sub>f-l</sub>	138.48 <sub>f-k</sub>	16.96 <sub>d-i</sub>	6.88 <sub>e-j</sub>	12.97 <sub>b-j</sub>	3.12 <sub>bc</sub>	8.48 <sub>bc</sub>	3.27 <sub>d-h</sub>	5.78 <sub>i-k</sub>	3.04 <sub>i-n</sub>
26	NGC41	62.41 <sub>g-l</sub>	154.55 <sub>b-i</sub>	19.07 <sub>b-g</sub>	9.56 <sub>b-f</sub>	12.51 <sub>c-k</sub>	3.20 <sub>bc</sub>	8.82 <sub>b</sub>	3.73 <sub>b-d</sub>	3.44 <sub>k</sub>	6.12 <sub>de</sub>
27	NGC47	62.23 <sub>g-l</sub>	128.88 <sub>g-k</sub>	14.43 <sub>f-i</sub>	7.20 <sub>e-j</sub>	12.93 <sub>c-j</sub>	3.58 <sub>a-c</sub>	8.86 <sub>b</sub>	3.32 <sub>d-g</sub>	13.00 <sub>c-j</sub>	3.00 <sub>i-n</sub>
28	NGC32	60.46 <sub>h-l</sub>	146.84 <sub>d-j</sub>	20.80 <sub>b-e</sub>	12.58 <sub>ab</sub>	11.24 <sub>h-l</sub>	2.89 <sub>bc</sub>	7.75 <sub>bc</sub>	3.32 <sub>d-g</sub>	17.21 <sub>c-e</sub>	2.61 <sub>j-o</sub>
29	NGC6	59.00 <sub>i-m</sub>	106.09 <sub>jk</sub>	12.93 <sub>hi</sub>	8.39 <sub>c-i</sub>	9.87 <sub>kl</sub>	3.29 <sub>bc</sub>	7.34 <sub>bc</sub>	3.16 <sub>e-h</sub>	5.18 <sub>jk</sub>	4.36 <sub>e-l</sub>
30	NGC46	58.39 <sub>j-m</sub>	150.21 <sub>c-i</sub>	16.31 <sub>e-i</sub>	9.05 <sub>c-g</sub>	11.94 <sub>d-k</sub>	3.38 <sub>bc</sub>	7.86 <sub>bc</sub>	3.30 <sub>d-g</sub>	12.24 <sub>c-j</sub>	4.57 <sub>e-k</sub>
31	NGC22	52.51 <sub>k-m</sub>	105.43 <sub>jk</sub>	13.67 <sub>g-i</sub>	6.91 <sub>e-j</sub>	11.80 <sub>e-l</sub>	2.88 <sub>bc</sub>	7.91 <sub>bc</sub>	2.96 <sub>gh</sub>	9.85 <sub>e-k</sub>	2.24 <sub>m-o</sub>
32	NGC48	50.65 <sub>lm</sub>	134.56 <sub>f-k</sub>	17.33 <sub>d-i</sub>	8.70 <sub>c-h</sub>	13.17 <sub>b-j</sub>	2.73 <sub>c</sub>	8.72 <sub>bc</sub>	3.51 <sub>c-f</sub>	6.13 <sub>i-k</sub>	4.91 <sub>e-i</sub>
33	NGC17	47.80 <sub>m</sub>	97.48 <sub>k</sub>	15.58 <sub>e-i</sub>	6.65 <sub>e-j</sub>	10.84 <sub>i-l</sub>	2.91 <sub>bc</sub>	8.23 <sub>bc</sub>	3.06 <sub>f-h</sub>	14.71 <sub>c-g</sub>	3.23 <sub>g-n</sub>
34	NGC55	34.26 <sub>n</sub>	43.18 <sub>i</sub>	6.29 <sub>j</sub>	2.40 <sub>k</sub>	9.28 <sub>i</sub>	2.79 <sub>bc</sub>	5.88 <sub>c</sub>	3.18 <sub>e-h</sub>	9.10 <sub>f-k</sub>	0.90 <sub>o</sub>

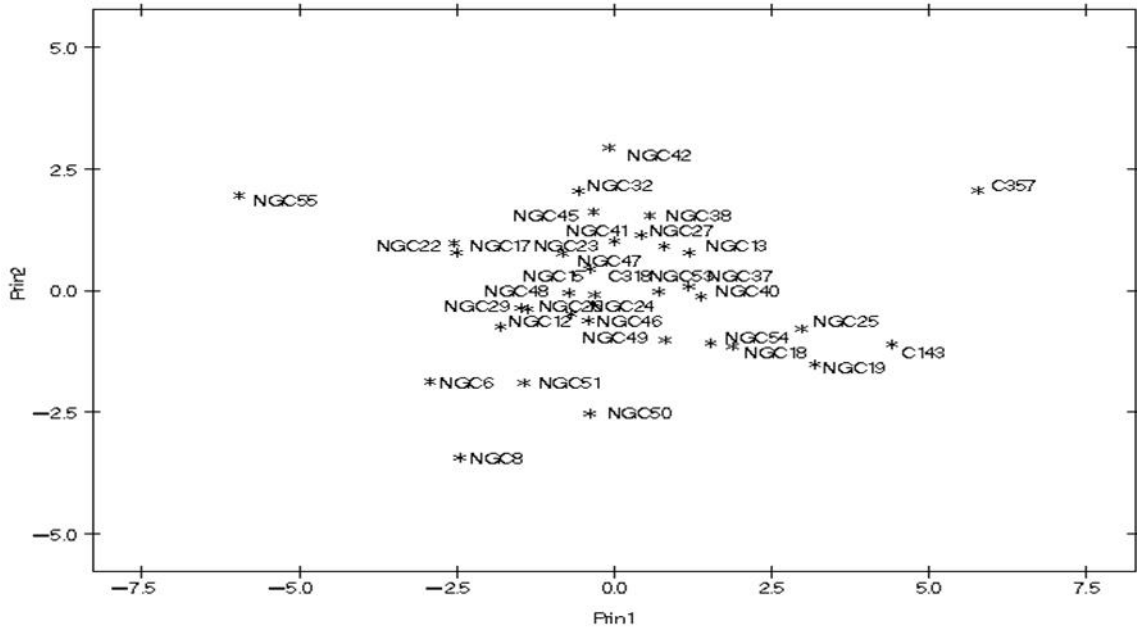
Means with the same letter along the column are not significantly different at 5% level of probability, using DMRT. Plant Height (PH), Number of Leaf (NL), Number of Branches (NB), Harvestable Point (HP), Stem Diameter (SD), Internodes Length (IL), Leaf Length (LL), Leaf Breadth (LB), Number of Flower Bud (NFB) and Yield/plant

**Table 3** Mean separation of protein, crude fibre and caffeine among 34 tea genotypes in 2 environments

S/N	Genotype	Protein	Crude Fibre	Caffeine
1	NGC38	22.74a	9.39h-j	2.34d-h
2	NGC 19	22.51ab	9.39h-j	2.29e-j
3	NGC 18	22.18bc	9.21j	2.53ab
4	C 143	22.15bc	9.67b-g	2.41b-e
5	NGC 17	22.13b-d	9.51d-i	2.39b-f
6	NGC 29	22.11b-d	9.45f-i	2.33d-h
7	C 357	22.08b-d	9.51d-i	2.39b-f
8	NGC 13	22.07b-d	9.70b-f	2.15jk
9	NGC 54	22.03b-e	9.29ij	2.26e-k
10	NGC 32	21.98b-e	9.70b-f	2.25e-k
11	NGC 26	21.98b-e	9.82bc	2.19h-k
12	NGC 46	21.95b-e	9.44g-j	2.09k
13	NGC 45	21.95b-e	9.59c-g	2.25e-k
14	NGC 27	21.83c-f	9.53d-i	2.23f-k
15	NGC 37	21.58c-g	9.73b-d	2.11k
16	NGC 41	21.53d-h	9.71b-e	2.17i-k
17	NGC 24	21.53d-h	9.29ij	2.25e-k
18	NGC 47	21.51d-h	9.62b-h	2.13jk
19	NGC 22	21.45e-i	9.81bc	2.21g-k
20	NGC 25	21.33f-j	9.61c-h	2.23f-k
21	NGC 53	21.28f-j	9.49d-i	2.51a-c
22	NGC 55	21.21g-j	9.66b-g	2.34c-h
23	C318	21.08g-k	9.86b	2.12k
24	NGC 6	21.01g-k	9.47e-i	2.15jk
25	NGC 12	21.00g-k	9.43g-j	2.15jk
26	NGC 15	20.95h-k	9.47e-i	2.46b-d
27	NGC 51	20.85i-k	9.39h-j	2.49b-d
28	NGC 48	20.80jk	9.32ij	2.37b-g
29	NGC 40	20.61k	10.16a	2.65a
30	NGC 49	20.55k	9.28ij	2.52ab
31	NGC 50	18.95l	8.55k	2.33d-i
32	NGC 8	18.83l	8.41k	1.37l
33	NGC23	20.55k	9.86b	2.47b-d
34	NGC42	21.11bd	9.81bc	2.14jk

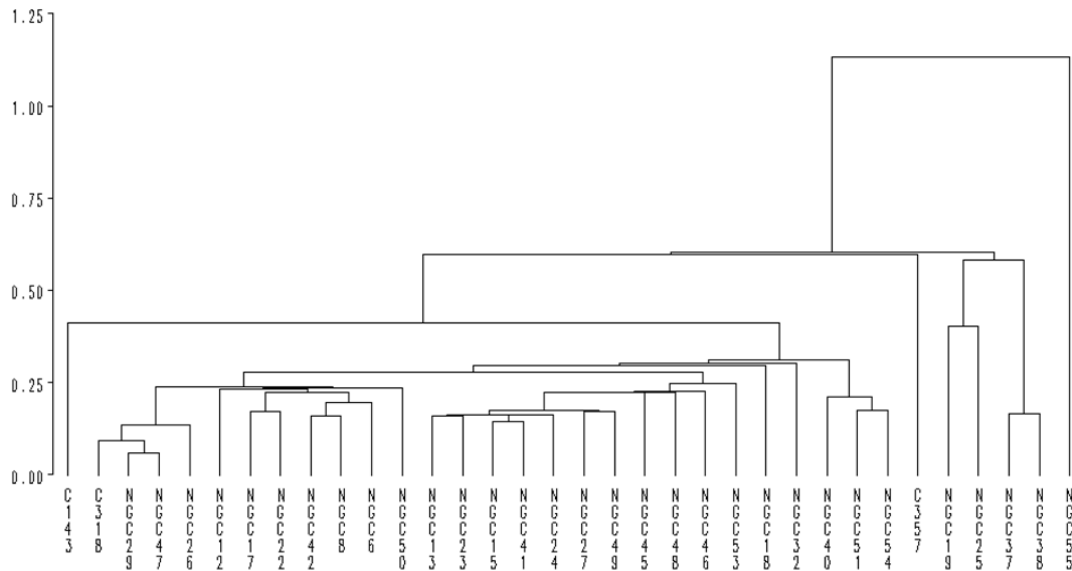
Note: Means with the same alphabet are not significantly different at 5% level of probability using DMRT.

The Principal Component Analysis (PCA) bi-plot shows the diversity existing among 34 tea genotypes is presented in figure 1, 2, and 3. The PCA 2 plotted against PCA1 (Figure 1). PCA 1 explained 37.23% of the total variation, while PC 2 accounted for 15.48% and both axes accounted for 52.72% of the diversity exists among the 34 tea genotypes. The bi-plot (Figure 1) showed that genotypes C357, NGC 55, NGC 8, NGC 42 and C143 were quite distinct from other tea genotypes that were clustered together at the centre of the bi-plot.



**Figure 1** PC1 And PC2 bi plot of variation existing among 34 tea genotypes

The dendrogram generated from single linkages cluster analysis (SLCA) using morphological characters is presented in Figure 2. The dendrogram illustrates the relationship among 34 tea genotypes. At a minimum 0.00 level of similarity, all genotypes were distinct from one another while at 1.25 level of similarity, all the genotypes had formed a single cluster. The dendrogram showed that the first cluster was observed between NGC29 and NGC 47 at 0.08 level of similarity. At 0.50 level of similarity the dendrogram revealed 5 distinct groups. Group I had highest number of genotypes (28), groups II and group V had only one member each C357 and NGC 55 respectively. Groups III and IV had two members each. Group III consist of NGC 19 NGC 25 and while group IV had NGC 37 and NGC 38.



**Figure 2** Dendrogram generated from Single Linkage Cluster Analysis (SLCA) on yield of 34 tea genotypes

Table 4 shows the results of principal component analysis of 34 tea genotypes tried. Only three of the 10 principal components had eigen values greater than 1 and the first 5 axes accounted for 37.23%, 15.48%, 10.75%, 0.09% and 0.07% of the total variation individually and 79.41% altogether. The first principal component was loaded largely by Plant height (PH) 0.39, stem diameter (SD) 0.39, Number of leaves (NL) 0.38, Number of branches (NB) 0.37, Harvestable point (HP) 0.31, and leaf breadth (LB) 0.30. Axis 2 was loaded with protein 0.45, crude fibre 0.57 and caffeine 0.45. However, axis 3 was largely loaded with harvestable point (HP), Internodes length (IL) and yield/plant with value of -0.44, 0.61 and -0.46 respectively. The relative discriminating power of the principal axes as indicated by eigen values was 4.84 for axis one and 0.69 for axis five.

**Table 4** Principal component analysis showing the contribution (factor scores), eigen values and percentage total variance accounted for by the first five principal component axes of each character of the 34 tea genotypes in 3 environments.

Character	Pc1	Pc2	Pc3	Pc4	Pc5
PH	0.39	-0.22	0.15	0.01	-0.07
NL	0.38	-0.15	-0.10	-0.28	0.17
NB	0.37	-0.16	-0.06	-0.21	0.09
HP	0.31	0.08	-0.44	0.17	0.02
SD	0.39	0.08	0.15	-0.23	-0.18
IL	0.15	-0.14	0.61	0.60	-0.26
LL	0.21	-0.19	0.19	0.36	0.29
LB	0.30	0.17	0.14	-0.17	-0.38
NFB	0.22	0.17	-0.05	-0.05	0.58
Yield/Plt	0.28	-0.09	-0.46	-0.05	-0.28
Protein	0.07	0.49	0.08	-0.45	0.04
Crude Fibre	0.06	0.57	-0.11	0.19	-0.22
Caffeine	0.14	0.45	0.25	0.18	0.28
Eigen value	4.84	2.01	1.40	0.94	0.69
% Variance	37.23	15.48	10.75	0.09	0.07
Cumulative	37.23	52.72	63.47	72.17	79.41

Plant Height (PH), Number of Leaf (NL), Number of Branches (NB), Stem Diameter (SD), harvestable points (HP), Internodes Length (IL), Leaf Length (LL), Leaf Breadth (LB), Number of Flower Bud (NFB) and Yield/plt.

Major characteristic pattern of tea genotypes by FASTCLUS technique is presented in Table 5. The 34 genotypes were partitioned into seven distinct groups by the FASTCLUS technique. Group I had only one genotype while group III and VII have three genotypes each. Group II had six genotypes while group VI and IV had the highest number of genotypes, ten and nine genotypes respectively. Group V contained only two genotypes. Group V with genotypes NGC 19 and NGC 25 were characterized by high plant height, number of leaves, number of branches, harvestable point as well as high yield. The highest caffeine and protein were observed in group III with genotypes NGC 38, C357 and NGC37.



**Table 5** Characteristic pattern of seven groups of tea genotypes by FASTCLUS techniques

	<b>Group I</b>	<b>Group II</b>	<b>Group III</b>	<b>Group IV</b>	<b>Group V</b>	<b>Group VI</b>	<b>Group VII</b>
	NGC55	NGC40, NGC51, NGC53, NGC54, C143, NGC18	NGC 38, C357, NGC37	NGC12, NGC26, NGC29, NGC32, NGC8, NGC42, NGC47, NGC50, C318	NGC19, NGC25	NGC13, NGC 15, NGC23, NGC24, NGC27, NGC41, NGC45, NGC46, NGC48, NGC49	NGC22, NGC6, NGC17
Plant height (cm)	30.30	81.59 (12.29)	76.68 (17.84)	64.79 (5.57)	91.44 (9.25)	71.50 (10.42)	52.89 (7.13)
Number of leaves	35.78	202.57 (8.78)	219.55 (9.62)	132.80 (8.17)	252.60 (1.15)	167.30 (9.73)	107.39 (6.84)
Number of branches	6.39	29.26 (5.74)	25.11 (1.75)	18.57 (3.14)	30.27 (1.75)	21.90 (1.93)	15.60 (1.89)
Harvestable points	2.50	10.28 (4.27)	11.57 (4.94)	9.15 (3.06)	12.60 (5.28)	9.60 (1.74)	7.89 (0.12)
Stem Diameter	9.71	13.54 (1.53)	14.22 (2.38)	11.94 (0.94)	14.36 (1.85)	12.84 (0.57)	10.88 (0.01)
Internodes length	2.86	3.54 (0.42)	3.38 (0.28)	3.34 (0.29)	3.15 (0.16)	3.39 (0.34)	3.09 (0.36)
Leaf length	5.35	8.78 (0.99)	9.21 (1.23)	8.17 (2.21)	9.20 (0.10)	8.78 (0.74)	8.34 (0.59)
Leaf Breadth	3.26	3.42 (0.47)	3.77 (1.33)	3.42 (0.29)	3.86 (0.46)	3.57 (0.22)	3.18 (0.05)
No of flower buds	2.06	8.95 (4.14)	45.78 (2.94)	9.93 (6.49)	15.14 (8.80)	9.39 (4.09)	6.42 (2.16)
Yield	0.97	5.40 (2.99)	4.79 (1.56)	3.26 (1.26)	8.19 (3.49)	3.79 (1.42)	3.34 (1.37)
Protein	20.85	20.71 (0.63)	21.21 (0.55)	20.59 (1.15)	20.52 (0.07)	20.68 (0.65)	20.57 (0.77)
Crude fibre	9.34	8.89 (0.41)	9.34 (0.29)	9.80 (0.48)	8.95 (0.25)	9.35 (0.41)	8.90 (0.31)
Caffeine	2.16	2.22 (0.22)	2.40 (0.47)	2.10 (0.37)	2.05 (0.02)	2.24 (0.24)	2.11 (0.43)

Note: Standard deviation in Parenthesis

#### 4. Discussion

The success of any breeding programme depends upon the variations in the genetic resource. The greater the genetic variability, the better is the chances for success to be achieved through selection. The significant variations among the 34 tea genotypes with respects to the 22 traits that were measured indicated the wealth of genetic diversity present within the genotypes and also gave a high prospect in varietal improvement of tea. Earlier studies on tea showed the presence of wide range of diversity in both quantitative and qualitative traits [13] and [16].

The significant mean squares obtained from the analysis of variance for the genotypes indicated that at least two genotypes were different, resulting to the possibility of selection. Earlier studies on tea genetic classification using agromorphological traits such as leaf length, leaf breadth, flower bud and yield parameter had been reported to be a great importance in distinguishing genotypes in tea [7]. However, the exploitation of these plant traits in the breeding programme of tea species will be enhanced by understanding the extent of variability existing for these traits and genetic components that governed the expression. The result of the principal component analysis confirms these patterns of character – co variation among the genotypes studied. It also identified the characters that contributed most to the variation within a group of entries [17]. The biological meaning of the principal component can be accessed from the contribution of the different variables to each principal component according to the eigen vectors [14]. The result of the principal component analysis revealed that different characters contributed differently to the total variation as indicated by their eigen vectors as well as their weight and loading on different principal axes.

The identification of principal component analysis (PCA) of plant height, number of leaves, number of branches, harvestable point, stem diameter and yield/plant as major components of variation among the tea genotypes indicated the reliability in the use of these characters in distinguishing among tea genotypes.

The observations are in line with those of [20] who stated that character coefficient greater than 0.3, irrespective of the arithmetic sign of the coefficient, be treated as having a large effect to be considered important in classifying the genotypes. The first four principal axes accounted for 72.17% of the total variation among the thirteen quantitative characters describing the genotypes. This confirmed the report of [4] who reported that the first three Principal components were the most important in reflecting the variation on patterns among genotypes and the characters highly associated with these should be used in differentiating genotypes along the principal component axis and the proportion of the total variation contributed by each of the different variables [23]

The FASTCLUS technique was used to sort the genotypes into seven groups with unique information about morphological characteristic were identified. The two genotypes in group V NGC19 and NGC25 can be described as high yielding genotypes while NGC55 only genotype in group I can be associated with low flowering and low yielding genotypes.

The wide range of similarity coefficient observed from the dendrogram generated by single linkage cluster analysis (SLCA) revealed high variability among the tea genotypes [2] reported that cluster analysis as a tool had singular efficacy and ability to identify crop accessions with high similarity using dendrogram.

Caffeine, protein and crude fiber are major constituents in tea. The activities of caffeine and when consumed by humans draws more attention to its degree of accumulation in different tea genotypes. This substance is naturally occurring in tea leaves and many crops such as coffee, kola e.t.c. [24]

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#### 5. Conclusion

The current study has shown that characterization of genetic materials provide a way of evaluating germplasm in order to identify genotypes that could be further evaluated and utilized at genetic level. 34 tea genotypes were studied using thirteen agro morphological traits

The result showed that variability exists among the genotypes considered in this study as indicated by analysis of variance, PCA and Dendogram.

This study has revealed greater variability among the 34 genotypes an indication for tea genetic improvement in Nigeria. It also manifested some quality traits in terms of crude fibre, protein and caffeine content which can also be incorporated into tea improvement programme to suit the preference of consumers in Nigeria and beyond.

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## Compliance with ethical standards

### *Disclosure of conflict of interest*

All authors declare that no conflict of interest is exist.

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