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# *Agroforestry Trees' Architecture As Evidence Of Domestication: Case Of African Mango Tree In The Dahomey Gap, West Africa*

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**Abstract – In tropical Africa, domestication mostly happens across to traditional agroforestry systems, in which natural variations of plants species are constantly manipulated to induce new and more socioeconomically profitable other ones. Irvingia gabonensis (Irvingiaceae) is one of the most valuable sub-Saharan bioresources that widely grow across West and Central Africa. This research evaluates how different sociocultural groups, in the Dahomey Gap (the climatic and vegetation discontinuity inside the Guinean forest continuum), reshape I. gabonensis trees' architecture in order to adapt this species to their agroforestry needs. Thus, a total of 180 I. gabonensis trees were collected across the Adja, Nago, Fon, and Ewé sociocultural areas and characterized with eight main trees' architectural factors: number of branches developed, number of sub trees per individual Irvingia tees, level of first large branches insertion on the trunk, crown diameter, leaf width and length, trees' total height, and crown shape. A Principal Component Analysis was used to classify individual trees and the phylogenetic relationship among them was evaluated by the mean of a Neighbor Joining tree analysis. Trees from the Adja sociocultural group presented the significantly largest crown diameter, the greatest number of branches, the higher number of subtrees the narrower leaves, and the lowest branching pattern.However, local communities did not significantly impact leaf length and trees' totalheight. Moreover, semicircular crown shape dominated in the Adja sociocultural area, while the broadly pyramidal and pyramidal ones were more represented across other sociocultural areas. These results are indicators of the advance traditional domestication programme led by the Adja community since decades, as the only opportunity to develop profitable productive systems across the exhausted lands this community populate. Irvingia gabonensis population in this area represent an important gene bank, valuable for intensive cultivation in West and Central Africa.**

**Keywords – Dahomey Gap, Ivingia species, Traditional domestication, Trees' architecture.**

## I. INTRODUCTION

Domestication demonstrates the ancient and complex evolutionary and transformation interrelationship between human and nature (Schaal, 2019). Thus, plant domestication is a key human multipurpose enterprise, since it contributes to biodiversity creation plus conservation, environmental variability and stability, food and nutritional security, etc. (Chaudhary, 2013; N'Danikou and Tchokponhoue, 2019). In tropical Africa, domestication mostly happens across to traditional agroforestry systems, in which natural variations of plants species are constantly manipulated to induce new and more socioeconomically profitable other ones (Ofori et al., 2014; Leakey et al., 2014). This permanent modification of natural variations engages traditional agroforestry systems in such an evolutionary process, on which depend the resilience and diversity of todays and future productive systems, communities' livelihoods, and African significant new businesses (Leakey & van Damm, 2014; Ofori et al., 2014).

In 1996, the World Agroforestry Centre started actively supporting traditional agroforestry through the acceleration and the scaling up endogenous achievements in the domestication of priority fruit trees species. Thus, transformation of the landscape, in order to adapt to climate change reversing environmental and soil degradation and rapid biodiversity lost, enhances local residents' resilience and adaptability, and livelihood (Atangana et al., 2014; Leakey and van Damm, 2014). Moreover, in West and Central Africa, priority agroforestry trees' domestication is market – led practices by small-scale farmers (Beedy et al., 2014; Vihotogbé et al., 2014; Leakey et al., 2022).Thus, impacts of domestication are often evaluated through the quantification of the yield, that is the variations in marketable traits (Jamnadass et al., 2019).

*Irvingia gabonensis* (Irvingiaceae), also called African mango tree, is one of the most valuable sub-Saharan bioresources that grows on deep and well drained soils, mostly in coastal areas of West and Central Africa (Vihotogbé et al., 2019). The kernel of *I. gabonensis* is a prized condiment and economically valuable non timber forest product for Blacks Africans in West and Central African (Iponga et al., 2018). Moreover, the fruit pulp tastes sweet and is widely consumed across African countries. The botanical materials (leaves, fruits, bark, leaves, and roots) of *I. gabonensis* are important sources of various biochemical and bioactive components, valuable inhuman healthcare system (Matsinkou et al., 2012; Etebu et al., 2013). These potential benefits provided by *I. gabonensis* are the causes for its priority status in domestication programmes across West and Central Africa.

Variations in yields, fruits size and fruit quality, kernels size and quality, fruit and kernel food properties remain the most investigated characters in assessing the domestication impacts on *I. gabonensis* (Atangana et al., 2002; Anegbeh et al., 2003; Leakey et al., 2005; Vihotogbé et al., 2013). However, changes in tropical tree architecture, under domestication, are indicative of better tree management and economically profitable human–induced variations: yield improvement and easy exploitation, etc. (Doust, 2007; Teichmann & Muhr, 2015).

In this study, we provide additional insight to the full understanding of traditional domestication impact by evaluating how different sociocultural groups, in the DG, reshape *I. gabonensis* trees' architecture in order to adapt this species to their agroforestry needs.

## II. Materials And Methods

### 2.1. Study area and sampling

This study was conducted in the Dahomey Gap (DG), which describes the climatic discontinuity inside the Guinean forest continuum. This mosaic of small-scale forests – savannas, plus various agroforestry systems, as a result both natural and anthropogenic factors, is characterized by lower rainfalls and higher temperatures, compared to the higher and lower Guinean forest zones (Demenou et al., 2016). In this wide ecological area from Accra in Ghana, across the south of Benin and Togo up to Badagry in Nigeria, mostly planted individuals of *I. gabonensis* occurs across agroforestry systems and afforested lands (Vihotogbé et al., 2020). In the DG, Vihotogbé et al. (2013) demonstrated that *I. gabonensis* is under different levels of domestication across the different sociocultural areas. Thus, totally heathy trees, that have never been pruned or physically threatened by any factor like fire, agricultural practices, etc., were sampled across different sociocultural areas. In Benin, trees were sampled across twelve regions in within three main sociocultural areas, where *I. gabonensis* is cultivated: Klouékanmey, Lalo, Toviklin, and Aplahoué, in Couffo (Adja area), Adja-Ouèrè – Pobè and Sakété in Plateau (Nago area), Allada, Abomey, Bohicon (Fon area). In Togo, trees were sampled across Lomé (Ewé area).Because the species mostly occurs in cultivation across the entire the DG, totally random sampling technique was used for individual trees' sampling. The most intensive sampling in the Adja sociocultural area was due to the intensive cultivation, and therefore, the high density of *I. gabonensis* in that area. Moreover, because of climatic variability, the bimodal fruiting pattern and the pick fruiting time recognized in June - July, were not observed in all socio-cultural areas. Thus 15 to 25 totally healthy and mature *I. gabonensis* trees, that have fruited at least the consecutive past three years, were sampled and georeferenced, using a Global Positioning System, GPS, Garmin 60 (Fig. 1).

### 2.2. Data collection

For each sampled tree, primary tree morphological descriptors, which are the total height and the level of the first large branch insertion on the trunk and above the soil (Fofana et al., 2014) were measured, using the Clinometer (Suunto PM-5 clinometer), and the measuring tape, respectively. Moreover, leaf length and width, the number of trunks developed below 130 cm height (sub-trees), the crown diameter and the total number of branches by individual trees were recorded. Thus, twelve leaves (three from each of the four directions: North, South, East and West) were randomly collected and the leaf length and width were measured, using the Neiko 01407A electronic digital caliper - 0-6 Inches. The ends of the widest width of the crown of each individual tree were projected on the soil. The distance separating these two ends was measured, using the Stanley 0-34-134 Ruban meter Inox 30 M. Then, we turned 90° from that position and repeated the measurement. The mean of these two values gave the crown diameter of any individual tree.

Moreover, a combination of crown shapes identified for *I. gabonensis* (Ladipo, 1996) and *Vitellaria paradoxa* (IPGRI and INIA, 2005) was used to identify individual tree's crow shape in the DG. The identified crown shapes were coded as follow: 1 = pyramidal, 2 = broadly pyramidal, 3 = spherical, 4 = oblong, 5 = semicircular, and 6 = elliptical.

### 2.3. Data analysis

First, in order to assess how the traditional domestication shapes *I. gabonensis* trees' morphology across the different sociocultural areas in the DG, we used the PAST software (Hammer et al., 2001) to perform a Principal Component Analysis on the total height, the level of the first large branch insertion on the trunk and above the soil, leaf length and width, number of trunks developed from below 130 cm height (subtrees), the crown diameter, and the total number of branches.

Second, the significance of the trees' morphological factors that determined the structure obtained from the PCA, was calculated. Thus, a multivariate analysis of variance (MANOVA) was performed on the total height, level of the first large branch insertion on the trunk above the soil, leaf length and width, number of subtrees of each individual tree, crown diameter, and total number of branches against sociocultural areas, using Past software. A Mann-Whitney pairwise mean comparison test was performed in addition to the MANOVA, in order to cluster sociocultural areas, based on the significance of differences between them, regarding each impacting architectural factor.

Third, Differences in crown shape was analyzed, using descriptive statistics.

Plant species phylogenetics might be efficiently studied using only morphological data (Mohannad & Saghir, 2010). To promote visibility, relationship between sampled *Irvingia* trees was assessed, using Neighbor Joining tree analysis, based on morphological distances among individual trees.

## III. Results

### 3.1. Irvingia trees' architecture across sociocultural areas in the DG

The first three components in the PCA account for 78.95% of the total variation in the morphological dataset. The first two components indicated two main groups among *Irvingia* trees, based on their morphological features in the DG. Table 1 shows the crown diameter, number of branches, and leaf length as determine the first component (20.64). Thus, trees from the Adja sociocultural group presented the largest crown diameter, the greatest number of branches, the shortest leaves, and the lowest branching pattern (Fig. 2a: G1 and Fig. 3.a, b, c.). Trees from the other areas presented opposite characters (Fig. 2a: G2 and Fig. 3.a, b, c.). The second component (20.64%) is indicative of *Irvingia* trees' leaf width. In opposition to any other individual tree from all areas, individuals from the Adja sociocultural area (Toviklin, Klouékanmey, Lalo and Aplahoué, in the Couffo) developed the wider leaves. The third component (17.4%) of the PCA determining the number of subtrees per tree, indicates two groups of *I. gabonensis* trees (Fig. 2b). Thus, more trees from the Adja area (Couffo) developed the greatest number of subtrees per tree (Fig. 2b: G4) than across any other sociocultural area (Fig. 2b: G3). Finally, only total trees' height has no significant contribution the structure observed for the PCA.

Results of the MANOVA, performed on the trees' architectural factors against sociocultural areas, indicated the significance of the six PCA – based group leading factors: the number of branches developed, the number of sub trees per individual *Irvingia* tees, the level of first large branches insertion on the trunk, the crown diameter, and the leaf width and length. Thus, trees from the Couffo area had significantly the greater number of branches (mean = 18±1.3 - 25±1.4) than those from other sociocultural areas (8±1.5 - 11±0.3) ($p<0.05$). Thus, the numbers of branches per *Irvingia* tree, in the Couffo areas (Toviklin, Klouékanmey, Lalo, and Aplahoué) are about two folds greater than those on other areas (Fig. 4A). Similar pattern was observed for the number of subtrees per trees (Fig. 4B: $p<0.05$). Low branching pattern *Irvingia* trees were common in the Couffo sociocultural area. Thus, in average, large branches were developed at 0.7±1.3 – 1.7±0.4 m above the soil on the trunk in the

Couffo area, while this level was comprised between 2.6±1.2 – 3.6±02 m in the other areas (Fig. 4C: $p<0.05$).Except in Lalo, the average crown diameter of *Irvingia* trees is generally greater than that observed in any other sociocultural area (Fig. 4D; $p<0.05$). Thus, in Toviklin, Klouékanmey, and Aplahoué, the average diameter value is 13.8±0.6 –10.3±0.6 Cm, with a maximum that reached 20 Cm, against around 13 Cm in other areas (Fig. 3D). Moreover, leaves of *Irvingia* trees in the Couffo areas are narrower and shorter than those in other areas investigated (Fig. 3E-F). However, leaf width was not demonstrated to be significant ($p>0.06$), while leaf length was ($p<0.05$). Lastly, trees' total presented no significant differences between sociocultural groups ($p>0.05$).

The Neighbor Joining analysis (Fig. 5), based on the trees' morphological features, presented *I. gabonensis* trees from other sociocultural areas (Nago/Plateau, Fon/Abomey, and Ewe/Lomé), as semi-wild parents of those from the Adja sociocultural area (Toviklin, Klouékanmey, Lalo, and Aplahoué). However, there was no differentiation among individuals in these two groups. Lastly, few individuals from each group fall in the other one (*OP* individuals originally from the Nago area classified in the Adja group and *K* individuals originally collected from the Adja area, but grouped with non-Adja sociocultural area trees).

### 3.2. Variation in Irvingia trees' crown shape

Six types of crown shape were observed withing *Irvingia gabonensis* trees in the DG: semi-circular, circular, elliptic, oblong, pyramidal and broadly pyramidal shapes. The Couffo (Adja sociocultural area: Toviklin, Klouékanmey, Lalo, Aplahoué) is mostly populated by trees with semicircular crown shape (≥ 50%: Fig. 6). In this sociocultural area, this crown shape was followed by the broadly pyramidal one, which was dominant in the Nago and Fon sociocultural areas (Plateau and Abomey, respectively). The pyramidal crown shape was dominant in the Ewe area (30%), and also present in low frequencies across other areas (Fig. 6).

## IV. Discussion

Traditional domestication shapes African mango trees in the Dahomey gap

Significant differences are calculated between sociocultural groups, for most of the *I. gabonensis* trees characteristics investigated in this study: number of branches developed, number of sub trees per individual *Irvingia* tees, level of first large branches insertion on the trunk, crown diameter, leaf width and length, and crown shape. Thus, in the DG, these morphological changes consistently distinguish the Couffo (Adja sociocultural group), where *I. gabonensis* trees is found at advanced domestication systems and level, based on fruit morphological evaluation (Vihotogbé et al., 2013; Padonou et al., 2017).Indeed, natural variations of *I. gabonensis* tees include a subset of the diversity revealed in this study (Ladipo, 1996; Tsobang et al., 2021). However, the new variations induced by locals and the combination on the profitable levels of these natural as well as human-induced variationsfor each morphological factors, distinguish the Adja sociocultural area. This is indicative of traditional domestication and selection ongoing programme, and defines *I. gabonensis* individuals from the Adja sociocultural area as a recognizable variety or ideotype to be promoted for economically profitable agrosystems establishment (Chaudhary, 2013). As an ecological adaptative feature, changes trees' branching pattern plus number of branches define their efficiency in water use, photosynthesis ability and yield (Pickett and Kempf, 1980; Ratikanta et al., 2014). It is well known that domestication induces deep changes in trees' morphology for the ultimate goal of yield improvement (Lema et al., 2019; Luo et al., 2022). It is likely that the characteristics of *I. gabonensis* trees in the Adja sociocultural area are those that guarantee the highest yield in the DG, as revealed by the established correlation between fruits, flesh, seed, and kernel analyses and this study. Any plant species pays a physiological price, when going through domestication and for human-induced variation gaining, like yield increasing (Luo et al., 2022). Thus, domestication of *I. gabonensis* in the Couffo generates higher yields, with multimodal fruiting pattern (Vihotogbé et al., 2013).

However, it is likely that biosynthesis for resistance against mango flies attack on the fruits flesh significantly decreases. Therefore, fruits infestation became, so long ago, the major constraint for *I. gabonensis* cultivation for the flesh commercialization (Codjia et al., 2008).

The Neighbor joining tree presented the Couffo trees as progenies of those from other areas. In the DG, the Couffo *I. gabonensis* population are the earlier fruiting one (3 years after plantation by seed), while the first fruiting time exceed 8 years after plantation. Thus, the traditional domestication programme in the Adja area is very recent, so that there is not yet significant dissemination of materials from the new gene bankacross the other part of the DG. Moreover, Codjia et al. (2008) reported that the Nago communities were also recognized for starting traditional domestication of *I. gabonensis* trees, mostly for fruit flesh commercialization, in contrast to the Adja people whose marketing goal was the kernel. However, there was differences regardingdomestication speedy between those two communities. Therefore, few advanced domesticated trees were found in the Nago area. Lastly, in the Adja sociocultural area, progenitors co-occur with the domesticated ones. *Irvingia gabonensis* in the Adja communities represents an important on-farm gene bank to be valued for large-scale development of this species and for sustainable kernel-based business development across West Africa.

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## List Of Tables

Table 1: Principal component loads on first three axis from PCA of the I. gabonensis trees' morphological factors

| Trees' morphological factors | PC 1 | PC 2 | PC 3 |
|---|---|---|---|
| Level of the first large branch insertion | -0,62 | -0,38 | 0,46 |
| Crown diameter | 0,70 | 0,38 | 0,27 |
| Number of branches | 0,84 | 0,25 | 0,08 |
| Number of subtrees | 0,36 | 0,13 | -0,78 |
| Leaf lenght | -0,67 | 0,65 | 0,04 |
| Leaf width | -0,53 | 0,79 | 0,05 |

## List Of Figures

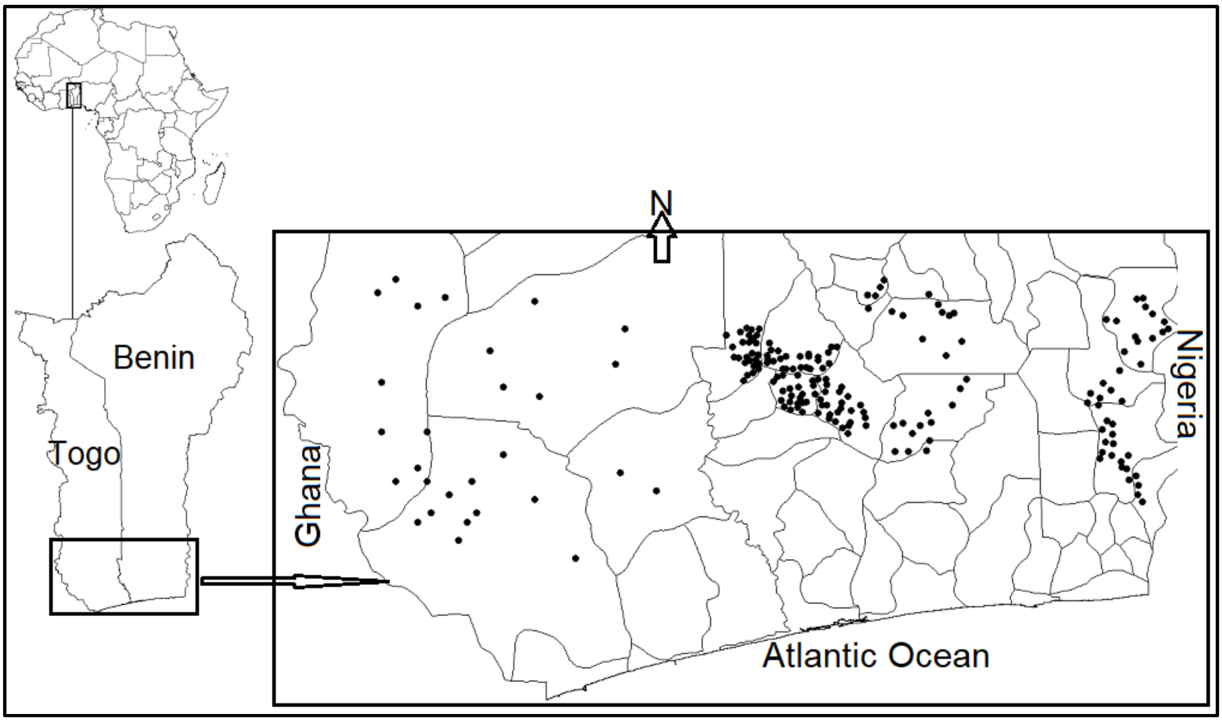


Figure 1: Geographical location of sampled *I. gabonensis* individual trees in the Dahomey Gap

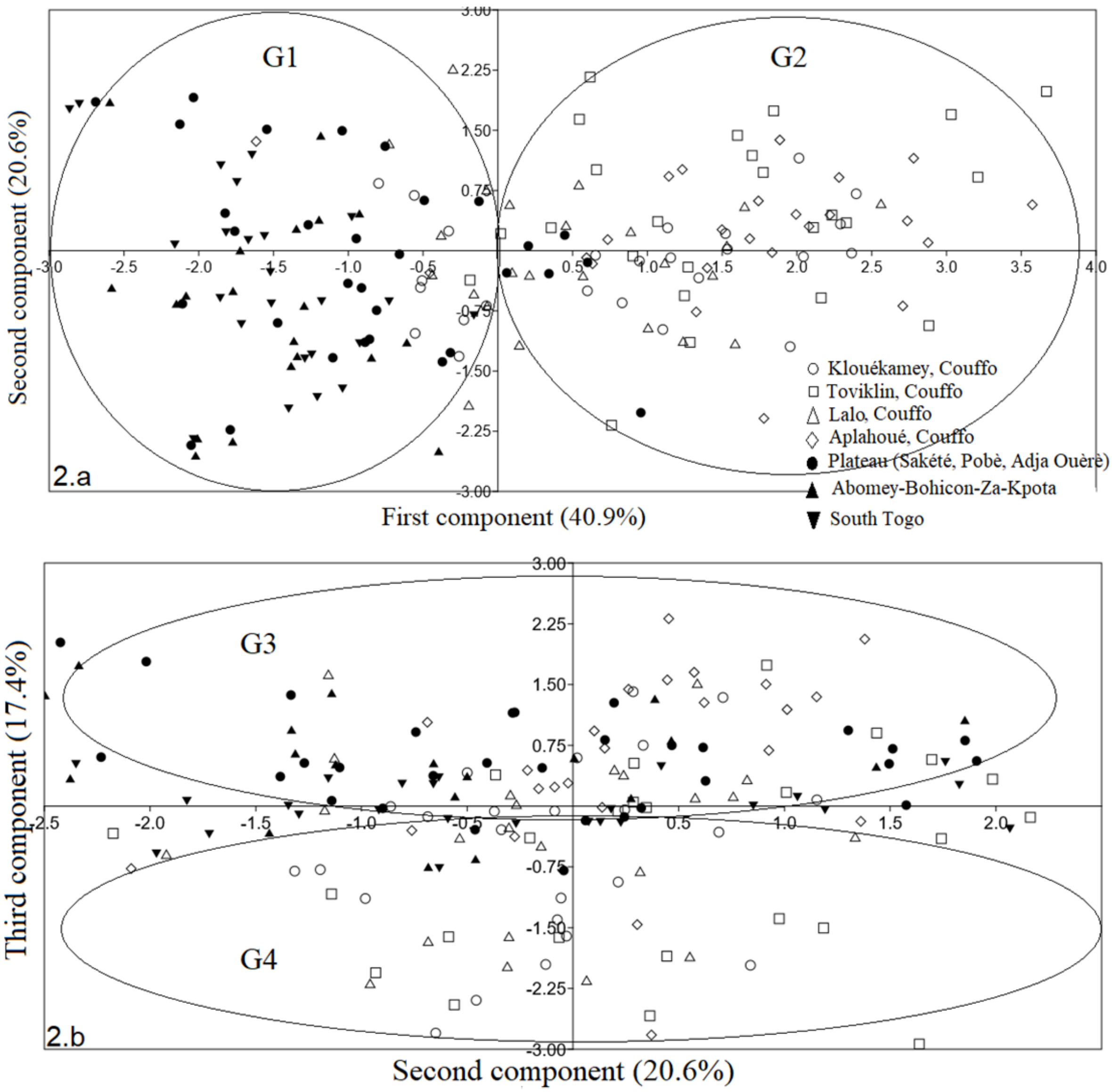


Figure 2: Results of the PCA classifying *Irvingia* trees based on their morphological traits

3.a 3.b 3.c

Figure 3: Primary morphological characters of *Irvingia* trees as impacts of traditional domestication led by the

Adja sociocultural group: 3.a- low branching pattern tree, 3.b- highly branched trees, 3.c- wide and low crown

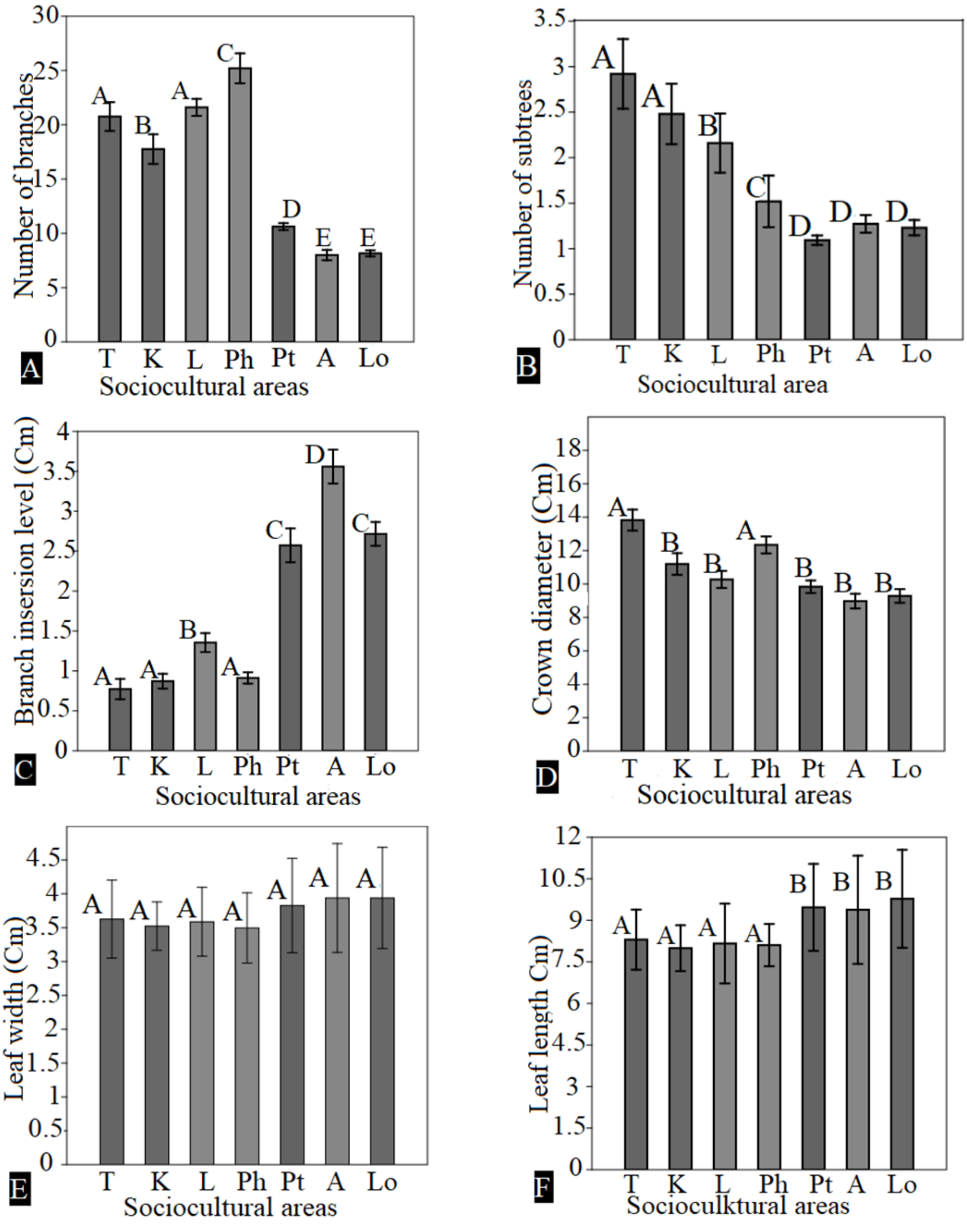


Figure 4: Results of the MANOVA of fruit, mesocarp and seed characteristics against populations

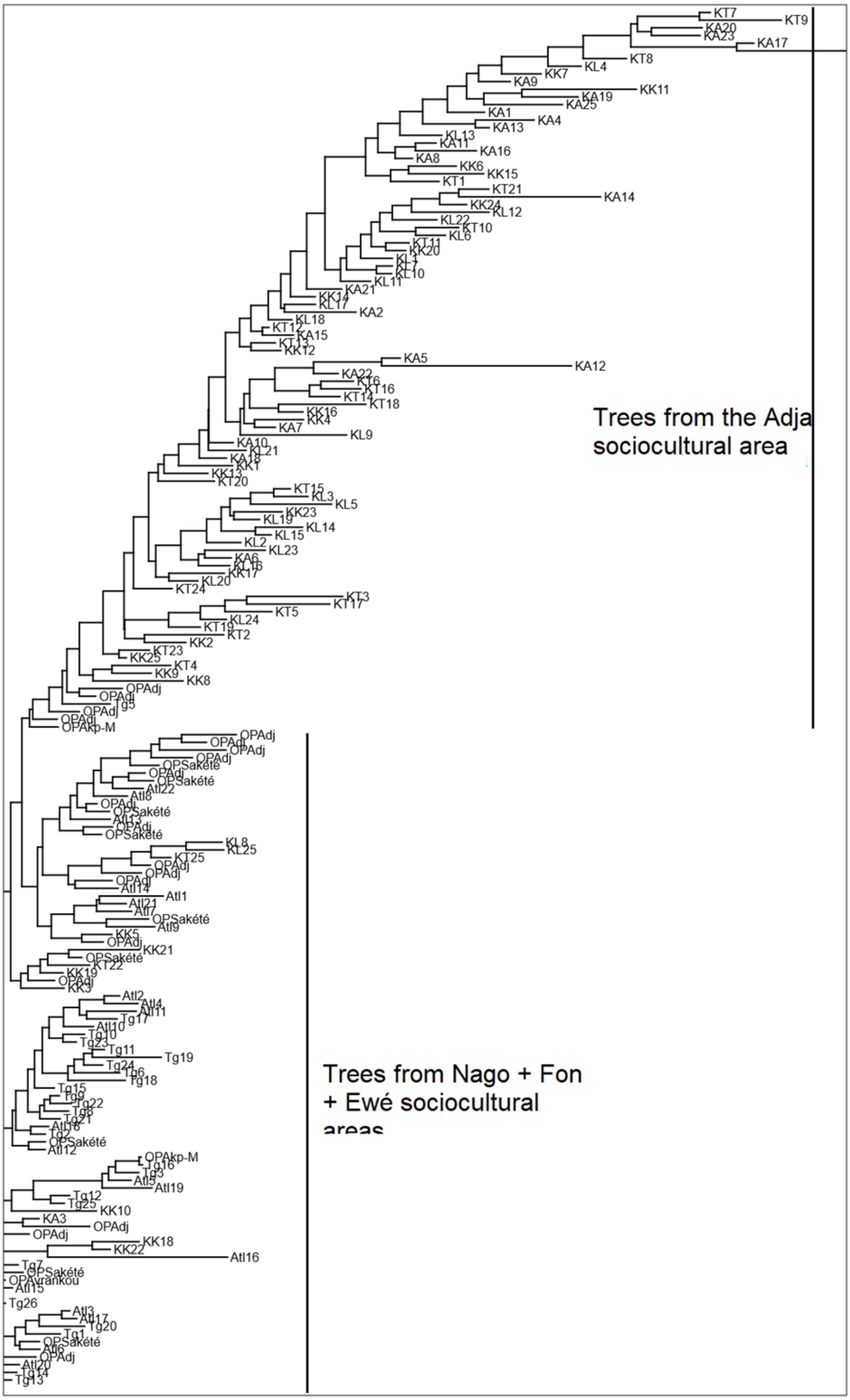


Figure 5: Result of the unrouted Neighbor Joining tree analysis: phylogenetic relationship among sample trees in the Dahomey Gap

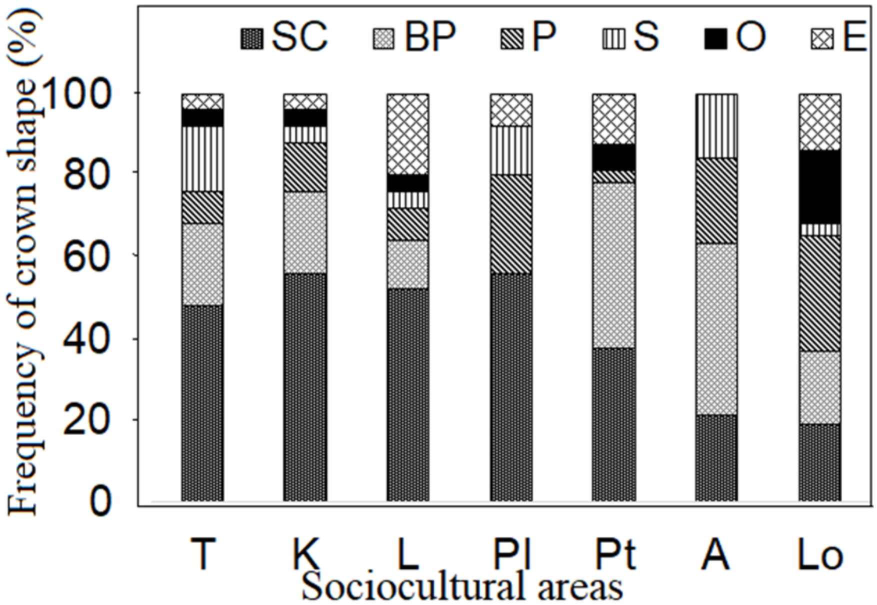


Figure 6: Frequency of crown *I. gabonensis* shapes across different sociocultural areas in the Dahomey Gap: T: Toviklin, K: Klouékanmey, L: lalo, Pl: Aplahoué, Pt: Plateau, A: Abomey, and Lo: Lomé.