Journal of Environmental Geography 16 (1–4), 95–101.

DOI: 10.14232/jengeo-2023-44667
ISSN 2060-467X

EFFECT OF CLIMATE AND HABITAT ON MORPHOLOGICAL CHARACTERISTICS AND FRUIT PRODUCTION OF *PICRALIMA NITIDA* (STAPF) IN WEST AFRICA

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Research article, received 12 May 2023, accepted 26 July 2023

Abstract

Picralima nitida is an important African medicinal plant species used in pharmaceutical industries and traditional medicine to treat several diseases. Despite its importance, the species faces conservation problem. This study evaluated the effect of climate and habitat on morphological characteristics and fruit production of *P. nitida*. A total of 132 fruiting trees was randomly sampled from three habitat types (home gardens, botanical garden and natural forest) and three soils (Nitisols, Arenosols and Acrisols) in Dahomey Gap and Guineo-Congolese zone. A total of 5 morphological traits and fruit production were recorded per tree to describe the relationship between morphological determinism of the species and climate. Pearson correlation was performed to identify the suitable habitat type in each climatic zone. Harmonized World Soil Database was used to determine physicochemical characteristics of the soil types on which the species occurred. Results revealed that the climatic zones ($p<0.001$) and habitat types ($p<0.0001$) influenced significantly the morphological characteristics and fruit production of *P. nitida*. High trees with more number of fruits were observed in home gardens on acid soils (Nitisols (pH: 5) and Arenosols (pH: 5.3)) in Dahomey Gap. In Guineo-Congolese zone, the species was more present in natural forest on acid Acrisols (pH: 5).

Keywords: *Picralima nitida*, climatic zones, morphological variabilities, habitat type, physiochemical characteristics, soil types

INTRODUCTION

Picralima nitida (Stapf) T. Durand & H. Durand is one of the endangered medicinal species across all its distribution range mainly in Dahomey Gap (DG) (Betti, 2004; Gbadamosi, 2014; Akabassi et al., 2017; Akabassi et al., 2021a). It is a forest species more present in Guineo-Congolese (GC) region (Erharuyi et al., 2014; Matig et al., 2006; Bickii et al., 2007). It is a very useful species for African local peoples because of its high medicinal potential (Akoegninou, 1998, Akabassi et al., 2020). In almost all of its distribution areas (DG, GC), the plant has high priority in the treatment of diseases such as malaria, diabetes, infectious diseases, tonsillitis, cancer, etc. (Adjanohoun et al., 1996; Aguwa et al., 2001; Teugwa et al., 2013; Holaly et al., 2015; Akabassi et al., 2017; Akabassi et al., 2021b). Despite its importance, the species faces serious problems of conservation in the different climatic zones where it occurs. In the GC region, it occurs only in the wild with a threat of extinction (Gbadamosi, 2014). It is the first critically endangered species among the four species used by the indigenous populations of the eastern region of Cameroon for the typhoid fever treatment (Betti, 2004). The species is quasi-absent in wild in DG but with occurrence of few isolated individuals in home gardens (Betti, 2004).

Climate is one of the most important environmental factors affecting the physiology and ecology of plants. The climate variability and alteration of biogeochemical cycles can alter the species environmental determinism, affecting firstly their physiology, then their phenology and ultimately their distribution (Parmesan, 2006). The main climate variables that affect the life and physiology of plants are light, temperature and precipitation (Jamieson et al., 2012). The action of each of these variables influences the productivity of the plant species. Climate therefore has important ecological consequences for plant species interactions that occur across multiple trophic levels. In addition to climate, soil also affect the morphological variations of the forest species (Chadare et al., 2008). Climate and soil are therefore important for assessing the production and the qualitative value of the forest species (Assogbadjo et al., 2012).

In DG, in addition to climate, most of the medicinal plant species are threatened because of the small size of the relict forests and the human pressure (Neuenschwander et al., 2011). Traditional agroforestry systems are considered as the second most important resource for the conservation of the threatened forest species (Idohou et al., 2014; Salako et al., 2014).

In contrary to other non-timber forest products (NTFPs) used for medicinal purposes, *P. nitida* has not yet attracted the attention of scientists in the field of domestication and/or conservation (Yakeu, 2012). The studies performed on *P. nitida* concerned the effect of Watering Regimes and Water Quantity on the Early Seedling Growth (Gbadamosi, 2014), ethnobotanical studies (Adjanohoun et al., 1996; Akabassi et al., 2017) and the physico-chemical properties of different part of *P. nitida* (Akabassi et al., 2022).

Plant species domestication program requires a deeper knowledge of the ecology and variability within the species. In addition, the valorization of NTFPs requires first a morphological characterization of their plant material. This description identifies interesting morphological characteristics according to the climate gradient and then those under the influence of environmental factors. There is lack of knowledge on the productivity of *P. nitida* according to climate zones and habitat. This information is necessary to identify, the environmental conditions favorable to a higher production of organs (fruits and seeds) and the role of habitat in the conservation and domestication of *P. nitida*.

In perspective to set up a sustainable conservation of the species in West Africa, the present study aims to (i) assess the influence of climate and habitat type on morphological variations and fruit production of *P. nitida* trees, (ii) assess the influence of soil physico-chemical characteristics on the distribution, morphological characteristics and fruit production of *P. nitida* trees. The hypotheses guiding these aims are (i) variability in tree morphological traits of *P. nitida* is more determined by climate than soil type, (ii) tree fruit production depends on environmental conditions, morphological characteristics and physico-chemical characteristics of the soil.

MATERIAL AND METHODS

Study areas

The study was carried out in two West Africa climate zones, DG and GC (Fig. 1). In DG, Benin and Togo were considered. Both countries are more affected by the Dahomey Gap phenomenon. DG is the dry zone that separates the two forest blocks from tropical Africa (Bongers et al., 2004). The overall annual rainfall varies between 900-1400 mm (Gbesso et al., 2021). The average temperature varies between 25 and 29°C with a relative humidity between 69 and 97% (Adomou, 2005). The vegetation is characterized by savanna that goes down to the coast with a mosaic of rain forest. There is also mangrove formations subject to tidal regimes (Akoegninou, 1998). In the GC region of West Africa, Ivory Coast was considered. This area is located in the typical GC region with a rainfall of up to 2500 mm characterized by the presence of dense rain forests. The average temperature of GC varies between 23 and 29°C with a relative humidity between 65 and 98%.

Sampling

The mating systems of the species were not yet clearly identified (Adjanohoun et al., 1996). However, it was more common in allogamous plants (Endress et al., 1996). Taking into account this information, and using stratified random sampling, individuals of *P. nitida* were collected by habitat types in each climatic zone. A distance of 100 m between individuals was considered using GPS (Global Positioning System) to avoid the collection of closely related individuals. Moreover, the individuals collected in the same climatic zone were consider to belong to the same population. The habitat types considered in this study were home garden, natural forest and botanical garden. A total of 132 individuals of the species were sampled (90 from DG and 42 from GC) across the study area.

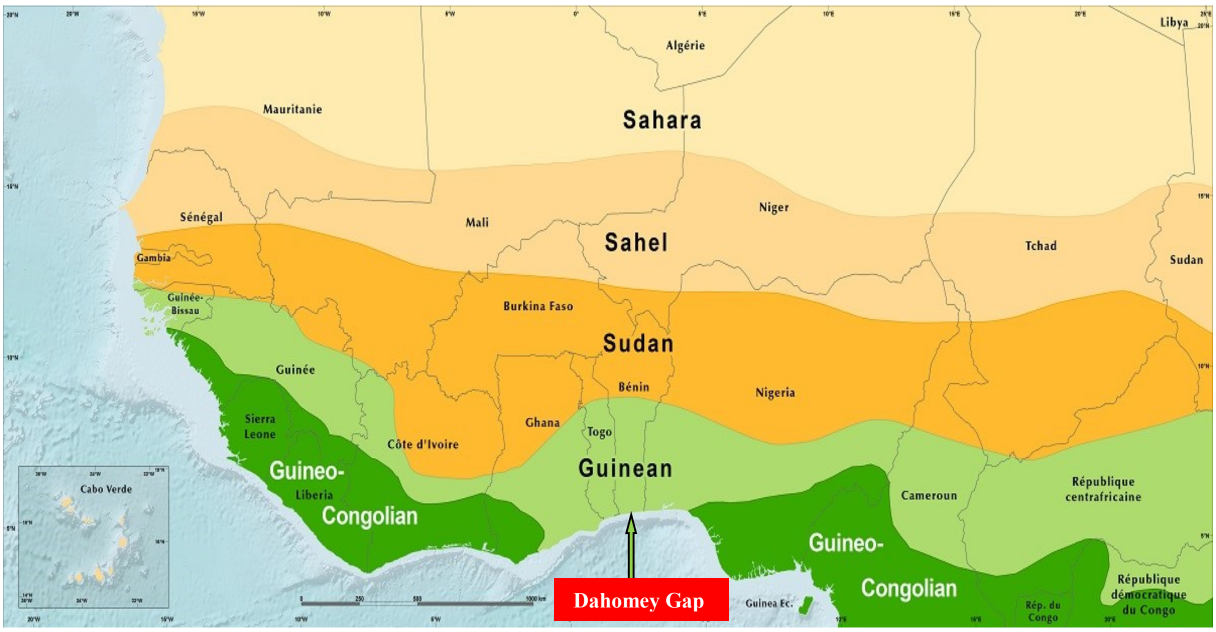

Fig.1 Guineo-Congolese region and Dahomey Gap (Church, 1966)

In DG, *P. nitida* were only collected in home gardens and botanical gardens because the species is absent in the wild (Akoegninou, 1998; Akabassi et al., 2017) while in the GC zone in addition to the home garden and botanical garden, the *P. nitida* trees were also collected in natural forests.

Data collection

Five tree's morphological traits were measured on each tree (The height (H), circumference at 1.30 m (Cir), large crown diameter (LCD), small crown diameter (SCD) and number of branches from the first branch (NB)). In addition to this morphological traits, the fruit production (FP) was taken on each *P. nitida* individual. The age of the tree was also estimated with local population. Fruit production was estimated using the Extrapolation Counting method (Nacoulma, 2012.). In addition, the major soil type (ferralitic soil of red color with sandy-clay texture) was identified using soil map of Willaime and Volkoff (1967) and georeferenced coordinates were recorded for each *P. nitida* individual.

Data analysis

Principal Component Analysis (PCA) was performed to assess the relationship between morphological traits of the species and the climatic zones. The Pearson correlation was then calculated to explain the linear relationship that exists between the main components defined by the morphological parameters of trees and fruit production according to the two climatic zones. In order to identify the suitable habitat type of the species in each climatic zone, the Pearson correlation was also performed between the PCA axes and the habitat types. Georeferenced coordinates recorded were projected on the map of the Harmonized World Soil Database Version 1.2 database (FAO / IIASA / ISRIC / ISSCAS / JRC 2012) in order to determine on a smaller scale the granulometric variables of soil types on which individuals of the species were collected. The granulometric variables were % clay, % silt, % sand and % gravel. Organic carbon content (C), pH-water, and soils salinity were also identified.

RESULTS

Influence of climate on morphological variation and fruit production of P. nitida trees in West Africa

The Principal Component Analysis (PCA) carried out on the dendrometric characteristics and fruit production of trees according to the two climatic zones revealed that the first two axes explained 65.35% of the total variation, which was sufficient to guarantee a precision of interpretation of morphological data. The first axis summarized 51.30% of the total variation data while the second axis summarized 14.05% of the total variation. Height, circumference, large and small crown diameter were strongly positively correlated with the first axis (Table 1a). Thus on the first axis, the high trees of *P. nitida* had big trunk and crown diameters. The number of branches was strongly positively correlated with the second axis. The Pearson correlation between the PCA axes, the fruit production and age of *P. nitida* trees indicated that the trees with big trunk and crown diameters were young with more branches with higher fruit production (Tables 1b).

Other result of the PCA indicated that high trees of *P. nitida* with big circumference, big crown diameters and more branches were observed in DG zone (Fig. 2).

The height of trees in the GC zone was slightly higher (6.74 ± 1.74m) than that of DG (6.25 ± 2.48m). The trees of DG had higher value of circumference (47.60 ± 22.75cm), crown diameter (5.77 ± 2.29m), fruit (99.35 ± 175.03 fruits) and number of branches (3.02 ± 1.65) than the trees in the GC zone (Table 2).

Influence of habitat on morphological variation and fruit production of P. nitida trees in West Africa

Projection of the habitat on the PCA axes showed that high trees of *P. nitida* with big circumference, big crown diameters and more branches were found in home gardens in both climatic zones (Fig. 3).

The height of the trees in natural forest was slightly higher (7.07 ± 1.59m) than that of the trees found in home gardens (6.35 ± 2.34m). While the trees in home gardens

Table 1 Correlation between (a) the morphological variables, the PCA axes and the fruit production and age of *P. nitida* trees; and (b) PCA axes, fruit production and age of *P. nitida* trees

(a)

Variables	Axes 1	Axes 2
H	0.72	-0.30
Cir	0.71	-0.20
GDH	0.90	-0.03
PDH	0.90	-0.01
NB	0.45	0.87

(b)

	FP	Age
FP	1.00	0.30***
Age	0.30***	1.00

H: hauteur / height; Cir: circonférence / circumference; GDH: Grand diamètre de houppier / large crown diameter; PDH: petit diamètre de houppier / small crown diamete; NB: nombre de branches / number of branching; FP: production fruitière / fruit production. *** $p < 0.001$

Table 2 Average values of morphological variables and the fruits production of *P. nitida* in both climatic zones.

	Dahomey Gap		Guineo-Congolese	
Variables	m	sd	m	sd
H	6.25	2.48	6.74	1.74
Cir	47.60	22.75	35.8	8.72
LCD	5.77	2.29	3.97	1.62
SCD	4.90	2.11	3	1.01
FP	99.35	175.03	42.36	124.92
NB	3.02	1.65	2.44	1.21

H: height; Cir: circumference; LCD: large crown diameter; SCD: small crown diameter; FP: fruit production; NB: number of branching; m: mean; sd: standard deviation

had highest values for the others variables (circumference, crown diameter, number of fruits and branches) (Table 3).

Type of major soil on which *P. nitida* was present in both climate zones (DG and GC) was ferralitic soil of red color with sandy-clay texture. On the smaller scale, we noticed that in DG region, *P. nitida* populations were found on two types of soil, namely Nitisols and Arenosols. In contrast, in GC region, populations of the species were present on Acrisols (Table 4). The pHs of these three soil types were acid and ranged from 5 to 5.3. The Organic Carbon content (Corg) of the three soil types was also substantially the same. Nitisols and Acrisols had four times more clay and two times more silty than Arenosols. In contrast, Arenosols had two times more sand than Nitisols and Arenosols. Overall, all soil types had the same salt content (Table 4).

DISCUSSION

The results showed that morphological variables and fruit production varied significantly between the two climatic zones. The population of *P. nitida* in DG had higher values for most of the morphological variables considered as well as fruit production than GC population. However, when considering the habitat, *P. nitida* individuals have the similar morphological variation and fruit production in home garden in both climatic zones that is different with the species morphology in natural forest or botanical garden. Thus, the difference between the two climatic zones may be related to the habitat. The individuals from DG were collected in home gardens and botanical gardens while those of the GC zone were collected in natural forest addition to home garden and botanical garden.

Fig.2 Projection of the climate zones on the PCA axes.
(DG: Dahomey Gap; GC: Guinean-Congolese)

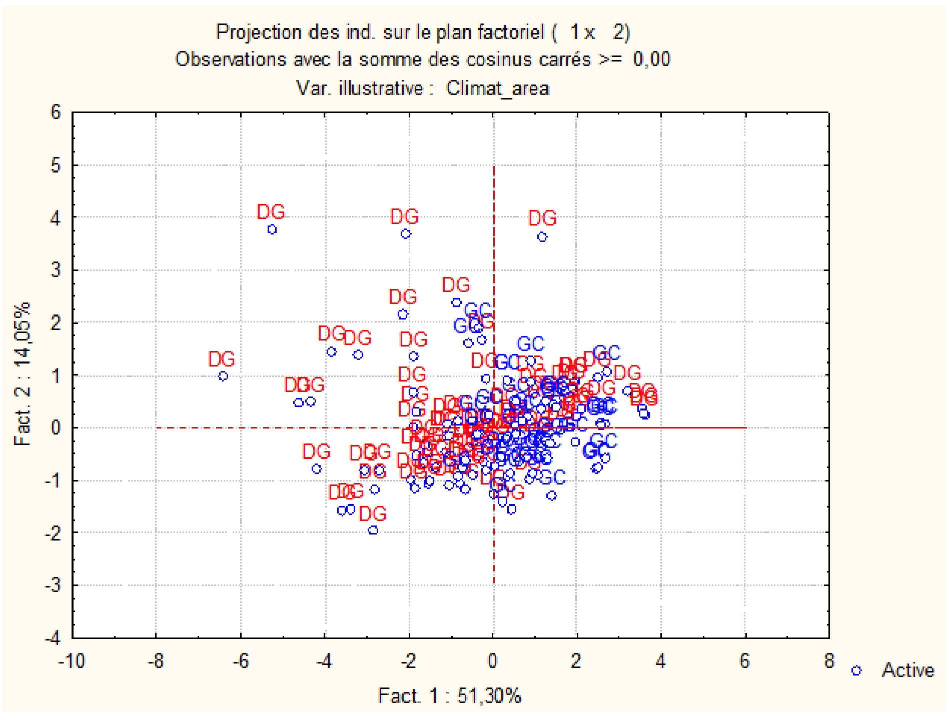

Table 3 Mean values of morphological variables and fruits production of the trees according to the habitat types.

Variables	Hom_garden	Fo_natur	Bo_garden
H	6.35±2.34	7.07±1.59	6.50±1.55
Cir	45.05±20.79	31.72±4.05	40.45±10.23
LCD	5.5±2.11	2±1.29	3.51±2
SCD	4.53±1.97	1.85±1.03	3.3±1
FP	88.90±168.25	1.6±0.51	25.72±51.34
NB	2.94±1.56	0.4±0.84	2±1

H: height; Cir: circumference; LCD: large crown diameter; SCD: small crown diameter; FP: fruit production; NB: number of branching; m: mean; sd: standard deviation; Hom_garden: Home garden; Fo_Natur: Natural forest; Bo_garden: Botanical garden.

Table 4 Physico-chemical properties of soils on which P. nitida populations were found in both climate zones.

		Physico-chemical properties of soils						
Climate zones	Soil types	pH (H_2O) Gr [%]	Corg [%]	Clay [%]	Si [%]	S [%]	Sa [ECe]	[dS/m]
Dahomey Gap	Nitisols	5	0.69	32	28.5	39.5	0.1	18.5
		(0.07)	(0,43)	(12,73)	(6,36)	(6,36)	(0)	(10.60)
	Arenosol	5.3	0.5	8	10.5	81.5	0.1	14.5
		(0.14)	(0,27)	(0)	(0.70)	(0.70)	(0)	(6,36)
Guineo-Congolaise	Acrisols	5	0.69	32	24.5	47	0.1	21
		(0.07)	(0.41)	(9.9)	(1.41)	(8.48)	(0)	(2.83)

Corg: Organic carbon; Si: Silt; S: Sand; Sa: Salinity; Gr: Gravel

In home gardens in both climatic zones, trees of *P. nitida* were bigger with large crown diameters, more branches and fruit production while the height of the trees in natural forest was slightly higher than that of the trees found in home gardens (Table 3). This difference could be attributed to the total decrease of photosynthesis and carbon fixation of trees in natural forest (Martın et al., 2015). *P. nitida* is an understorey with a maximum height of 35 m (Adjanohoun et al., 1996). Thus, in forest, it may be affected by light competition for photosynthesis. These results corroborated with those of Fandohan et al. (2009) on Tamarindus indica and Shackleton et al. (2003) on Sclerocarya birrea who explained that the tallest trees with low diameter found in gallery forests were a possible result of higher competition for light.

Moreover, correlation of fruit production with tree morphological traits indicated that the youngest individuals had more branches with higher fruit production in contrast with the old trees. This could be explained by the fact that the old trees may have reached their cruising production year (Nacoulm et al., 2016). Each type of fruit tree has its age of maturity from which it begins to bear fruit and another age from which it reaches its cruising production (Vanninen et al., 1996; AFRISTAT, 2001). Moreover, a decreasing tree growth and productivity over time could probably be attributed to variations in the supply rate of required resources (light, nutrients and water), changing balance between photosynthesis and respiration, increased hydraulic resistance, decreased nutrient supply, or genetic changes with meristem age (Day et al., 2001). Our results corroborated with those of Kutsch et al. (2009) who found that the productions of fruit trees decrease over time. The decrease in production was remained below 2% until the age of about 100 years, after which it reached the level of about 5% by the age of 200 years. This suggests that branch senescence decreases as the tree grows older and becomes less dense (Gaoue and Ticktin, 2008).

Preferred soils of *P. nitida* in DG were Nitisols and Arenosols. Previous studies in Benin (DG) showed that the frequency of *P. nitida* was high on Nitisols than Arenosols (Akabassi et al., 2017). Nitisols in DG and Acrisols in GC had almost similar physico-chemical characteristics (Table 4). This result confirmed that the difference between the morphological variables and the fruits production of the trees in both climatic zones may not be related to the soil but to the habitat types. The light would certainly have an influence on the trees morphology. Moreover, the significant difference between the individuals found in forest and those in home gardens confirmed that *P. nitida* is a heliophilous species that required more light. Some studies dealing with different plant species already reported that out of genetic factors, morphological variation of NTFPs were low on the soils with the same physico-chemical characteristics but vary with and ecological gradients (Assogbadjo et al., 2012; Chadare et al., 2009).

Implication for conservation and sustainable management

This study revealed how climate and habitat influenced the morphology and production of *P. nitida*. Results can serve as a springboard to investigate the climate gradient effect on the evolutionary history of *P. nitida* populations in West Africa. It could be important to infer ancestral states of climatic zone preferences of the species. In forest, *P. nitida* had low fruit production, whereas in home gardens, fruit production is high. Thus light is an important factor for the species. This could be taken into account in the conservation and production policy of the species.

Habitat types and age of trees could significantly decreased the quantity and quality of fruits and seeds, which could compromise the chances of natural regeneration of this multipurpose tree species in the long-term. The fact that *P. nitida* requires more light, its conservation and production must take into account open spaces.

This study represents an important step towards understanding the role of climate and habitats in the conservation and production of *P. nitida*.

CONCLUSION

The study provides the effect of climate and habitat on morphological characteristics and fruit production of *P. nitida*. High trees of *P. nitida* with large circumference and crown diameters, more branches and fruits were observed in home garden. The habitat types and tree age influenced significantly the morphological variables and fruit production of *P. nitida*. Moreover, *P. nitida* population preferred open habitat with an acid soil. Home gardens provide a springboard for the conservation and sustainable management of *P. nitida*.

ACKNOWLEDGEMENTS

Our honest thanks to "Centre d'Excellence Africain sur les Changements Climatiques, la Biodiversité et l'Agriculture Durable (CEA-CCBAD)" of Côte d'Ivoire which took charge of the field works.

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