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Correlations between some phenotypic characters of *Prunus africana* and chemical characteristics of soils in Cameroon

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Abstract

Prunus africana (Hook. f.) Kalkman is one of vulnerable biodiversity components mainly used for medicinal purpose in Africa. In Cameroon, farmers are not aware of the soil types in which this plant yields best so far as its phenotypic parameters are concerned. In seeking for a solution to this problem, this study was carried out at Manengouba mountain forest and within Bamenda highland area with the aim to quantify the phenotypic characters of *P. africana* and appreciate the correlations between them and chemical characteristics of the soil. The sample was made up of 80 trees, 2085 leaves randomly collected and 6 soils samples from 6 plots. Nine phenotypic characters quantified among others were; the height of the first big branch which varied from 1.97 to 2.35 m, the weight of the leaf from 252.20 to 380.45 mg and its area from 3 309 to 3935 mm². Pearson test shows 13 significant correlations between the phenotypic characters of *P. africana* and chemical characteristics of the soils. Multivariable analysis shows the grouping of trees. It was established that *P. africana* is a calcifuges' plant as far as growth of leaf surface is concerned while nitrogen, sulphur and phosphorus favored the longitudinal and radial growth of the tree stem respectively.

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Introduction

P. africana (Hook. f.) Kalkman is a biodiversity component whose bark is exploited for international market due to its medicinal properties that show great efficacy in the cure of prostatic hypertrophy and hyperplasia. The natural regeneration of this species hasn't been able to insure the rehabilitation of its populations which are over exploited in Cameroon (Avana, 2006). *P. africana* represents 6 % of species used in forest plantations by farmers in Western High Land agro-ecological zone in Cameroon (Tchouakionie, 2010). Farmers are not aware of the soil types in which, this plant can give the best yield with respect to its phenotypic parameters. The objective of this study carried out for about 24 months, is to appreciate the effects of chemical characteristics of the soil on the phenotypic characters of *P. africana* thereby contributing to resolve this problem. Specific objectives were to appreciate the correlation between some quantified phenotypic characters and chemical elements of soils collected under *P. africana* trees.

P. africana is a tree (Fig. 1) whose base of trunk is made up of a simple embattlement or buttress roots with the height ranging from 8 to 100 cm. The trunk is straight and its diameter can attaint 1 m while the tree can attain a height of 25 m. The leaves (Fig. 2) are simple, alternate with spiral phyllotaxis. The leaf area is 6-15 x 3-6 cm or from 18 - 90 cm². The lamella is smooth and shining, while the leaf margin is irregular. At the base of lamella 1 or 2 glands can be found while 6 to12 pairs of lateral veins can also appear per lamella (Vivien and Faure, 2011).

Variation of phenotypic characters according to biotic and abiotic factors has been studded by many authors. Dawson and Powell (1999) established approximately 23 % genetic variation within *P africana* after collecting data from four sites in Cameroon, and concluded that the genetic variation is considerably low between its populations.
Abiotic factors such as latitude, rain fall and constituents of soils influence the behavior of plants, *P. africana* inclusive (Hall *et al*., 2000). As the value of latitude decreases towards the equatorial regions (0°), there is a general tendency in increase frequency of *P. africana*. The distribution of *P. africana* is associated with the mean annual rainfall that range from 500-700 mm at higher altitudes to 3000 mm at lower altitudes (Hall *et al*., 2000).

It is a forest tree geographically extended in high altitude's forests in the African continent. Countries concerned are South Africa, Angola, Cameroon, Ethiopia, Kenya, Malawi, Nigeria, Uganda, Democratic Republic of Congo, Somalia, Soudan, Swaziland, Tanzania, Zimbabwe) and nearest Islands such as Bioko, Grande Comoros, Madagascar, Sao Tomé (Dawson and Were, 2000).

Materials and methods

Zones of study concerned the South-West and North-West Region of Cameroon (Fig. 3). The choice of these regions was due to the presence of *P. africana* plantations hence the need to find a solution to the farmer's problem relative to the best types of soils for creating *P. africana* plantations in the area.

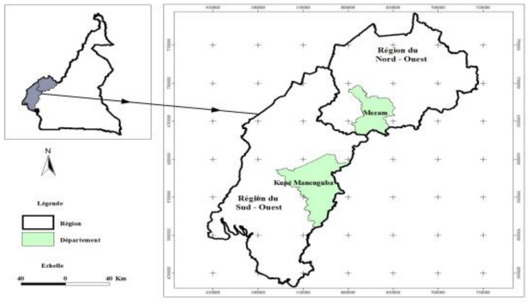


Fig. 3. Zones of study.

The tracking's geo-references through which phytogenetic materials were collected and the description of its environment are in Table 1. Kupe & Muanenguba Division, one of the study zones in the South-West Region is dominated by equatorial climate as précised in the Annual for statistics of Cameroon by National Institute of Statistics (2008). The climatological data collected from the weather station post in Tombel, a near by town to the experimental site showed that the quantity of rain fall is 3133 mm per year with 148 days of rain. The graph of rain fall is monomodal. The temperature varied from an average minimum of 20.0 °C to an average maximum of 28.6 °C.

Mezam Division in the North-West Region is characterized by a mountainous tropical climate. Data collected from the Secondary Centre for Meteorological watch of Bamenda Airport, situated at the heart of the study zone revealed that the amount of rain fall here is l2473 mm / year within 164 days of rains. The graph of rain fall is also monomodal. The average of minimal temperature is 15.8 °C while its maximal attaints 23.7 °C.

During the field trip, the tools used for data collection were as the follow:
- GPS (Global Positioning System), Mark GARMINT 5 for appreciating different altitudes along the slope of mount Muanenguba in the South-West Region and in some agro-ecosystems for the North-West Region;
- numerical photo camera, mark HP Photosmart E 427 for capturing images of pertinent components of the study zone;
- digital meter of 7.5 m ;
- small plastic bags to separately keep the different samples;
- cutlass to wound the bark of the tree for easy characterization of the plant
- clisimeter, SUUNTO's Mark for determining the different height of trees.

Experimental disposition of plots

Completely randomized blocks (Table 2) had been chosen as experimental scheme where six plots constituted the different blocks within which 15 population of trees, 80 trees and 2085 leaves of *P. africana* were randomly chosen.

In the North-West Region of Cameroon, it has been observed that in agro-forest plantations, *P. africana* tree older than 16 years are excessively attacked by pathogenic agents (Fig. 4). The pathogen concerned is *Coleopterous borers* that provoke many holes on the boles of *P. africana*.

These attacks constituted a real menace for *P. africana* in plantations. The phenotypic characters such as the length or the width of leaves, the height of tree top of *P .africana* can be influenced by the action of these pathogenic agents. Due to this pathogenic attacks, only sample of adult trees with average age of 10 to 12 years were chosen per plot.
Biometrical measurement of phytogenetic materials concerned nine phenotypic characters. They were quantified in the field and laboratory of Plant Biotechnology and Environment of the University of Yaounde I in Cameroon:

- height of the first big branch of tree was measured and calculated using the following formula.

Height of the first big branch = Distance (d1) x tg (α) + 1.30 m

d1 = distance between the tree and observer, tg = tangent, α = angle found from the base to the first big branch of the tree.

- height of the tree top was determined using the same method above

Height of the tree top = Distance (d1) x tg (β) + 1.30 m β = angle found from the base to the tree top.

- circumference of the trunk at 1.30 m from the ground which was determined by measuring the circumference of the tree bole using digital meter.
- length of leaf without the petiole where only lamella is concerned. It was determined by measuring the segment of lines joining the two extremities of the leaf using digital meter.
- width of leaf is the widest segment of line perpendicular to the mid rib. The sample of leaves were always collected from the first big branch of the tree and on the surface exposed to the sun after noon
- number of left and right veins from the mid rib per leaf were determined through simple counting .
- leaf area (SF) was determined using the formula of Raunkiaer,

SF = k x L x l

L = length of leaf, l = width of leaf and k = 2/3 specific weight of leaf was determined, after drying at the ambient temperature varied from 26 à 27 °C for five days using a highly sensitive balance, mark SCALTEL SPB 55.

Analyses of soil samples were carried out. Each of the soil used for constituting the six composite samples of the soils were collected in a hole dug with cutlass at 20 cm depth. The analyses of the sample of soil carried out at the Laboratory of Institute of Agricultural Research for Development (IRAD) Yaounde. Soil analysis was focused on 15 chemical characteristics which are:

organic matter: total organic matter, organic carbon, total nitrogen and C/N ;
assimilable phosphor;
exchange acidity: $Al^{3+} + H^{+}$;
exchangeable bases: Ca^{3+}, Mg^{2+}, K^{+}, Na^{+}, S, T(CEC), V=S/T (x100) .
acidity /alkalinity: pH water- 1/2.5 ; pH KCl-1/2.5

The biometrical data obtained was subjected to statistical analyses to find the variability of phenotypic characters of *P. africana* within and between plots and appreciate the effect of chemical elements of the soils from the six experimental plots towards the above characters. Therefore, the Statistical Analysis Software (SAS) was used.

Results and discussion

Soil characteristic of experimental plots was quantified. The analyses of the soils from mount Muanenguba and those of mountain lands of Bamenda show 16 x 6 parameters, in other words 96 chemical characteristics relative to its composite samples.

Table 1. Characteristics of sites for phytogenetic material's samples.

Localities or Population of trees	Longitudes	Latitudes	Altitudes	Description of site's environment
BANGEM	0585364	0560819	1279 m	In front of DDPW/ TOMBEL's road
Njom	0585401	0559303	1337 m	Presence of gallery forests
NKACK P. 3.1	0585133	0559274	1331 m	Presence of Population and nursery of *P. africana*
NKACK P. 3.2	0585132	0559250		
NKACK P. 3. 3	0585130	0555248		
NKACK	0586648	0556875	1518 m	Presence of gallery forests
NKACK	0588962	0556522	1916 m	Shrub's savanna and Forests in the valley
Bororo's village	0589865	0556560	1975 m	Gallery Forest
Lakes	0591579	0556883	1976 m	Greening vast plateau
Population of trees 1.1	0633292	0668883	1242 m	Quickset hedge
Population of trees 1.2	0633494	0668882	1247 m	Arboretum
Population of trees 1.3	0633376	0636828	1248 m	Forest ecosystem
Population of trees 2.1	0636983	0665277	1274 m	Agro-forest populations
Population of trees 2.2	0636969	0665388	1281 m	Agro-forest populations
Population of trees 2.3	0636910	0665392	1285 m	Quickset hedge
Population of trees 4.1	0640293	0667040	1414 m	Agro-forest populations
Population of trees 4.2	0626735	0654248	1565 m	Agro-forest populations
Population of trees 5.1	0641760	0666762	1595 m	Agro-forest ecosystem
Population of trees 5.2	0628111	0651516	1596 m	Agro-forest populations
Population of trees 6.1	0627868	0661532	1606 m	Agro-forest populations
Population of trees 6.2	0628218	0651407	1633 m	Agro-forest populations

The correlations between phenotypic characters of *P. africana* and the characteristics of the soils colleted under *P. africana* (Table 3) were established using SAS software with emphasis on Pearson's test.

Table 2. Experimental dispositive for plots and traceability of collected leaves

Plot	Population	Tree	Leaves
Plot 1	Population 1.1	Tree 01	Leaf N° P1A1F1 à P1A1F30
		Tree 02	Leaf N° P1A2F1 à P1A2F30
	Population 1.2	Tree 03	Leaf N° P1A3F1 à P1A3F39
		Tree 04	Leaf N° P1A4F1 à P1A4F32
		Tree 05	Leaf N° P1A5F1 à P1A1F35
	Population 1.3	Tree 06	Leaf N° P1A6F1 à P1A6F34
		Tree 07	Leaf N° P1A7F1 à P1A7F35
		Tree 08	Leaf N° P1A8F1 à P1A8F22
Plot 2	Population 2.1	Tree 09	Leaf N° P2A9F1 à P2A9F 30
		Tree …*	Leaf N° P2A…F…*à
		Tree 22	Leaf N° P2A22F1 à P2A22F34
	Population 2.2	Tree 23	Leaf N° P2A23F1 à P2A23F27
		Tree …*	Leaf N° P2A…F…*à P2A…F…*
		Tree 26	Leaf N° P2A26F1 à P2A26F22
	Population 2.3	Tree 27	Leaf N° P2A27F1 à P2A27F24
		Tree …*	Leaf N° P2A…F…*à P2A…F…*
		Tree 31	Leaf N° P2A31F1 à P2A31F40
Plot 3	Population 3.1	Tree 32	Leaf N° P3A32F1 à P2A23F30
	Population 3.2	Tree 33	Leaf N° P3A33F1 à P2A23F32
	Population 3.3	Tree 34	Leaf N° P3A34F1 à P2A34F33
Plot 4	Population 4.1	Tree 35	Leaf N° P4A35F1 à P2A35F41
		Tree …*	Leaf N° P4A…F…*à P2A…F…*
		Tree 38	Leaf N° P4A38F1 à P2A38F36
	Population 4.2	Tree 39	Leaf N° P4A39F1 à P2A39F44
		Tree …*	Leaf N° P4A…F…*à P2A…F…*
		Tree 45	Leaf N° P4A45F1 à P4A45F27
Plot 5	Population 5.1	Tree 46	Leaf N° P5A46F1 à P5A46F35
		Tree …*	Leaf N° P5A…F… à P5A…F…*
		Tree 56	Leaf N° P5A56F1 à P5A56F32
	Population 5.2	Tree 57	Leaf N° P5A57F1 à P5A57F30
		Tree …*	Leaf N° P5A…F… à P5A…F…*
		Tree 66	Leaf N° P5A66F1 à P5A57F30
Plot 6	Population 6.1	Tree 67	Leaf N° P6A67F1 à P6A67F35
		Tree …*	Leaf N° P6A…F1 à P6A…F…*
		Tree 77	Leaf N° P6A77F1 à P6A77F37
	Population 6.2	Tree 78	Leaf N° P6A78F1 à P6A78F33
		Tree …*	Leaf N° P6A…F1 à P6A…F…*
		Tree 80	Leaf N° P6A80F1 à P6A80F33

The dash (…*) represents existing numbers of tree populations and leaves samples but not mentioned in this experimental design for clarity purpose.

Interpretations of the result show eight positive and five negative significant correlations between chemical elements of the soils and biotic factors of *P. africana*. It has been established from the exploitation of Table 3 that.

Table 3. Correlation between the phenotypic characters of *P. africana* and chemical characteristics of the soils

* Coefficient of significant correlation (p<r, on the threshold of 5 %.)

Phenotypic characters of *P. africana* / Chemical characteristics of the soils		height of the first big branch of tree (m)	height of the tree top (m)	circumference of the trunk at 1,30 m (cm)	length of leaf (mm)	width of leaf (mm)	Average number of left veins	Average of number of right veins	Average of Specific weight of leaf (mg)	Average of leaf 's area (mm²)
Organic Matters	Total Organic Mat. (%)	-0 .55	-0.13	0.18	-0.64	-0.41	-0.13	-0.35	-0.20	-0.55
	Organic Carbon (%)	-0.52	-0.20	0.12	-0.54	-0.31	-0.09	-0.31	-0.16	-0.46
	Total Ntrogen (%)	-0.43	-0.73	-0.47	0.10	0.43	-0.06	-0.31	0.24	0.33
	C/N (%)	0.64	0.91*	0.65	0.10	-0.55	0.61	0.60	-0.57	-0.42
Phosphoric Acid -Bray II	assimilable Phosphor us (mg/kg)	-0.27	0.69	0.86*	-0.56	-0.52	-0.23	-0.43	0.02	-0.62
Acidity of exchange	Al^{3+} + H^{+} (cmole/kg)	0.37	0.67	0.50	0.52	-0.07	0.63	0.39	-0.20	0.05
Exchangeable Bases	Ca^{2+} (cmole/kg)	0.17	0.83*	0.87*	-0.52	-0.86*	0.19	0.07	-0.49	-0.89*
	Mg^{2+} (cmole/kg)	0.66	0.75	0.50	0.00	-0.77	0.73	0.68	-0.85*	-0.63
	K^{+} (cmole/kg)	0.46	0.78	0.52	-0.03	-0.65	0.51	0.41	-0.63	-0.18
	Na^{+} (cmole/kg)	-0.05	-0.00	0.18	-0.63	-0.62	-0.01	0.03	-0.44	-0.73
	S (cmole/kg)	0.30	0.87*	0.83*	-0.41	-0.89*	0.33	0.22	-0.61	-0.80*
	T(CEC) (cmole/kg)	-0.10	-0.37	-0.24	0.19	0.04	0.47	0.27	-0.28	-0.02
	V=S/T (100) (cmole/kg)	0.23	0.88*	0.90*	-0.51	-0.77	0.02	-0.00	-0.32	-0.81
Acid / Alkalinity	pH.water-1/2,5	-0.29	-0.79	-0.66	-0.00	0.20	0.06	0.03	-0.10	0.19
	pH.KCl-1/2,5	-0.28	-0.66	-0.45	-0.17	0.06	-0.02	-0.02	-0.10	-0.03

the correlation is positive and significant (r = 0.91*) between the ratio carbone /azote of the soils collected under tree of *P. africana* and the height of the tree top of this forest species. In the normal conditions of atmospheric absorption of carbon, this correlation shows that the increase of nitrogen concentration in the soil stimulates the the longitudinal growth of *P. africana* bole.

The correlation (r = 0.83*) between calcium ions of the soils and the height of the tree top is significantly positive. It is therefore established that the increase in calcium ion's concentration in the soils favored the longitudinal growth of *P. africana*. This result is in conformity with that of Denain (2005) who shown that the main role of calcium is to ameliorate the structure of the soils.

Fig. 1. Stem of P. africana tree in forest plantations

the correlation (r = 0.87*) which existes between the concentration of soufre in the soils and height of the tree top of *P. africana* is significantly positive. This correlation shows that an increase in soil sulphure content stimulates the growth in height of *P. africana*.

the positive and significant correlation between the concentration of nitrogen in the soils conforms to the result of the study carried out by Denain (2005) which noted that those chemical elements are growth's factors of plant including *P. africana*.

Fig. 2. Leaf of an adult *P. africana* tree

the correlation is positive and significant (r = 0.87*) between the ratio (V) of S/T (100) of the soils and the height of the tree top of *P. africana*. This correlation prove that the incraese in the sum of cations in the soils favors the development in the height of this forest species.

the correlation is possitive and significant (r = 0.86*) between the concentration of assimilable phosphore in the soils and the circumference of the bole of *P. africana*. The increase in concentration of assimilable phosphorus in the soils stimulate radial growth of *P. africana*. Phosphorus among others is involved in the transfers of energy for photosynthesis and the degradation of carbohydrates. This element is essential for the development of flowers, early flowering , makes fruits became bigger as well as favors the seeds maturation (Denain, 2005) .

the concentration of the soils in calcium ions is positively and significatively correlated (r = 0.87*) to the circumference of the bole of *P. africana*. The radial growth of bole of this specie is positively influenced by the increase of calcium ions concentration in the soils.

the correlation (r = 0.83*) is significantly positive between the concentration of sulphur ions in the soils and the circumference of the bole of *P. africana*. In other words, soils rich in sulphur favors radial growth of the bole of *P. africana* in forest plantations.

there is positive and significant correlation (r = 0.90*) between the ratio of the sum of cations per cationic exchange's capacity where T stands for total capacity ($V = S/Tx10^{-2}$) and the circumference of the bole of *P. africana*. It is therefore exstablished that the increase of the sum of cations in the soils also stimulates the radial growth of the bole of *P. africana*.

a negative and significant correlation (r = - 0.86*) between the content of soils in calcium ions and the wide of leaves of *P. africana* shows that the incraese of the concentration of calcium ions in the soils stimulates the development in the widen direction of leaves.

A negative and significant correlation (r = - 0.89*) exites between the concentration of sulphur in the soils of experimental plots and width of leaf of *P. africana*. It is therefore, established that from this correlation, the increase in concentation of sulphur in the soils inhibits the width development of *P. africana* leaves.

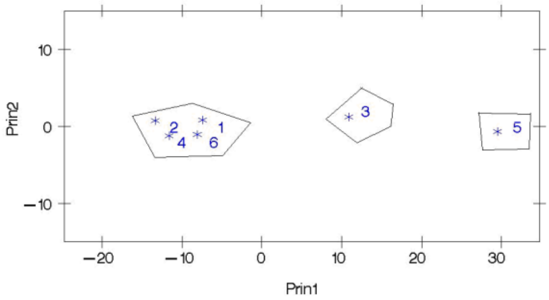
Fig. 4. Stem of P. africana attacked by Coleopterous borers

It has been established that there is a negative and significant correlation (r = - 0.89*) between the concentration of calcium ions in the soils and the leaves area of *P. africana*. This correlation therefore, shows that soils riched in calcium ion inhibit the growth of leave areas of *P. africana*.

the negative and significant correlation (r = - 0.80*) exites between the concentration of sulphur in the soils and the area of leaf of *P. africana*. It result from this correlation that an increase in soil sulphur concentration inhibits the development the area of leaves of *P. africana*.

the correlation is negative and significant (r = - 0.85*) between magnesium ions content in the soils and the specific weight of the leaves of *P. africana*. It is therefore established that a decrease of magnesium ions concentration in the soils favours an increase in specific weight of *P. africana* leaves. Magnesium is a constituent of chlorophyll and plays a very important role in the process of photosynthesis (Denain, 2005).

The multivariable analyse relative to the trunk of tree concerned the height of the first big branch of tree, height of the tree top and the circumference of the main stem. The result of principal components analyses is given in Fig. 5.



Prin1 = Principal composante 1 and Prin2 = Principal composante 2)

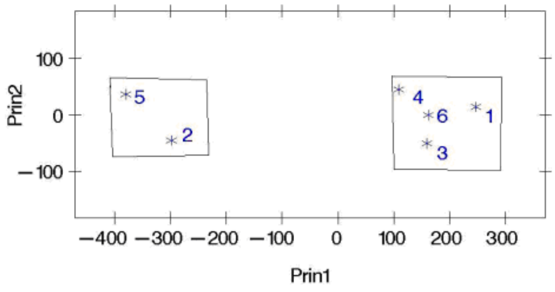
Fig. 5. Graph of multivariable analyses relative to the stem of *P. africana*

The numbers 1, 2, 3, 4, 5 and 6 in the graph representes Plots P1, P2, P3, P4, P5 and P6 respectively. It was observed that phenotypic characters of *P. africana* stem found in Plots P1, P2, P4 and P6 are similar and constitute the first group. P3 and P5 form respectively the second and third group.The plots of the first group are found in the North-West Region..The similarities between the phenotypic caracters of *P. africana*'s in plot P3 situated in the South-West Region, hundreds of km from Plot P5 may be justified by genetic links of seeds used during the creation of tree plantations sampled in this study.

The early development of the first big branch of the tree may be due to the slight competition of the stem of *P. africana* concerned with the other surrounding trees. In Plots P2, P4, P5 and P6 distance between one tree and the next is more than 25 m

The multivariable analyses relative to the leaves had to do with the lengtht and width, the number of veins in the left and right side of the mid rib, the spectiic weigth and their areas. The resultat is given (Fig. 6).

The group of trees from Plots P2, P5 and those of P1, P3, P4 and P6 have leaves with approximatively identical phenotypic characters. This grouping of *P. africana*'s phenotypic characters established through analyses of biometric measurements is so close and confirms the result of Dawson and Powell (1999) who have shown that there is a slight varaiation between the *P. africana*' s populations of Cameroon.



(Prin1 = Principal composante 1 and Prin2 = Principal composante 2)

Fig. 6. Graph of multivariable analyses relative to the leaves of *P. africana*

Conclusion and perspectives

According to the results of the present study, longitudinal growth of *P. africana* stem highly correlated with the concentration of soil in nitrogen, calcium and sulphur in its natural geographic zones. The soils with higher assimilable phosphorus content favour the radial growth of the stem of this species. *P. africana* is a calcifuges plant with regards to the growth of the leaf area.

This result is a pertinent tool for choosing appropriate soils and for sustainable management of *P. africana* plantations with respect to the yield related to a precise phenotypic character.

In perspective, the other study on the correlation between soil's factors and the active matter contents such as ß-sitosterol found in *P. africana*'s back would help to improve the management plan of this useful but vulnerable tree in the natural forest of Cameroon.

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