Influence de *Cassia sieberiana* DC (casse de Sieber, Fabacées) dans quelques propriétés physico-chimiques du sol du terroir de Fandene, Sénégal

Abstract

Senegal is facing increasing soil degradation, particularly in arid and semi-arid zones. This degradation is largely due to climate change and inappropriate farming practices, which have led to a decline in soil fertility and lower agricultural productivity. To enhance soil fertility, certain legumes such as *Cassia sieberiana* DC are seen as a potential solution. Despite their socio-economic, ecological and medicinal importance, research into the species' specific effects on soil fertility remains insufficient and patchy. This study aims to assess the influence of *Cassia sieberiana* on certain physico-chemical soil properties. Soil samples were taken from natural *Cassia sieberiana* stands in Fandène in three diameter classes, under and above the crown, and at two depths. Soil physico-chemical parameters were measured. Results showed that soil texture under *Cassia sieberiana* is silty-clayey-sandy. The results showed a highly significant effect of diameter class, radius, depth and class-depth and radius-depth interactions on carbon, organic matter (OM) and nitrogen (N). However, pH varies with depth. Electrical conductivity (EC) varies with depth and interactions. The results show that C and OM contents are highest at 2/3R of the crown, at diameter class (C2) and at a depth of 0-20cm. These results underline the importance of sustainable management of this tree in agroforestry systems to combat soil degradation and improve agricultural productivity.

However, it would be interesting to study the effect of the species on cation exchange capacity (CEC), calcium (Ca), potassium (K), magnesium (Mg), sodium (Na) and sulfur (S).

Key words: Fandene, *Cassia sieberiana* DC, Soil physico-chemical parameters, Tree crown, Depth, Diameter classes, Silty-clay-sandy texture.

Introduction

Cassia sieberiana DC., a small tree found in the Sudano-Guinean and Sudanese savannahs belonging to the Caesalpinioideae subfamily (Fabaceae family)[1] is a small tree 8 to 10 metres tall with a short trunk. It is usually branched near the base and characterised by its flexible, drooping branches. Its bark is brownish and turns blackish with age. The leaves are compound, paripinnate with 6 to 10 pairs of leaflets, opposite, alternate, dark green in colour, oval or oblong, with a rounded base and a wedge-shaped tip. Its flowers are golden yellow and appear in very long, drooping terminal racemes (25 to 40 cm). Beautiful, large clusters completely cover the tree in March-May. The fruits are long, cylindrical pods up to 40-60 cm long and 10-15 mm in diameter, straight, dark brown or blackish, and persist on the tree for a long time[2,3]. Its seeds vary in colour from greenish brown to dark brown with a smooth surface and may have small brightly coloured stripes on the outer surface[4]. *C. sieberiana* is a multi-purpose species[2]. The leaves, roots and pods of *Cassia sieberiana* are commonly used in traditional medicine[5]. The species is certainly one of the plants most often cited for its purgative and diuretic properties[6]. In Uganda, powder from various plant parts is applied to the teeth to treat toothache. Mixed with butter, it is used to treat skin diseases. Extracts from *C. sieberiana* leaves are very effective at killing the Plasmodium falciparum parasite, as this protozoan parasite is one of the most dangerous human pathogens, responsible for the most severe forms of malaria[7]. *C. sieberiana* has a high content of calcium oxalate crystals in addition to other phytochemical compounds such as quercitrin, isoquercitrin and rheine, anthraquinones, flavonoids, saponins, steroids, terpenoids, tannins, cardiac glycosides, and reducing sugars. The triterpenoids and polyphenols (flavonoids and tannins) found in the roots of C. sieberiana are responsible for its antiparasitic effect[8]. In Benin, the twigs are used to treat sleeping sickness, etc. [9]. *C. sieberiana* leaf accelerates banana ripening[10]. The species likes the moist, well-drained soils of forest galleries in regions with at least 500 mm of annual rainfall. It also grows as bushes on lateritic or arid sites, often in groups[2]. It can be planted singly on farms at a spacing of four metres or more. The interaction of trees and shrubs with the soil can influence its physical, chemical and biological properties, thereby affecting its structure, fertility and ability to provide ecosystem services. Trees increase soil cover through litter and pruning residues, form partially permeable hedgerows, particularly against wind, lead to the gradual development of terraces through the accumulation of soil upstream of hedges, stabilise soil structures through their root systems, and reduce runoff [11]. Plant growth is strongly influenced by soil structure, but the reverse is negligible[12]. Soil fertility encompasses the biological, physical and chemical properties of the soil and represents its ability to maintain favourable conditions in these properties in order to facilitate sustainable plant growth. Many authors refer to increases in the carbon (C), nitrogen (N), cation and assimilable phosphorus content of the soil under tree canopies, which constitute islands of fertility in the savannahpH is a parameter that plant roots can directly modify through multiple processes, including mainly root respiration, the excretion of root substances from trees and crops, and the release of H+ and OH- to compensate for a net excess of cations or anions[13, 14]. Research by Dalila confirms that crops sown on soils that have formed under tree cover compared to those on uncovered control plots highlight the role of trees in improving soil fertility[15]. Soil nutrient concentrations as a function of distance from trees indicate significantly higher levels of carbon, nitrogen, phosphorus and potassium under tree canopies than outside them[16]. In general, concentrations of these elements decrease with distance from the tree and with soil depth[17]. The effect of legumes on improving soil carbon and nitrogen content, thereby promoting the fertility and productivity of agricultural soils[18]. It is accepted that green manures such as legumes provide nutrients to the soil to improve its chemical properties and crop yields[19]. They can provide shelter for soils, plants and livestock and increase the organic matter and sometimes nitrogen content of the soil[20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30]. The contribution of organic matter from biomass produced by agroforestry systems affects nutrient recycling. However, some species emit substances that can affect the development of weeds and also certain crops by depleting soil resources, as is the case with *Eucalyptus*[31]. Although the benefits of *Cassia sieberiana* are recognised, documentation of the species' impact on the physico-chemical characteristics of soils remains limited and fragmented[25], unlike other species such as *F. albida, V. paradoxa* and *P. biglobosa*. However, it is known that the species is a non-nodulating legume. The objective of this study is to evaluate the influence of Sieber's cassia on certain physico-chemical parameters of soils. The research question that could arise from a study is as follows: do diameter class (factor 1) and distance to the tree (factor 2) influence soil parameters at depths of 0-20 cm and 20-40 cm ?

Material and methods

Presentation of the study area

The study was conducted in the municipality of Fandene, in the Thiès region (14° 27′ N, 16° 55′ W), which is characterised by a Sudano-Sahelian climate with a long dry season and a rainy season lasting just over three months (Figure 1). The region is influenced by maritime trade winds and the harmattan[32]. The soils are ferruginous and hydromorphic. The vegetation consists mainly of degraded shrub savannah, with monospecific stands of *Acacia seyal*, *Adansonia digitata, Faidherbia albida and Borassus aethiopum*. Rainfed agriculture is the main activity, practised by almost the entire population.

Tree selection

An inventory was carried out in the wooded parks in *C. sieberiana*. Trees with a diameter of ≥5 cm were measured using a forest compass. The dendrometric data recorded in inventory sheets and then entered into an Excel spreadsheet enabled the trees to be classified according to their size into three (03) classes: C1 (5-15 cm) ; C2 (15-25 cm) and C3 (>25 cm). For each diameter class, three (03) individuals were chosen at random, for a total of nine (09) individuals. These individuals were geolocated using a GPS and then marked with paint. For each tree, the crown radius was determined using a tape measure. A digital camera was used to visually document the environment, plant specimens and soil conditions. Soil samples were taken at four levels: 1/3 of the radius, 2/3 of the radius and 3/3 of the radius, and outside the crown (control) using an auger at two (02) depths: 0-20 cm and 20-40 cm. The total number of samples is estimated at 72, with 36 sampling points (3 diameters x 3 trees/diameter x 4 distances to the tree x 2 depths). The samples were then placed in bags numbered with a marker and sent to the soil science laboratory of the high national school of agriculture (ENSA) in Thies, Senegal, for complete analysis.

Physicochemical analysis of soil samples

Measurements were taken for pH, electrical conductivity (EC), particle size distribution (sand, clay, silt), organic carbon (C), and nitrogen (N). The samples were air-dried and then sieved to 2 mm. Particle size analysis was performed using the Robinson pipette method. Soil pH was determined using the potentiometric method with a pH meter in an aqueous extract with a soil/water ratio of 1/2.5. Electrical conductivity was determined using a conductivity meter. The organic matter content was assessed using the modified Anne method (spectrophotometry). The carbon content (ppm) was read using a spectrophotometer at a wave length of 600 nm.

Data processing

The physicochemical data were subjected to two two-factor analyses of variance, one performed on the 36 observations at 0-20 cm, the other on the 36 observations at 20-40 cm using XLSTAT 2013. The Tuckey test was performed to compare the means. The data were also used to develop the textural triangle using the GEPPA sigales 2020 database.

Results

Physical characteristics of soils under the influence of *C. sieberiana*

The analysis of variance showed no significant difference between treatments (class, rays) for almost all of the variables studied. A significant effect between C2 and C3 in relation to total sand content was detected (Table 1). The highest silt and sand contents were found in class C2. However, clay contents were low in all classes (2.9%, 2.3% and 1.1%).

The texture triangle of the different samples taken shows a silt-clay-sand or sand-silt texture under the canopy and outside the canopy.

Chemical characteristics of soils under the influence of *C. sieberiana*

Variations in soil pH and electrical conductivity values

Table II illustrates the analysis of variance of soil pH and electrical conductivity values. A significant effect of diameter classes on pH was observed. The highest pH values were found in C1, followed by C2 and C3 respectively. No significant difference was detected between crown radii and sampling depth on pH.

Table II shows that diameter classes and crown radius have no effect on EC.

Variations in soil organic carbon (C) and total nitrogen (N) content

C, N and C/N contents are recorded in Table III. An effect of diameter class on C was observed. An effect of crown radius on C and N was detected. The highest C (1%) and OM (2%) contents were observed in C2. Class C3 had the lowest C and OM contents. C (1.87%) and OM (0.93%) contents are higher at a depth of 0-20 cm. At 20-40 cm, the C and OM contents are 0.86% and 0.43% respectively. They are also much higher at 2/3R, followed by 3/3R and 1/3R. The control (outside the crown) gave the lowest C and OM values.

Nitrogen and the C/N ratio follow the same trend as organic carbon for the diameter classes and sampling depths. However, N levels are higher outside the crown (0.09%) of Cassia sieberiana than under the crown (0.07%). Depending on the radius, 1/3R recorded 0.08% and 2/3R and 3/3R each gave 0.06% N.

Influence of interactions on the physicochemical parameters of soils

Table V shows the variations in chemical parameters according to interactions between diameter classes and radius. For each diameter class, significant variations are observed according to depth. The pH is generally higher at the surface (0-20 cm) than at depth (20-40 cm), particularly in class C2, while the pH remains almost constant in C3.

Electrical conductivity is higher in the surface layer, especially at 1/3 R. At 2/3R with a depth of 0-20 cm, EC reaches 54.189µS/cm. Nitrogen follows a similar trend, with higher concentrations at the surface and decreasing with depth. The C/N ratio decreases slightly with increasing radius and depth, reflecting variations in carbon and nitrogen concentrations.

For class C1, the values of the chemical parameters are relatively moderate at 1/3 R. At 2/3 R, a notable increase in EC, carbon and organic matter is observed. These values decrease at 3/3 R. At C2, EC, carbon and organic matter concentrations are high at 2/3 R. For C3, variations in chemical parameters as a function of radius are less pronounced, but an overall decrease in carbon, organic matter and nitrogen concentrations is observed at higher radii.

Discussion

Physical characteristics of soils under the influence of Cassia sieberiana

The significant difference observed between C2 and C3 for sand could be related to the gradual development of the Cassia sieberiana root system and its ability to trap and retain soil particles over time. The absence of significant differences based on crown radius suggests that the influence of Cassia sieberiana on soil texture is relatively uniform around the tree, which corroborates the work of[12].

Chemical characteristics of soils under the influence of Cassia sieberiana

Effect of diameter classes

Although moderate, the soil acidity caused by Cassia sieberiana is more pronounced in trees belonging to C3. This difference could be related to the accumulation of organic matter and the degradation of leaves and roots, which release organic acids into the soil. Diameter classes significantly influence pH, carbon (C), organic matter (OM), nitrogen (N) and the C/N ratio. These results corroborate those of [33], which show that trees of different diameters can have different root systems and litter inputs, thereby altering the chemical composition of the soil under the canopy. Larger trees can store and recycle more nutrients. C2 class trees have the highest C and OM contents, which could be attributed to their growth stage and maximum biomass accumulation[34]. In contrast, trees in class C3 have lower values, which may be due to less advanced development or faster litter decomposition. These results confirm the work of[12].

Effects of canopy radius

In the nutrient cycle through soil-plant systems, plants cause changes in the spatial distribution of nutrients, organic matter and other ecosystem properties due to their physical presence and concomitant influences[17]. Indeed, C and OM are higher at 1/3R and 2/3R. However, the results reveal that N is higher as one moves away from the trunk. Cassia is a non-nodulating legume. Our results corroborate those obtained by [36] under *Balanites eagyptiaca* and [37]with *Vitellaria paradoxa* concerning carbon and organic matter, but contrary to nitrogen. The high N contents outside the canopy could be explained by conditions favourable to nitrogen-fixing bacteria or other soil microorganisms that contribute to higher nitrogen levels.

Effects of depth

A highly significant effect of depth on all variables studied except pH was observed. C and OM levels decrease with depth due to reduced OM inputs and microbial activity in deeper layers [38]. The same trend was reported by [39] under *Piliostigma reticulatum*. pH is less affected because it is often more stable and influenced by factors such as parent material and drainage conditions [40, 17]. Overall, the results indicate that the study area (site) is not very fertile. Improving the Corga content under the canopy makes it possible to exceed the theoretical critical threshold of 1.5% OM but not to exceed the minimum threshold of 2.5%. The decrease in pH under the C3s is slight but falls below the aluminium acidity constant (= 5.5), which could be unfavourable (aluminium toxicity) for crops.

Conclusion

The study conducted on the influence of *C. sieberiana* DC on the physicochemical properties of soils in the Fandene region highlighted several key points concerning soil fertility under this tree species. The main objectives of this research were to assess the variability of fertiliser content under and outside the canopy of *C. sieberiana*, to determine these levels according to crown radius and diameter classes, and to examine the variation according to sampling depth.

The results show higher levels of organic carbon (C) and organic matter (OM) under the canopy than outside it. They are also higher at C2, two-thirds of the way up the canopy, at a depth of 0-20 cm. However, nitrogen (N) levels increase as one moves away from the trunk. The levels of physicochemical parameters vary according to depth. The highest levels were observed at 0-20 cm, except for pH. These high surface levels confirm the vertical gradients typical of forest soils. These results confirm hypotheses 1, 2 and 4 and refute hypothesis 3.

This study highlights the ecological importance of *C. sieberiana* in soil fertility management in arid and semi-arid environments.

In light of the results, the following recommendations are proposed:

- promote the sustainable management of Cassia sieberiana for the enhancement of marginal land, as a barrier against desertification, and for erosion control ;
- continue research on other chemical properties ;
- raise awareness among farmers and local populations about the ecological and agronomic benefits of *C. sieberiana*.

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List of tables

***Table I**: Analysis of variance of the different soil particle size fractions*

Diameter classes	clay %	Total silt %	Total sand %
C1	2,94 [a]	26,61 [a]	70,44 [ab]
C2	2,27 [a]	29,75 [a]	76,98 [b]
C3	1,08 [a]	21,93 [a]	67,97 [a]
Pr > F	0,346	0,065	0,043
Crown radii			
1/3R	3,396 [a]	24,695 [a]	71,909 [a]

2/3R	1,899 [a]	25,131 [a]	72,970 [a]
3/3R	0,854 [a]	28,718 [a]	70,428 [a]
T	2,242 [a]	25,872 [a]	71,886 [a]
Pr > F	0,401	0,741	0,953

Table II: *Analysis of variance of soil pH and electrical conductivity values*

Diameter classes	**(pHeau 1/ 2,5)**	**(CE 1/ 10 µs/Cm)**
C1	5,68 [a]	27,8 [a]
C2	5,59 [ab]	33,41 [a]
C3	5,43 [b]	28,19 [a]
Pr > F	**0,01**	**0,63**
crown radii		
1/3R	5,49 [a]	27,49 [a]
2/3R	5,59 [a]	36,38 [a]
3/3R	5,55 [a]	26,72 [a]
Pr > F	**0,456**	**0,558**

The averages marked with the same letter on the same line are not statistically different at the 5% level.

Table III: *Analysis of variance of organic matter, carbon and total nitrogen contents in soils*

Diameter classes	**(%C)**	**(OM %)**	**(N %)**	**(C/N)**
C1	0,63 [b]	1,27 [b]	0,07 [b]	8,79 [a]
C2	1,00 [a]	2 ,00 [a]	0,10 [a]	9,564 [a]
C3	0,41 [b]	0,82 [b]	0,050 [b]	7,24 [b]
Pr > F	**0,01**	**0,03**	**0,001**	**< 0,0001**
crown radii				
1/3R	0,77 [b]	1,77 [b]	0,06 [a]	8,79 [a]

2/3R	0,89 [b]	1,53 [b]	0,06 [a]	8,81 [a]
3/3R	0,56 [a]	1,13 [a]	0,08 [b]	8,14 [a]
T	0,51 [a]	1,02 [a]	0,09 [b]	8,39 [a]
Pr > F	**0,005**	**0,005**	**0,005**	**0,47**

The averages marked with the same letter on the same line are not statistically different at the 5% level.

List of figures

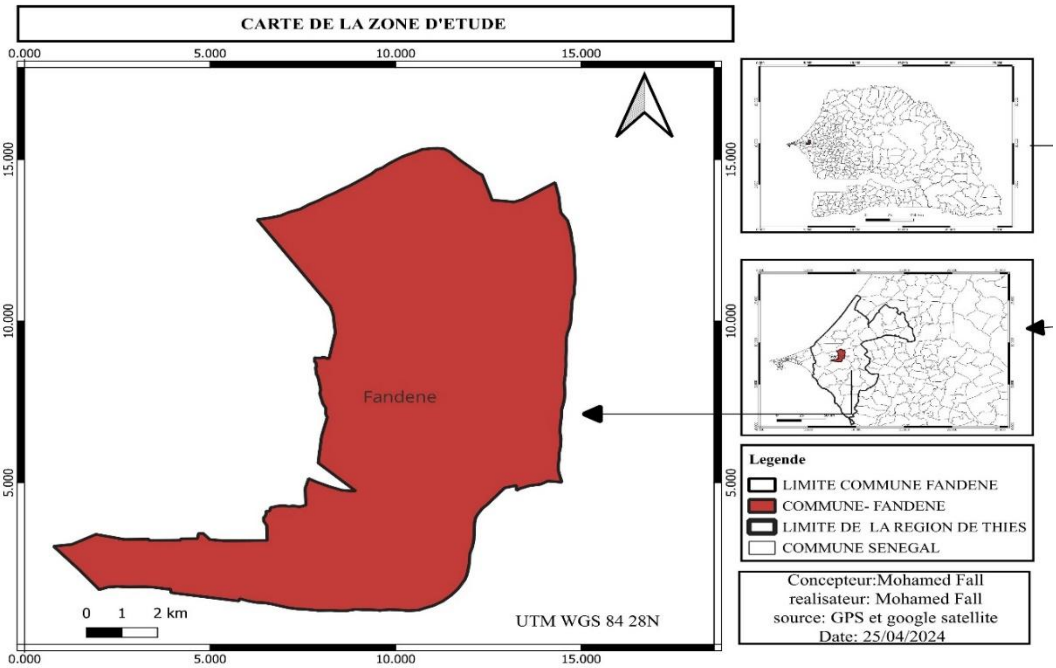

Figure 1: *Map of the study area*

List of photos

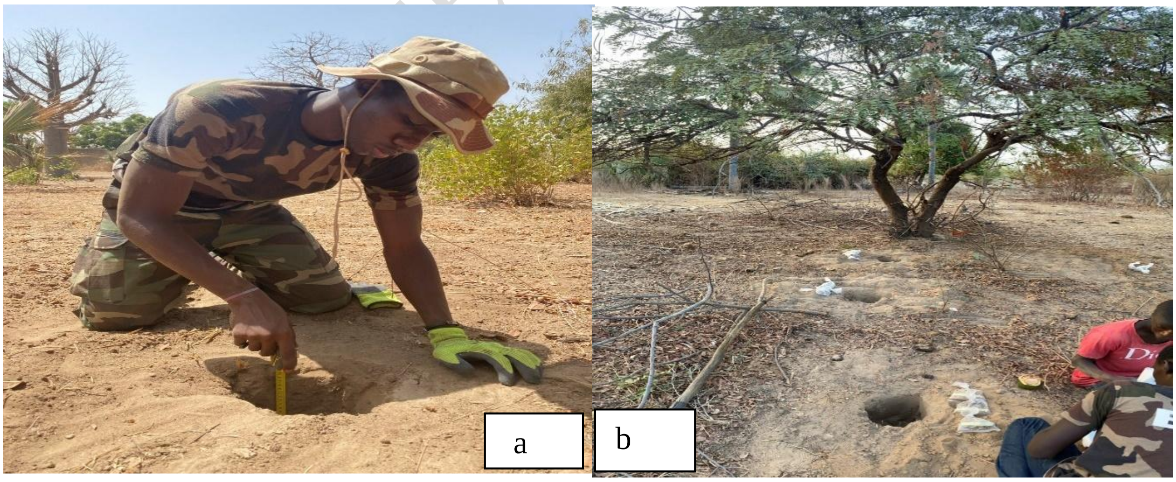

Photo 1: *measuring profile depth (a) and arranging profiles according to the different radii of the crown (b)*