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Contribution of Tree Legumes in the Production Dynamics of Yellow Yam (*Dioscorea cayenensis Lam*) in the South Cameroon Plateau

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***Abstract*— *The overexploitation of agricultural soils as a result of the increased need for food by local populations is leading to serious dysfunctions in land restoration. These dysfunctions, aggravated by climate change, require the implementation of ecological engineering strategies to rehabilitate the soil. The soils of the South Cameroonian plateau suffer significant degradation in terms of loss of fertilizing elements due to extensive agricultural practices, which limits agricultural production. This work showed how tree legumes contribute to improving the yield of yellow yam (Dioscorea cayenensis) in the South Cameroonian plateau, to ultimately support the production of agroecosystems in this environment. Within the framework of this study, an experimental set-up was designed to measure the performance of tree legumes in the field. The experimental set-up is a randomized complete block trial with three treatments and three replications on 3000 m2. The control plot without shrubs, the plot with Calliandra, and the plot with Senna. This trial was carried out in the district of Mbankomo, Mefou, and Akono Department, Central Region. After monitoring the experiment, it was found that Senna spectabilis produced more nutrients than Calliandra calothyrsus. Thus, each Senna shrub produced 1.54 kg of litter in the first year and 2.04 kg in the second year for a quantity of nitrogen of 192.76 kg/ha and 260 kg/ha respectively in the first and second year. Each Calliandra shrub produced 1.46 kg and 1.87 kg of litter for a nutrient amount of 183 kg/ha and 236.81 kg/ha of nitrogen during the two years of the experiment. The combination of tree legumes and field crops increased yam yields by a factor of 2 or 3 compared to traditional agriculture. The growth rate of the yam is accelerated as well as its vegetative cycle, which is reduced from 7.5 months to 6 months as a result of the increase in soil organic matter through the shrub legume litter. Agroforestry practices could have a positive impact on soil characteristics and microbial communities, resulting in enhanced soil fertility and long-term sustainability of agricultural production. According to the results obtained, the insertion of tree legumes in agrosystems is a more efficient and less costly way to gradually and sustainably increase nitrogen availability and soil fertility.*
***Keywords*— South Cameroon Plateau, shrub legumes, litter, yellow yam, agrosystems.**

I. INTRODUCTION

The South Cameroon plateau is a vast platform that extends between the 2nd and 6th degrees of North latitude and between the 2nd and 6th degrees of East longitude. It comprises three administrative regions of Cameroon: the Centre, the South, and the East. The South Cameroonian plateau is bordered to the North by the Adamaoua plateau, to the East by the Central African Republic, to the West by the western highlands and the coastal plain, and to the South by Equatorial Guinea, Gabon, and Congo (Camerecole.org). It is also a vast erosion surface sloping towards the Congo basin in the southeast, in the west it ends abruptly with an escarpment dominating the coastal surface. Its average altitude is about 650 m, but in Yaoundé, it is close to 750 m.

The South Cameroonian plateau has an equatorial climate of the Guinean type, characterized by constant temperatures (24 to 26°C), abundant rainfall, and the existence of four seasons: a long dry season from December to February, a short rainy season from March to May, a short dry season from June to August and a long rainy season from September to November. The entire southern Cameroonian plateau receives an average of 1,500 to 2,000 mm of rainfall per year, although some areas are relatively deficient due to the continental nature of the region and deforestation [1]. However, with the phenomenon of climatic disruption observed over the last few decades, the dry season has tended to lengthen to the detriment of the rainy season. This climatic disruption leads to a disruption of the rainfall calendar with the appearance of extreme phenomena and consequently a disorganization of agricultural activities. All this has effects on human health [2].

In this geographical area, there are extremely complex ferralitic soils that cover 2/3 of the country and have been in place for millions of years. These are nutrient-poor, acidic, and fragile soils. They are largely covered by forest, very permeable, and rich in humus [1]. These soils have suffered significant degradation in terms of loss of fertilizing elements due to extensive agricultural practices [3].

Agriculture remains the mainstay of the economy in this area and employs more than 50% of the working population in the Centre, nearly 75% in the East, and around 80% in the South (Camerecole.org). A wide variety of products are grown, both for export (cocoa, coffee) and for food (plantain, yams). Food crops are grown in fields where mixed cropping is common for production intended primarily for self-consumption. But increasingly, they are sold on domestic and sub-regional markets.

Cropping techniques and systems, as well as poor soils, contribute to reduced productivity and increased malnutrition, and poor living conditions for people. It can be seen that yam plays an important role in the food security of at least 60 million people [4], [5], [6]. However, there is rapid soil depletion accelerated by a significant erosion of cultivated plots leading to reduced productivity and yam production, coupled with the high cost and scarcity of imported chemical fertilizers [6].

To overcome these difficulties, the importance of shrub legumes with high nitrogen fixation capacities such as *Calliandra* and Senna becomes obvious, especially for regions where soils are generally fragile as in the southern plateau of Cameroon. Symbiotic nitrogen fixation by these legumes is also becoming an essential element of policies to limit the importation of nitrogen fertilizers, whether for economic, ecological, or agrosystem sustainability reasons [7], [8].

To improve yam yields and effectively combat soil infertility in the southern plateau of Cameroon, it was necessary to conduct a study on the contribution of tree legumes to yam production, using *Calliandra calothyrsus* and Senna spectabilis as species in the locality of Mbankomo in the Central Region.

II. MATERIALS AND METHODS

2.1. Materials

2-1.1. Location of the study site

The study was carried out in the Centre region, in the Mefou and Akono departments, and in the Mbankomo district, which is a locality in the secondary forest zone that has been degraded by urbanization and anthropization of the environment [9], [10]. The vegetation is characterized by tree species and swampy lowlands. The main forest species found in the area are Terminalia superba, Entandrophragma cylindricum, Baillonella toxisperma, Milletia exelsa, Disthemonianthus benthamianus, Triplochiton scleroxylon, Ceiba pentadra. The fallows are mainly colonized by Musanga cecropioides, Eupatorium sp., and Chromolaena odorata.

(Figure 1).

Fig.1: Localization map.

2.1.2. Materials used

The field equipment used in the framework of this work is made up of the A-frame for the measurement of the contour lines, the stakes to delimit the surface to be cultivated, the hoes for the making of mounds for the cultivation of the plant material and to fight against erosion. A strong, machetes, a triple decameter, stakes, an auger for various soil samples in the study site, a dendrometer to measure the height of the trees, gloves, boots, and a helmet to protect the hands, feet, and head, and tarpaulins to collect the leaves after pruning the shrubs.

The plant material consists of *Senna spectabilis* and *Calliandra calothyrsus* seeds for the shrub hedges, and yam seeds as a specimen to be cultivated in the experimental plots. The seeds of these shrubs are obtained from pre-existing trees and the traditional variety of yam seeds are obtained in the Mokolo market in Yaoundé and the mass of these seeds varies between 350 and 500g.

The laboratory equipment consists of sieves with different mesh sizes (2 mm, 0.5 mm) composed of metal support that encircles the screen or sieve and a soil conservation device. The sieve allows the removal of elements such as roots and other elements that are not part of our study. The conservation device maintains the soil with all the living organisms in it.

Each plant material (yam seed, leaf biomass of each legume, crop) is weighed using a commercial price-weight scale brand 56PPI. In addition, microbalances are used for weighing to the hundredth of a milligram, and an analyzer for chemical analysis of the crushed and dried leaf samples, an oven.

2.1.3. Experimental design

The experimental set-up is a randomized complete block trial with three treatments and three replications on 3000 m2. There is the control plot, the *Calliandra* plot, and the *Senna* plot. Each block covers an area of 1000 m2, containing the three treatments and representing one replication. Block 1 is located at Eloumden I (3° 29' N and 11° 16'E), Block 2 at Eloumden II (3° 50'N and 11°26'N), and Block 3 at Ekoko (3°49'N and 12° 7'E) [11].These trials were continued [12], and were conducted for two years on the same plots with the same treatments but with different doses of litter.

The different sites were chosen based on criteria such as the rapid increase in population in the locality of Mbankomo, galloping urbanization, a decrease in cultivable land, overexploitation of the soil, and a drastic decline in soil fertility [13]. The experiment takes place at the beginning of each rainy season. The preparation of the different plots is done manually with a hoe. But before this, the plots are already marked out and planted with shrubs. The control plot without shrubs covers an area of 190 m2 (Fig. 2), where yams are planted on mounds 40 cm high and spaced 1 m apart in all directions [14], [15].

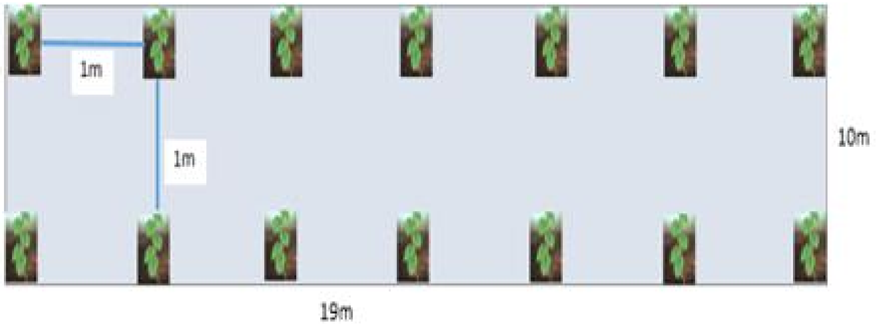

Fig.2: Experimental set-up of the control plot (PT)

The *Calliandra* and *Senna* plots (Fig. 3) are separated from each other by 3 m and cover a usable area of 190 m2 each, i.e. the area planted with yams without taking into account the space occupied by shrubs. The yams are planted at a density of 1m between plants and 1m between rows. The bushes are 50 cm apart in the rows and 6 m between rows.

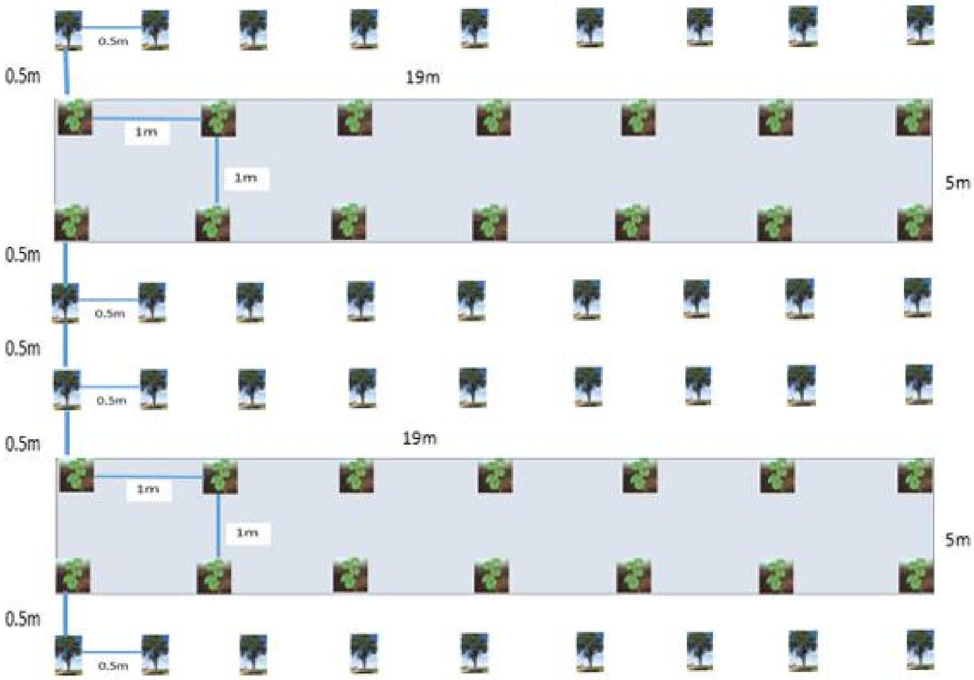

Fig.3: Legume Experimental plot dispositive [16]

2.2. Method

2.2.1. Burial of litter

In the plots planted with shrubs, each plot receives a dose of litter that will be buried at a depth of 15 cm. The dose is defined in advance and is 8 t/ha in the first year and 10 t/ha in the second year [17]. These different doses correspond to 152 kg and 190 kg in the first and second year respectively for each plot, namely the *Calliandra* (Pc) and *Senna* (Ps) plots. Two weeks after plowing in the organic matter [18], soil samples are taken before yam planting at 0-15 cm depth [19], using an auger following a Z pattern [20].

The yams are planted at a density of 1 m between plants and 1 m between rows on 40 cm high mounds.*Calliandra* and *Senna* are chosen based on their characteristics. These shrubs are fast growing, have a deep root system, abundant foliage, and provide stakes for yams. They fix atmospheric nitrogen (*Calliandra*) and tolerate acidic soils. This system was set up in August 2016 with the planting of shrubs from the nursery set up in June 2016.

The planting of shrubs that have reached 10 cm in height is done on contour lines, using the A-frame, at a distance of 6 m, following the spacing of 50 cm [21]. The height (H, m) of these shrubs is measured using both a triple decameter and a vertex electronic dendrometer, every two months on ten plants [19]. The first pruning took place in February 2017 and the second in February 2018 when the shrubs had reached heights of 3.5 m and 6.1 m for *Calliandra* and 4.25 m and 8.7 m for *Senna*.

2.2.2. Obtaining leaf biomass (litter)

Ten trees were selected based on their diameter for the estimation of leaf biomass. At the time of pruning, the diameter of *Calliandra* trees was between 15 and 18 cm and that of Senna trees between 22 and 24 cm. The biomass of the aerial compartments (leaves) was estimated from sampling based on the method described by [22]. Destructive sampling of shrubs was carried out. These shrubs were pruned to 50 cm from the ground [21] and the collected samples were used to estimate the leaf biomass. The leaves of these legumes were collected by dropping them on a large tarpaulin and weighing them. The branches are discarded to avoid cluttering the plot and are not included in the fertilizer.

2.2.3. Determination of nutrients in Calliandra and Senna leaves

To determine the nutrient content of *Calliandra* and *Senna* leaves, six months after planting and one year after the first pruning, the leaves were collected and the plant samples were dried at 65°C in ovens at the IITA laboratory in Nkolbisson, the evaluation of the nutrients was done by grinding the dried leaves. An aliquot of each ground sample is sent to the laboratory where it is further ground. A 3.5 mg test sample is weighed to the hundredth of an mg on the MX5 Mettler Toledo and MC5 Sartorius microbalances. The chemical analyses of the plant samples were carried out with the NCS 2500 Thermo Quest analyzer.

2.2.4. Chemical analysis of soils

Chemical analyses were carried out at the IITA laboratory in Nkolbisson using the following methods: soil samples were dried and crushed and then sieved using a 2 mm mesh sieve. For C and N, the soil samples were further crushed and sieved using a 0.5 mm mesh sieve. The pH-water is determined at 1:2.5 (w/v) of the suspended water. Organic carbon is determined by the chromic acid digestion method and by spectrophotometric analysis using the UV-VIS spectrophotometer [23].

Total nitrogen is determined by wet acid digestion [24] and analysis is done by colorimetry [25]. Exchangeable cations (Ca, Mg, K, and Na) are extracted using the Mehlich-3 procedure or method and determined by flame atomic spectrophotometric absorption (FAS). CECs are extracted using ammonium acetate at pH 7 and analyzed by colorimetry. Exchangeable acidity is extracted using 1M KCl and quantified by titration.

2.2.5. Shrub legume litter and yam production

2.2.5.1. Monitoring of yam growth

To monitor the growth of the aerial system of yam in each treatment on ten individuals, the criterion used is the evolution of the sum of the lengths of the aerial axes as a function of time [26]. Every 10 days after emergence, the length of each aerial axis is measured on a given individual, using a string applied along the winding of the axes. This staggered measurement could not be maintained throughout the growth period in some series where a large number of plants were highly developed and branched at the same time. The absolute error is of the order of one cm (main axis), and several cm (lateral axes). Growth is said to be linear when the increase in dimension Δ 1 is proportional to time. We have constant dl/dt. The successive values of the measured dimension are arranged on a straight line as a function of time. The linear growth phase is preceded by an accelerated growth phase and followed by a slow growth phase.

2.2.5.2. Evaluation of yam production

To assess yam production, ten plants per plot were harvested in the Z pattern and weighed using a commercial price-weight scale, brand 56PPI. The total mass of yam per plant is subtracted from the mass of seed used at planting to assess the gain or performance of the cropping system. The masses per plant and per plot are added together and divided by 10 to give the average mass of a plant. This mass is multiplied by the total number of plants per plot in kg/m2, then reduced to the hectare by multiplying by 10,000 to obtain the yield in tones/ha (paden@paden-senegal.org / www.paden-senegal.org).

2.2.6. Statistical analysis

Statistical analyses were carried out in three replications and the results are expressed as means plus or minus standard deviation. The data were analyzed using the ANOVA test and the Posthoc LSD test for multiple comparisons. The paired Student's t-test was used for pairwise comparisons. IBM/SPSS 20 for Windows was used at the 5% significance level. Microsoft Office Excel 2013 was used for graphical representations. Significant differences between treatments were observed in the number of nutrients returned to the soil via the application of litter from the shrub cut. The differences between the treatments in soil fertility and productivity were noted.

III. RESULTS AND DISCUSSION

3.1 Results

3.1.1. Growth of Calliandra calothyrsus Meisn.

Calliandra calothyrsus is a fast-growing shrub legume, its regeneration and management are simple. On impoverished and degraded soils, their germination does not require special fertilization. When *Calliandra* is associated with crops, it must be constantly pruned to prevent its shading from competing with the associated crops. The growth of tree legumes such as *Calliandra* differs from one area to another depending on soil, rainfall, and light. After transplanting *Calliandra*, a growth of 61.08 cm was obtained after 60 days i.e., from August to October 2016.

Shading considerably affects the growth of this legume if it is important for the plot to be cultivated. After the fourth month of our experiment, this growth was accelerated from 61.08 cm to 204.52 cm, an additional increase of 143.44 cm. In February 2017, the total growth of *Calliandra* was 299.37 cm with a standard deviation of 1.21 (Table 1). It appears that *Calliandra* which has a deep root system allows other crops to grow easily as a well-maintained leguminous hedge takes in the deep soil horizons and maintains a state of relative moisture in the organic horizon.

Table 1: Height of Calliandra (cm)

Date	Aug. 6, 2016	Oct.5, 2016	Dec. 5, 2016	Feb. 5, 2017
Height	10.12 ± 0.03^{a}	61.08 ± 0.34^{b}	204.52 ± 1.04^{c}	309.37 ± 1.21^{d}

Values are expressed as mean ± standard deviation (n = 3). Values with the same letter on the same line are not significantly different ($p > 0.05$).

When growing *Calliandra*, it was observed that after the second month of planting, the height of the shrub increased fourfold to 310 cm six months after planting (Figure. 4). The rapid growth of the shrub allows for a rapid and abundant supply of litter to enrich and nourish the soil life.

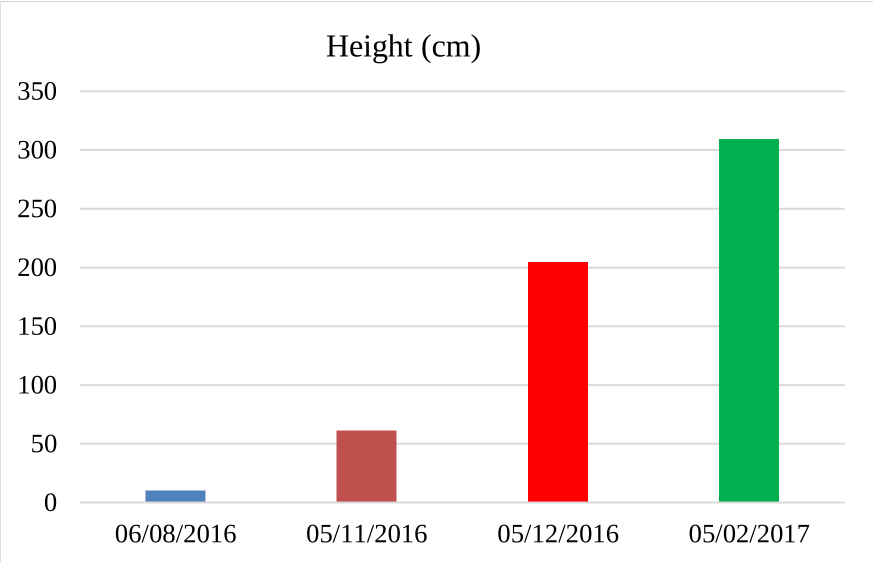

Fig.4: Height of Calliandra

3.1.2. Obtaining the leaf biomass of Calliandra

After planting the *Calliandra* shrubs in hedges 6 m apart with a spacing of 50 cm between the shrubs, we waited until these shrubs could reach a height of 3.10 m, the first pruning was done six months after planting. This pruning was done at 50 cm from the ground. Average annual leaf biomass of 8.46 tons/ha was obtained. Each shrub provided 1.46 kg/shrub as green matter. The harvesting of this plant material allowed us to fertilize the plot. In the second year of the experiment, the cutting took place twelve months after the first in February 2018.

This operation allowed us to obtain an average annual leaf biomass of 11.02 kg/ha, with each shrub producing 1.87 kg/shrub (Table 2). The amounts of leaf biomass/shrub, and total leaf biomass increased significantly from the year 2016 - 2017 to the year 2017 - 2018 with ($t = -33.84$; $p = 0.001$), ($t = -50.07$ $p = 0.000$) respectively. This increase in leaf biomass is because after pruning, several shoots are formed on the shrub and the leaf mass increases similarly.

Table 2: Litter production of Calliandra hedges during the two years of experiment (tons/ha)

Quantity/shrub (kg)		Leaf biomass (t/ha)
2016 – 2017	1.46 ± 0.01	8.46 ± 0.21
2017 – 2018	1.87 ± 0.03	11.02 ± 0.17
t (student) probability	t = -33.84 (p = 0.001)	t = - 50.07 (p = 0.000)

3.1.3. Growth of Senna spectabilis H.S

Senna spectabilis is another example of green manure that is intended to improve soil fertility in agrosystems. It is planted in rows six meters apart, with a distance of 50 cm between plants in the rows. Pruning was carried out six months after planting and one year after the first pruning at a height of 50 cm from the ground. *Senna spectabilis* is also a very fast-growing plant. A very deep root system prevents competition with associated crops. After 60 days, the growth of the shrub is 68.67 cm.

After the fourth month, this growth increased from 68.67 cm to 217.93 cm to reach a height of almost 4.50 m before the first pruning took place six months after planting, with a standard deviation of 3.76. One year after the first pruning, the height reached 870 cm. With a very deep root system, *Senna spectabilis* draws mineral elements from deep in the soil and brings them to the upper soil surface. Table 3 shows a significant increase in the height of *Senna* from one date to the next.

Table 3: Measurement of the height of Senna spectabilis

Date	Aug. 6, 2016	Oct.5, 2016	Dec. 5, 2016	Feb. 5, 2017
Height	10.72 ± 0.10^{a}	68.67 ± 0.90^{b}	217.93 ± 2.17^{c}	434.90 ± 3.76^{d}

Values are expressed as mean ± standard deviation (n = 3). Values with the same letter on the same line are not significantly different ($p > 0.05$).

Four months after planting, the height of *Senna spectabilis*, which is 217 cm, doubled after two months (Figure5)

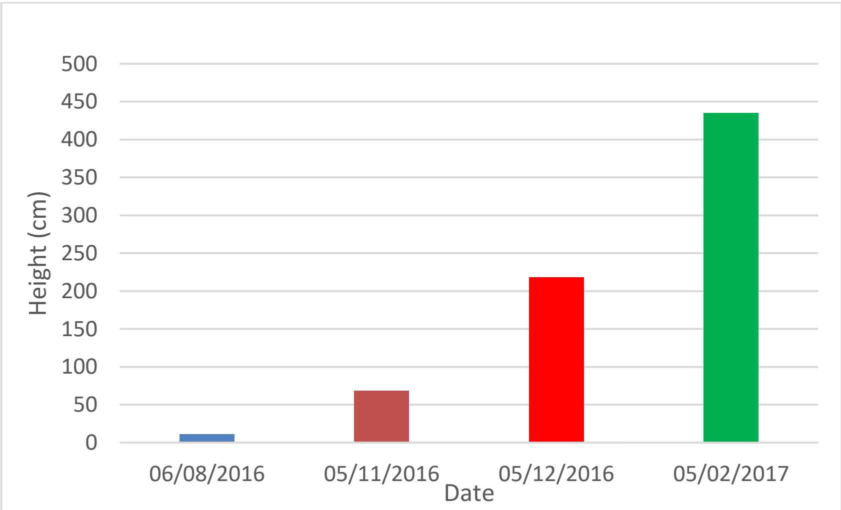

Fig.5: Height of Senna

3.1.4. Obtaining the leaf biomass of Senna

Senna plants spaced 50 cm apart and planted in 6 m rows reached a height of 4.5 m six months after planting. It produced an average annual leaf biomass of 9.25 tons per hectare after the first pruning six months after planting (Table 4). Each shrub produced a biomass of 1.57 kg. In the second year, 2017-2018, the leaf biomass per shrub increased by 0.5 kg, similarly increasing the average annual leaf biomass to 12.06 tons per hectare. After the first pruning of Senna spectabilis, several offshoots were formed, the number of which varied from 5 to 7 offshoots on the shrubs considered in our sample. The amounts of leaf biomass/shrub, and annual leaf biomass also increased significantly from the year 2016 - 2017 to the year 2017 - 2018 with (t = - 16.09; p = 0.004), (t = - 16.15; p = 0.004) respectively. The leaf biomass of Senna spectabilis is all the higher as its root system is very deep, reaching more than 120 cm in depth. This allows it to draw mineral elements from deeper in the soil and bring them back to the soil surface.

Table 4: Litter production of Senna hedges during the two years of experiment (tons/ha)

	Quantity/shrub (kg)	Leaf biomass (t/ha)
2016 – 2017	1.57 ± 0.04	9.25 ± 0.24
2017 – 2018	2.04 ± 0.05	12.06 ± 0.27
t (student) probability	t = -16.09 (p = 0.004)	t = - 16.15 (p = 0.004)

3.1.5. Amount of nutrients supplied by each type of litter

3.1.5.1. Amount of nutrients supplied by Calliandra calothyrsus

On the soils of our experimental plots, no fertilizer was applied to the shrub hedges during planting. The yield of the shrubs in fertilizer and the chemical composition of the foliage determines the number of nutrients supplied to the soil. After the various prunings of the shrubs, large amounts of litter were obtained. This litter released high amounts of nitrogen and other nutrients.

After using the *Calliandra* litter between 2016 and 2017, the amount of fertilizer added to the plot provided the following proportions: 183 kg/ha of nitrogen, 6.44 of phosphorus, 71.79 of potassium, 114.68 of calcium, and 25.57 of magnesium. In the following year, there was an increase of 53.81 kg/ha of nitrogen, 1.83 kg/ha of phosphorus, 21.07 kg/ha of potassium, 33.77 kg/ha of calcium, and 7.39 kg/ha of magnesium (Table 5). The number of nutrients supplied by *Calliandra* varied from 6.44 to 183 kg/ha for phosphorus and nitrogen respectively between 2016 and 2017

Table 5: Average annual amounts of nutrients supplied through Calliandra litter at Mbankomo, 2016- 2018

	N (kg/ha)	P (kg/ha)	K (kg/ha)	Ca (kg/ha)	Mg (kg/ha)
2016 - 2017	183.00 ± 2.12	6,44 ± 0.06	71.79 ± 0.04	114.68 ± 0.07	25.57 ± 0.55
2017 – 2018	236.81 ± 2.64	8.27 ± 0.03	92.86 ± 0.71	148.45 ± 0.69	32.96 ± 0.51
t- student	t = -177.37	t = - 61.00	t = -51.78	t = 79.71	t = - 24.22
(probability)	(p = 0.000)	(p = 0.000)	(p = 0.000)	(p = 0.000)	(p = 0.002)

The amount of all nutrients (nitrogen, phosphorus, potassium, calcium, and magnesium) supplied by *Calliandra* increased significantly from the first year of the experiment (2016-2017) to the second year (2017-2018) (Fig. 6). the dry air consists mainly of noble gases, oxygen (21%) and nitrogen (78%). Thus, *Calliandra* contracts a symbiosis with a bacterium of the genus *Rhyzobium* to form the nodules, thus allowing privileged access to nitrogen from the air.

These bacteria have an enzyme, nitrogenase, which enables them to fix atmospheric nitrogen and transform it into NH4+ that can be directly used by the plant. This enzyme is irreversibly inhibited by oxygen, which is why the bacteria work anaerobically. Once the bacterium is installed in the nodules, the legume will trap the oxygen near the bacterium's nitrogenase to avoid an accumulation or an increase in O2 pressure.

3.1.5.2. Quantities of nutrients supplied by Senna spectabilis

Leguminous trees and shrubs contribute to maintaining soil fertility through nitrogen fixation. The high nitrogen production of *Senna spectabilis*, which does not nodulate, with a value of 259.30 kg/ha is very interesting. When *Senna* litter is used to enrich the soil in our agrosystem, the number of nutrients supplied increases considerably from year to year. For example, in 2016-2017, with a litter of 9.25 tons/ha, the amount of nitrogen is 192.76 kg, phosphorus is 6.76 kg and potassium is 76.82 kg.

In the second year of the experiment, 2017-2018, the increase in nitrogen was 66.54 kg, the increase in phosphorus was 2.38 kg, the increase in potassium was 26.05 kg, the increase in calcium was 41.39 kg and the increase in magnesium was 8.99 kg (Table 6). The number of nutrients supplied by *senna* varied from 6.76 to 192.76 kg/ha for phosphorus and nitrogen, respectively, between 2016 and 2018.

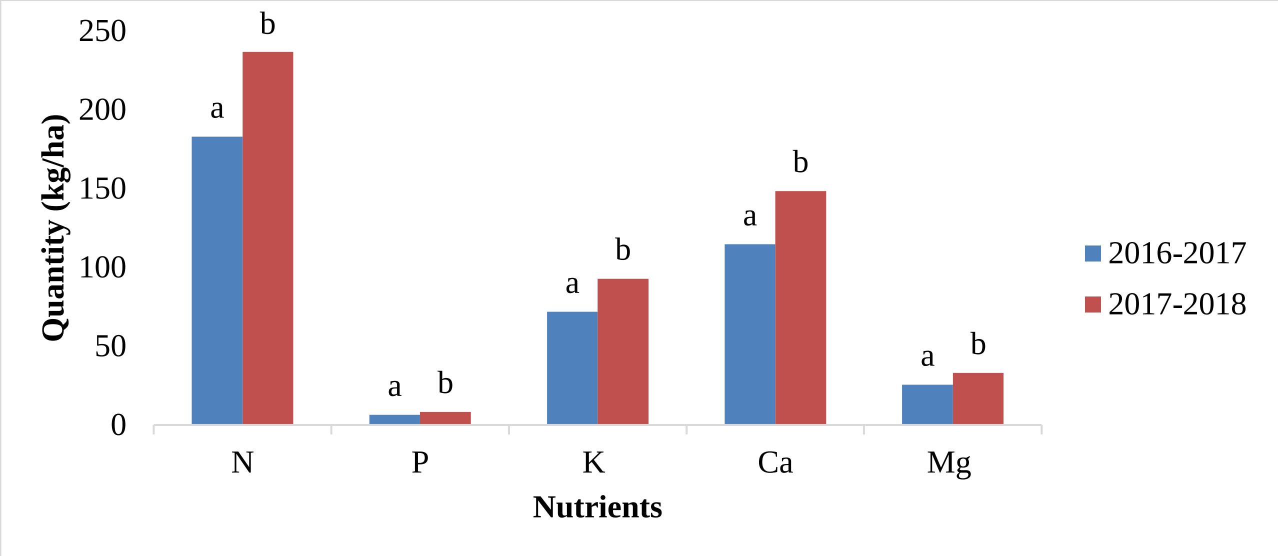

Fig.6: Amount of nutrients provided by Calliandra

Table 6: Average annual amounts of nutrients supplied through Senna litter at Mbankomo, 2016- 2018

	N (kg/ha)	P (kg/ha)	K (kg/ha)	Ca (kg/ha)	Mg (kg/ha)
2016 - 2017	192.76 ± 0.49	6,76 ± 0.06	76.82 ± 0.48	122.44 ± 0.58	27.01 ± 0.86
2017 – 2018	259.30 ± 1.06	9.14 ± 0.06	102.87 ± 0.64	163.83 ± 0.03	36.00 ± 0.61
t- student	t = -149.15	t = - 37.32	t = -144.50	t = -118.78	t = - 42.76
(probability)	(p = 0.000)	(p = 0.001)	(p = 0.000)	(p = 0.000)	(p = 0.001)

The amount of all nutrients provided by *senna spectabilis* increased significantly between the years 2016 - 2018 (Figure7)

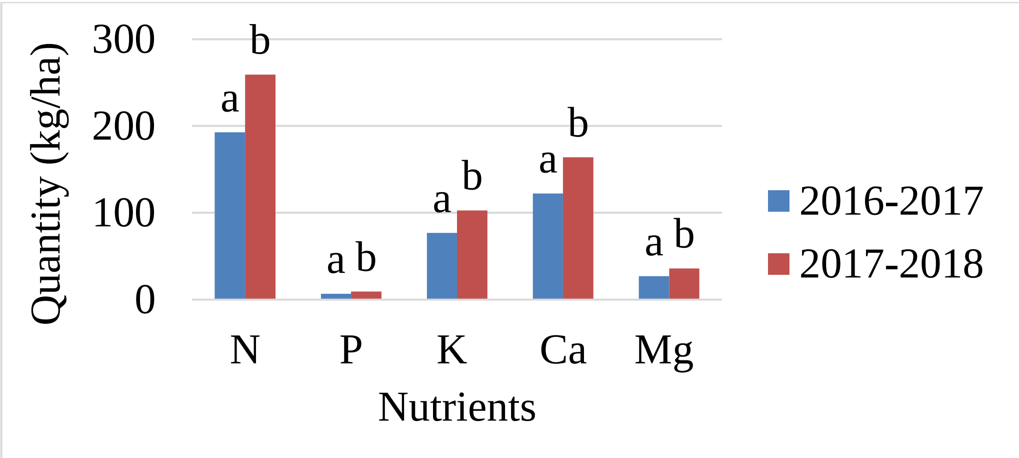

Fig.7: Amount of nutrients provided by Senna

3.1.5.3. Effects of tree legumes on soil fertility

3.1.5.3.1. Effects of tree legumes on soil fertility in the first year

Improving soil fertility is a fundamental value for agriculture. But too little attention has been paid to the conservation of fertile soils. Organic farming depends heavily on good natural soil fertility. Damaged and weakened soils can no longer provide the services expected of them. Soil fertility must be carefully maintained and sustained over a very long period. Soil fertility is both an ecological and biological process. Soil is inhabited by a huge diversity of microorganisms, animals, and plant roots. Fertile soil can provide healthy and abundant crops for generations with little or no need for chemical fertilizers, plant protection products, and energy.

In healthy soil, the living organisms that inhabit it efficiently transform organic matter, build humus, protect plants against diseases and make the soil lumpy, a very suitable structure for agricultural soils because soil with a lumpy structure is easy to work, absorbs rainwater well and is effectively resistant to slaking and erosion. Our experimental field consists of three separate plots. The first is the control plot in which yams were planted without nutrients and had no association with legumes.

The mineral elements were observed before planting. In the first year in the control plot, at a depth of 0-15 cm, a pH of 4.31 is noted. The quantity of ions is 0.97 C mol (+) kg-1 for calcium, 0.45 C mol (+) kg-1 for magnesium, 0.22 C mol (+) kg-1 for potassium, and 0.013 C mol (+) kg-1 for sodium. The cation exchange capacity is 5.32 C mol (+) kg-1. Organic carbon is 1.42%, and total nitrogen is 0.130%. The C/N ratio is 10.92 (Table 7).

The permanent presence of leguminous shrub species that form microenvironments is considered as indicator of fertility islands. Thus, in the *Calliandra* plot, which is our second experimental plot, still, at a depth of 0-15 cm, a pH of 4.87 was evaluated. The value of the ions is 2.83 C mol (+) kg-1 for calcium, 1.52 C mol (+) kg-1 for magnesium, 0.27 C mol (+) kg-1 for potassium, 0.015 C mol (+) kg-1 for sodium. The cation exchange capacity is 7.22 C mol (+) kg-1.

An improvement in mineral elements can be noted thanks to the legumes introduced into the plot. In addition, the shrub *Senna spectabilis* has an equally high and significant fertilizer potential. Thus, at a depth of 0-15 cm, in the Senna plot representing the third plot, before the planting of yams in the first year, the mineral elements increased, as did the pH, the cation exchange capacity, and the C/N ratio, whose values are respectively 4.97, 8.39 and 10.29. This shows an improvement in soil fertility.

Thus, in the first year of the experiment, all the mineral elements of the soils collected in the *Calliandra* and *Senna* plots are significantly ($p > 0.05$) different compared to the soils of the control plot. However, the C/N ratio of the control plot is very high (10.92) compared to that of the *Calliandra* plot (10.60) and the *Senna* plot (10.29)

Table 7: Impact of legumes on soil fertility

Year	Plot	Depth (cm)	PH eau	Ca	Mg	K	Na	CEC	C org	N total	C/N
Cmol (+) /kg											
Year 1	control	0–15	4.31 ±	0.97 ±	0.46 ±	0.23 ±	0.01 ±	5.36 ±	1.42 ±	0.13 ±	10.92 ±
			0.01^a	0.01^a	0.01^a	0.02^a	0.00^a	0.04^a	0.01^a	0.00^a	0.01^c
	Calliandra	0-15	4.90 ±	2.86 ±	1.55 ±	0.28 ±	0.02 ±	7.27 ±	1.87 ±	0.16 ±	10.60 ±
			0.04^b	0.04^b	0.04^b	0.02^{ab}	0.00^b	0.07^b	0.02^b	0.03^{ab}	0.08^b
	Senna	0-15	4.97 ±	3.02 ±	1.69 ±	0.37 ±	0.02 ±	8.39 ±	1.85 ±	0.18 ±	10.29 ±
			0.02^b	0.04^c	0.05^c	0.07^b	0.00^b	0.05^c	0.04^b	0.00^b	0.16^a

Values are expressed as mean ± standard deviation (n = 3). Values with the same letter in the same column in the same year are not significantly different ($p > 0.05$)

3.1.5.3.2. Effect of tree legumes on soil fertility in the second year

The introduction of tree legumes in the experimental plot showed a significant increase in soil mineral elements in the second season. When observing the evolution of mineral matter in the control plot after harvest, it is important to note that the pH decreased by 1. In this context, acidification of the control plot is noted. The other minerals also underwent a reduction in their proportions: 0.2 C mol (+) kg-1 for calcium, 0.1 C mol (+) kg-1 for magnesium, 0.1 C mol (+) kg-1 for potassium, 0.03 C mol (+) kg-1 for sodium, 2 C mol (+) kg-1 for the cation exchange capacity. Only the C/N ratio increased by 0.28.

In the *Calliandra* plot, a significant increase in the mineral matter was observed. This increase varies between 0.015 C mol (+) kg-1 and 9.22 C mol (+) kg-1 (Table 8). The regular addition of shrub pruning products on the reclaimed plots improves the soil pH. The pH of the soil increased from 3.31 in the control plot to 5.87 and 6.02 in the plots enriched with tree legumes. Furthermore, the cation exchange capacity increased by 6.53 C mol (+) /kg and the C/N ratio was around 10 in the *Calliandra* and *Senna* plots.

Thus, tree legumes affect soil properties. The soil during our experiment

Our experiment showed a clear improvement in the mineral content (Ca, Mg, K, Na) in the plots enriched with woody legumes compared to the control plot. The pH also increased from one year to the next in the leguminous plots and decreased in the control plot.

It can therefore be said that in the second year of the experiment, all the mineral elements measured were significantly ($p > 0.05$) higher in the soils collected from the *Calliandra* and *Senna* plots compared to the soils collected from the control plot. However, there is a significant difference in the soils from the *Calliandra* plot and the *Senna* plot except for the total N and C/N ratio where there is no significant difference between these two legume-enriched plots. The litter brought to the soil after pruning the shrubs is mineralized by soil microorganisms (bacteria, fungi, actinomycetes), thus providing the crops with the mineral elements they need for the hydromineral nutrition of the crops grown.

Table 8:Improvement of mineral elements by tree legumes (Cmol (+)/kg

Year	Plot	Depth (cm)	PH eau	Ca	Mg	K	Na	CEC	C org	N total	C/N
Cmol (+) /kg											
Year 2	control	0–15	3.31 ±	0.77 ±	0.35 ±	0.12 ±	0.01 ±	3.32 ±	1.20 ±	0.37±	11.69 ±
			0.01^{a}	0.01^{a}	0.01^{a}	0.01^{a}	0.00^{a}	0.01^{a}	0.02^{a}	0.46^{a}	0.42^{b}
	Calliandra	0-15	5.88 ±	2.24 ±	1.33 ±	0.21 ±	0.01 ±	9.93 ±	1.98 ±	0.19 ±	10.20 ±
			0.01^{b}	0.01^{b}	0.02^{b}	0.01^{b}	0.00^{a}	0.01^{b}	0.01^{b}	0.00^{a}	0.11^{a}
	Senna	0-15	6.04 ±	2.54 ±	1.47 ±	0.31 ±	0.02 ±	9.87 ±	2.03 ±	0.20 ±	10.15 ±
			0.03^{c}	0.03^{c}	0.03^{c}	0.03^{c}	0.00^{b}	0.03^{c}	0.03^{c}	0.00^{a}	0.10^{a}

Values are expressed as mean ± standard deviation (n = 3). Values with the same letter in the same column in the same year are not significantly different ($p > 0.05$)

3.1.5.3.3. Effects of tree legumes on yam growth.

3.1.5.3.3.1. Growth of the aerial system of yam in the different plots

During our experiment in the first year, on the 10 yam plants studied in the 190 planted on the control plot, three phases were obtained: the accelerated phase, the linear phase, and the slowing down phase for 63 days and the following results were obtained: in the accelerated phase, 4.9 m in length was obtained for 21 days. In the linear phase, the length achieved was 20.1 m in 33 days while in the slow phase, the growth was zero. The following year (2017-2018), differential growth of -1.1 m at the accelerated phase and -1.7 m at the linear phase was achieved in 70 days with a lift occurring after 37 days. This situation reflects degradation of soil fertility in Mbankomo (Table 9)

Table 9: Growth of all the aerial axes of Dioscorea cayenensis on the control plot

year	Number of plants	Survey (days)	Accelerated phase		Linear phase		Slow phase	Total duration (days)
2016-2017	10		D (j)	LR(m)	D (j)	LR (m)	D (j)	
		35 ± 2	21 ±3	4,9 ± 1,2	33 ± 7	20,1 ±3,9	9 ± 6	63 ± 7
2017-2018	10	37 ± 2,11	23 ± 3,2	3,8 ± 0,92	35 ± 7,42	18,4 ± 3,5	12 ± 8	70 ± 8

The *Calliandra* plot on our farm during the study period shows that of the 10 yam plants studied out of 190 planted, emergence occurred after 33 days in the first year, with the growth of 5.2 m in the accelerated phase and 25.1 m in the linear phase in 58 days. In contrast, from 2017 to 2018, the following lengths were measured: 6.1 m in the accelerated phase and 26.5 m in the linear phase, i.e. an overall growth of 32.6 m during 53 days (Table 10). In the *Calliandra* plot, the vegetative cycle varies from 195 to 180 days, characterized by an emergence lasting one month

Table 10: Growth of all the aerial axes of Dioscorea cayenensis on the plot with Calliandra

year	Number of plants	Survey (days)	Accelerated phase		Linear phase		Slow phase	Total duration (days)
			D (j)	LR(m)	D (j)	LR (m)	D (j)	
2016-2017	10	33 ± 1,8	20 ± 2,85	5,2 ± 1,27	30 ± 6,36	25,1 ± 4,87	8 ± 5,33	58 ± 5
2017-2018	10	30 ± 1,79	18 ± 2,57	6,1 ± 1,49	28 ± 5,93	26,5 ± 5,14	7 ± 4,26	53 ± 3

In the *Senna* plot, of the ten yam plants studied, emergence occurred one month after planting in the first year of the experiment. The accelerated phase lasted 20 days, the linear phase 28 days, and the slow phase 7 days. The lengths reached during these different phases were 5.6 m for the accelerated phase, 25.8 m for the linear phase. In 2017-2018, the lift occurred after 28 days with the accelerated phase lasting two weeks, and the linear phase 25 days. The total duration of days was 55 days in the first year of the experiment and 45 days in the second year (Table 11)

Table 11: Growth of all the aerial axes of Dioscorea cayenensis on the plot with Senna

year	Number of plants	Survey (days)	Accelerated phase		Linear phase		Slow phase	Total duration (days)
			D (j)	LR(m)	D (j)	LR (m)	D (j)	
2016-2017	10	32 ± 1,74	20 ± 2,85	5,6 ± 1,36	28 ± 5,93	25,8 ± 5,09	7± 4,66	55 ± 4
2017-2018	10	28 ± 1,67	15 ± 2,14	7,05 ± 1,74	25 ± 5,29	29,4 ± 5,70	5 ± 3,32	45 ± 2

The observation of emergence frequencies shows a general tendency for emergence to be faster on a plot with legumes than on a plot without fertilizing shrubs.

3.1.5.3.3.2. Parameters for the end of yam growth on the different plots

From the general observation of yam growth, it can be noted that the aerial axis in the control plot between 2016 and 2017 reached a length of 27.8 m while the main axis had 5.6 m and produced 636 leaves during its vegetative period. From planting to drying out, it took about 214 days. In the second year, the observation period lasted 234 days, i.e. from planting to drying out, and the following lengths were measured: length of the aerial axes 24.7 m, length of the main axis 4.01 m with a total number of leaves of 512 (Table 12).

In the *Calliandra* plot, it is observed that the aerial axis increased by 35.8 m during the 2016-2017 crop year. The main axis reached an average length of 7.6 m and provided 797 leaves during its vegetative period. During the same period, the growth stoppage to desiccation was found to be 104 days. From senescence to desiccation was 30 days. The time from planting to desiccation is 195 days.

During the second year of the experiment, a differential evolution of some of the end-of-growth parameters of *Dioscorea cayenensis* was noted. The length of the main axis increased by 1.2 m, the length of the aerial axes by 2.7 m, and the number of leaves increased by 109 compared to the first season. Growth arrest to desiccation lasts about 97 days while senescence before desiccation is 28 days. Finally, the vegetative cycle of *Dioscorea cayenensis* of 180 days (Table 13)

Table 12: End of growth parameters of Dioscorea cayenensis on the control plot

Year	End of growth parameter				No growth		Vegetative cycle
	Length of the air axis (m)	Length of the main axis (m)	Total number of sheets	Number of leaves of the main axis	D (d) of stopped of growth at drying out	Senescence before drying out (J)	Duration planting to drying out (J)
2016-2017	27,8 ± 4,3	5,6 ± 0,5	636 ± 131	96 ± 11	115 ± 11	38 ± 15	214 ± 9
2017-2018	24,7 ± 3,82	4,01 ± 0,35	512 ± 105	81 ± 9	127 ± 12	41 ± 16	234 ± 10

Table 13: End of growth parameters of Dioscorea cayenensis on the Calliandra plot

Year	End of growth parameter				No growth		Vegetative cycle
	Length of the air axis (m)	Length of the main axis (m)	Total number of sheets		Length of the air axis (m)	Length of the main axis (m)	Total number of sheets
2016-2017	35,8 ± 5,83	7,6 ± 0,67	797 ± 164	105 ± 12	104 ± 10	30 ± 12	195 ± 8
2017-2018	38,5 ± 5,95	8,8 ± 0,78	906 ± 186	148 ± 17	97 ± 9	28 ± 11	180 ± 7

During the 2016-2017 season, it was observed at the end of the growth of *Dioscorea cayenensis* that the average length of the aerial axes was 36.05 m while the main axis was 7.9 m long. The average total number of leaves was 806 per plant on the *Senna* enriched plot. The duration from growth arrest to desiccation was noted to be 98 days. During this time, senescence before desiccation is observed, which is 28 days. It can therefore be concluded that the vegetative cycle of this crop is approximately 181 days (Table 14).

In the second season of 2017-2018, a differential increase in growth was observed in the length of the aerial axes, which is 4.05 m. This growth is also reflected in the main axis, which is 1.6 m. The average number of leaves increases from 806 to 980 leaves, with a reduction in the cessation of growth at drying out, which is one day. In terms of senescence before drying out, the duration has also decreased by one day. There was also a regression of the vegetative cycle by eleven days. The use of *Senna* in the experimental plot has shown its effectiveness in enriching the plot and in the evolution of our crop, which has increased the growth and reduced the vegetative cycle of *Dioscorea cayenensis*.

Table 14: End of growth parameters of Dioscorea cayenensis on the Senna plot

Year	End of growth parameter				No growth		Vegetative cycle
	Length of the air axis (m)	Length of the main axis (m)	Total number of sheets		Length of the air axis (m)	Length of the main axis (m)	Total number of sheets
2016-2017	36,05 ± 5,87	7,9 ± 0,69	806 ± 165,85	110 ± 12,57	98 ± 9,42	28 ± 11,2	181 ± 7,47
2017-2018	40,1 ± 6,19	9,5 ± 0,84	980 ± 201,19	158 ± 18,19	97 ± 9	27 ± 10,60	170 ± 6,61

Using the two legumes *Calliandra calothyrsus* and *Senna spectabilis* as soil fertilizers in our experimental plot for the cultivation of our specimen *Dioscorea cayenensis*, a difference in the growth of this yam variety was noted. The plot enriched with *Senna* appears to have the highest productivity with differences of 0.25 m in the aerial axes, 0.3 m in the main axis, 9 in the total number of leaves, and 5 in the number of leaves on the main axis.

A reduction of 6 days from growth arrest to desiccation is observed when using the *Senna* species. 2 days of reduction of senescence before desiccation and finally a reduction of the vegetative cycle of 14 days when using the latter species mentioned above in the first crop year. In the second crop year 2017-2018, there is no significant difference in the evolution of the late growth parameters. On the other hand, it is observed that the parameters of the cessation of growth at drying up are similar and remain limited to 97 days. (Table 15).

The litter provided by the tree legumes contributes to feeding the soil microorganisms. Living soil rich in microbial diversity allows crops to withstand various abiotic and biotic stresses. Thus, the production of molecules such as salicylic acid or exopolysaccharides by soil microorganisms allows plants to fight against water deficit and pathogens. This agricultural practice aims to provide shelter and food for microorganisms and more generally for soil life. This creates a favorable environment for maintaining a good soil structure with good organic matter levels and therefore better plant growth.

Another stress adaptation aid provided by rhizosphere microorganisms is the production of the enzyme AAC-deaminase. This enzyme limits the production of ethylene in plants and limits the effect of various stresses. AAC-deaminase is an enzyme that degrades the AAC molecule, which is a precursor of ethylene in the plant. Ethylene is a plant hormone that is naturally produced in plants, but when it is produced in too large quantities, often in response to various stresses, it can be an accelerator of early senescence and death of the plant

Table 15: Comparison of the parameters of end of growth of Dioscorea cayenensis enriched with Calliandra and Senna

Year		End of growth parameter				No growth		Vegetative cycle
		Length of the air axis (m)	Length of the main axis (m)	Total number of sheets		Length of the air axis (m)	Length of the main axis (m)	Total number of sheets
2016-2017	*Calliandra*	35,8 ± 5,83	7,6 ± 0,67	797 ± 164	105 ± 12	104 ± 10	30 ± 12	195 ± 8
	Senna	36,05 ± 5,87	7,9 ± 0,69	806 ± 165,85	110 ± 12,57	98 ± 9,42	28 ± 11,2	181 ± 7,47
2017-2018	*Calliandra*	38,5 ± 5,95	8,8 ± 0,78	906 ± 186	148 ± 17	97 ± 9	28 ± 11	180 ± 7
	Senna	40,1 ± 6,19	9,5 ± 0,84	980 ± 201,19	158 ± 18,19	97 ± 9	27 ± 10,60	170 ± 6,61

3.1.5.3.3.3. Crop production as a function of legume litter quality

Legumes

The increase in livestock and crop production in developing countries is a crucial issue not only for the people of these countries but also for their governments. The government of Cameroon intended to double its agricultural production and export volume by 2015. However, how food crops are grown influences their yield. This model is still extensive. When agricultural production is done without fertilizers, as in the case of the control plot where there are no legumes, production is 24 tons/ha in the first year. On the other hand, using Senna as a fertilizer shrub, production is 60.9 tons/ha. With *Calliandra*, production is 52.6 tons/ha in the first year of the experiment (Figure 8). By using tree legumes in our experiment, the crop production doubles compared to the control. The multiplication factor is 2.5 for *Senna spectabilis* and 2.2 for *Calliandra calothyrsus* in year 1.

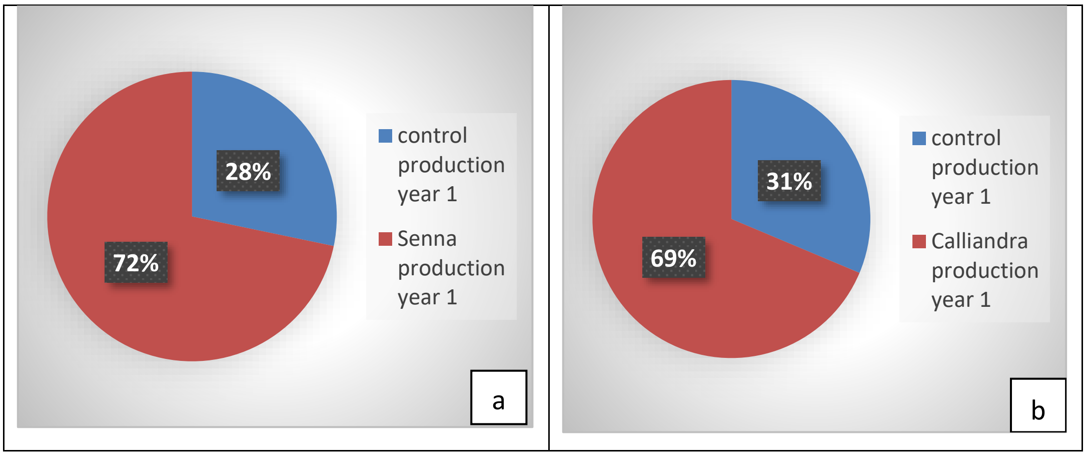

Fig.8: Agricultural production in the first year of study.

(a) Agricultural production according to *Senna* (b) Agricultural production according to *Calliandra*

Agricultural production has an economic, social, and even political impact. The stability of food production is precarious because of the progressive decline in soil fertility in tropical areas, hence the itinerancy observed in most Cameroonian peasantry in general and in Mbankomo in particular. This is in search of new cultivable land. From one year to the next, in our experiment, agricultural production decreased by 5.9 tons/ha in the control plot in the second year of our experiment. However, at the same time, i.e. in year 2, crop production increased steadily in the plots enriched with tree legumes. *Senna spectabilis*, gave a 4-fold increase in crop production compared to the control plot and *Calliandra calothyrsus* gave a 3.5-fold increase (Figure9).

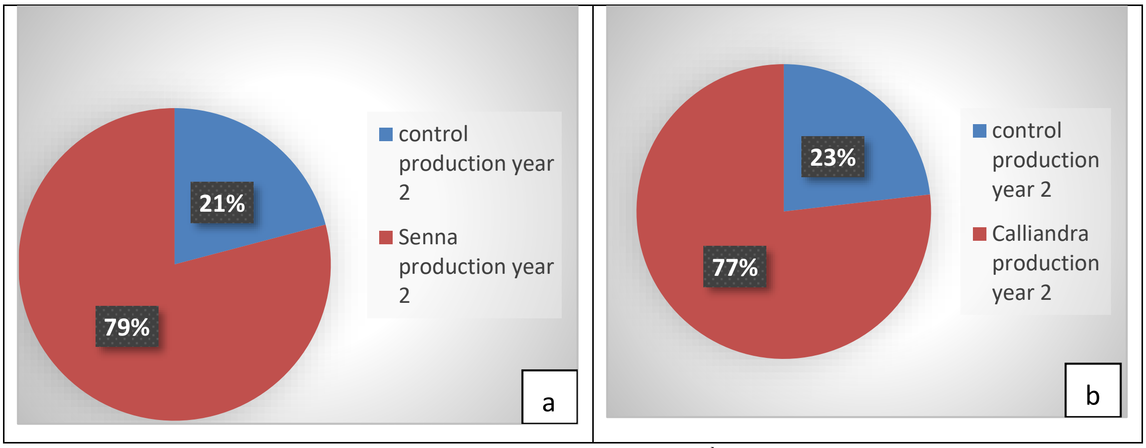

Fig.9: Agricultural production in the 2nd year of study.

(a) Agricultural production according to *Senna* (b) Agricultural production according to *Calliandra*

Evaluation of tree legume species for tree rows indicates that *Calliandra calothyrsus Meisn* and *Senna spectabilis HS* are well suited for our study area. The use of tree legumes, notably *Calliandra calothyrsus* and *Senna spectabilis*, is effective in restoring soils depleted by over-exploitation or erosion. Thanks to the cultivation of tree legumes, this cultivation technique has succeeded in increasing and stabilizing the productivity of degraded land to a significant extent. In the context of improving soil fertility, these species have also led to a significant reduction in runoff and soil erosion. An increase in yam tuber yields was then observed in both plots enriched with legumes. However, *Senna* is much more productive than *Calliandra* in terms of crop production (Figure10).

Nitrogen is a constituent element of chlorophyll, whose gross formula is C55H72O5N4Mg. Chlorophyll is a pigment that is involved in photosynthesis. The more intense the photosynthesis, the greater the production. Plots enriched with tree legumes have seen an increase in the amount of nitrogen incorporated into the soil. This contributed to a consequent increase in yam yield in plots enriched with leguminous shrubs.

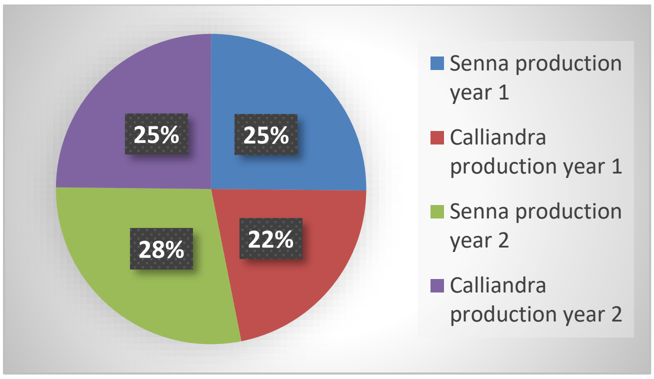

Fig.10: Comparison of total agricultural production by type of tree legumes

3.2. Discussion

The use of tree legumes in yellow yam production was intended to optimize the yield of this crop while improving soil fertility. However, this study had some constraints and limitations. The constraints are related to the time allocated to the study due to academic requirements. This made it possible to conduct the research within a short time frame and to obtain appreciable results. In addition, the scarcity of seeds did not allow for the establishment of a large-scale experimental farm that would allow for a better appreciation of the fluctuations in yam growth dynamics. Nevertheless, this constraint has made it possible to methodically monitor the vegetative cycle of this crop while collecting the data necessary for the development of this work. On the other hand, agroforestry techniques were the subject of some research in the 1980s and 1990s. This period does not offer recent results to enrich and compare our results with theirs covering the same period. However, this work has made it possible to update the knowledge related to this cropping technique and to add value in terms of improving yam yields and conserving soil biodiversity and fertility.

Soil fertility management is essential for improving and maintaining agronomic and biomass productivity. Nutrients removed from crops (i.e., cereals, roots and tubers, canes, fruits, and wood) must be replaced to ensure that the soil's innate nutrient capital is not eroded. Intensively managed agroecosystems are only sustainable in the long term if the production of all components is balanced by appropriate inputs, the number of nutrients needed to achieve the desired yield can be achieved through the use of legumes. The growth of tree legumes is not homogeneous in the experimental farms of Mbankomo locality because the growth of these legumes was a function of the soil, the volume of rainfall, and also the state of sunshine. This result shows a difference from the work done by [27] who observed a homogeneous growth using biological fertilizers. Furthermore, for the germination and growth of *Calliandra* and Senna, no fertilizer was applied to facilitate or accelerate their growth. This work is different from that of [28] who used rhizobial and mycorrhizal biofertilizers to facilitate the germination and growth of *Pericopsis elata*. The use of tree legumes no longer requires additional expenditure for the purchase of any fertilizer to boost their growth, this contributes to making economic gains.

An increase in dry matter yields and the chemical composition of the foliage was observed, which determine the number of nutrients incorporated into the soil. Nitrogen addition increased after each year. *Calliandra* and Senna can be considered better nutrient providers. This result is not similar to the one obtained by [29] where *Calliandra* provided low amounts of dry matter, i.e., 3.37 tons/ha and Senna 4.04 tons/ha. This different result is explained by the fact that the environment where their experiments were carried out was in a semi-arid zone with poor soil (Organic carbon = 8 g.kg-1, Total nitrogen = 0.75 g.kg-1, Bray 11 phosphorus = 8 mg.kg-1 PH water = 5.52, Exchangeable calcium = 13.0 m mol .kg-1, magnesium = 8.0 mmol.kg-1 and potassium = 4.9 m mol .kg-1). Despite these different results, legumes can be adapted in almost all ecosystems and give satisfactory results because the regular addition of legume litter even on nutrient-poor soil improves its fertilizing potential.

The dry matter yield of the shrubs and the chemical composition of the foliage determine the number of nutrients added to the soil. The addition of nitrogen varied from 183 Kg/ha to 260 Kg/ha. The best nitrogen provider was Senna spectabilis. These results are different from those of [29]. This difference can be explained by the fact that the soils were infertile, acidic, and nutrient-poor, as there is a relationship between the soils and the adaptation of the trees and shrubs on these soils. On the other hand, our results are similar to those of [30], [31], [32] as they were obtained under the same environmental conditions in sub-humid regions.

Shrub legumes recycle soil nutrients by supplying the soil with organic matter through litter, which varies from 8.46 tons/ha to 12.6 tons/ha. These results are different from those of [33]. They showed that a forest fallow was more effective than a leguminous or herbaceous cover in recycling nutrients and enriching the soil with organic matter. Traditional farmers in Africa in general and in Cameroon in particular kept some tree species on their land that would help the soil regenerate during the fallow. These include *Alchornea cordifolia*, *Acioa barterii*, *Anthonata macrophylla*, *Harungana* *madagascariensis*, *Dialtum guineense*, *Crestis ferruginea*, and *Nuclea latifolia* on acidic soils [34], [35] and *Gliricidia sepium* on alkaline soils [36], [37]. However, efforts should be made to increase the efficiency of the fallow with tree species such as tree legumes that can accelerate the nutrient accumulation process and enrich and preserve soil organic matter. *Calliandra* and Senna accumulate more calcium and magnesium compared to the control plot.

Tree legumes release high amounts of nitrogen at six-meter row spacings and 50-cm plant spacings. *Calliandra* and Senna released 236.81 Kg/ha and 260 Kg/ha of nitrogen respectively. These results differ from those obtained by [31], [32] in that leguminous species and associated farming techniques showed that legumes such as *L. leucocephala* and *G. sepium,* planted in hedgerows for alley cropping purposes, only released high amounts of nitrogen if the shrub rows were very narrow. Separated by rows 4 m wide and after five annual prunings, *Leucaena* and *Gliricidia* have grown on degraded alfisol producing about 210 and 110 kg of nitrogen per hectare per year, respectively. [38] showed that nitrogen production could be further increased by pruning the trees to higher levels and by less frequent pruning of the parts that produced a large amount of biomass. The higher the amount of litter, the higher the number of nutrients added to the soil. However, *Senna spectabilis*, which does not nodulate, produced more nutrients than *Calliandra*. The high nitrogen production of 192.76 Kg/ha in 2016-2017 and 260 Kg/ha is very interesting. It seems that the root system of tree legumes recycles nutrients released from weathering rocks in the B/C or C horizons [39]. Under the growing conditions in our study area, the average annual amounts of nutrients added to the soil through the leaves of the legumes increased. This plant material restored the soil with large amounts of nitrogen, phosphorus, and potassium. Thanks to tree legumes, the use of synthetic chemical fertilizers will be reduced and farmers will no longer be dependent on synthetic fertilizers which are more expensive, destroy the soil and deteriorate the quality of the crops.

If nutrient additions were made to the plots, it should be noted that yam production was positive on our farm because yam cultivation exports quantities of nitrogen and potassium according to [40]: This shows that the harvest of one ton of fresh yam tubers exports 3.5 kg of nitrogen, 0.39 kg of phosphorus and 4.2 kg of potassium. The increase in the litter is explained by the fact that after pruning, several shoots are formed and therefore the leaf biomass is increased. This result is different from the work of [41]. According to the results of their trials in Machakos district, dry matter yields for Leucaena were about 1.5 kg/tree per season with an average row spacing of 0.62 m and a row spacing of 3.5 m. The production per hectare of leaves per season was thus approximately 6,900 kg, distributed over a cultivated area of 6,600 m2 (one-third of the total area being occupied by hedges), this quantity allowed an application rate of approximately 1 kg/m2. Thus, tree legumes help to compensate for nutrient losses due to crop exports and conserve soil organic matter.

Planting tree legumes in agrosystems help to maintain soil fertility through nitrogen fixation and nutrient recycling, preserves a reasonable amount of organic matter in the soil, allow the provision of mulch to protect the soil and control water infiltration, runoff and erosion, provision fuelwood, provision of stakes and woody materials for commercial use, provision of browse or fodder, with fallow limited to narrow corridors, thus saving land and allowing either continuous cropping or cropping interspersed with very short fallow periods. This result is different from that of [18]. In their work, they used the litter of species such as *Annona senegalensis*, *Parkia Biglobosa*, and *Terminalia macroptera* whose leaves were collected from under these trees and cut into fine particles before burial in the soil. The use of off-farm fertilizers includes transport and spreading costs, which affect production costs. On the other hand, the use of tree legumes contributes to the long-term practice of agriculture. One can farm the same plot for a very long time and have good results. These results are different from those of [42] who farmed for 20 years. This experiment contributes to permanent cultivation without fallow and during the same time the forest massif, which was already more than 60% degraded, is progressively reconstituted.

Yam yields increase strongly with the level of nitrogen and organic matter in the soil. The plot that enriches the soil with organic matter and nitrogen produces the highest yam yield. Indeed, the essential characteristic of legumes is their ability to symbiotically fix nitrogen through Rhizobium bacteria, enriching the soil with nitrogen. This result is similar to those obtained by [39], [43], [44] who confirmed the importance of the organic matter and nitrogen produced by leguminous trees and shrubs in improving soil fertility and agricultural yields.

However, it differs from those of [45] who showed that the fertility test of yam plots showed the superiority in yield of *A. mangium* (8.83 t/ha) and *A. auriculiformis* (5.22 t/ha) fallows over the natural *Chromolaena odorata* fallow which gave the lowest yields (2.67 t/ha). Shrub legumes increased the yields of the traditional *Dioscorea cayennensis* variety. Yield differences varied between treatments. Total yam production in our experimental plots during the study period ranged from 18.1 tons per hectare to 70 tons per hectare. These results are different from those obtained by [46], [47]. Their average annual production of the yam *Dioscorea cayennensis rotundata* was 13062.5kg/cultivator or an overall average yield of 5160.5kg/ha. The difference in yam production in our study area and some West African countries is justified by the fact that our yam production technique was associated with the use of tree legumes which are plants with high soil enrichment potential. [49] obtained a yield of 8 to 15.5 tons of yam with mineral fertilization of 280 kg/ha of NPK (15 15 15) and 580 kg/ha of NPK (15 15 15). The observed difference in yield between the fertilization levels is very small to conclude from an optimal fertilizer dose. Our yields are well above the estimated world yields of 9.1 tons per hectare in 2003 (www.gret.org.). Yam production has exploded on the African continent since the 1980s (http://spore.cta.int).

Thus, our cultivation practice can be considered as a means of effectively combating the poor productivity of the soils in the South Cameroonian plateau because by using tree legumes, production is multiplied by 3 or 4. This result is similar to that of [36] who used *Gliricidia sepium* litter for yam fertilization. Furthermore, the seedling variety used in our experiment was the traditional variety and not the improved variety. The production would have had a significant margin of improvement not only with this cultivation practice but also by using the improved varieties. For example, [48] estimated that the use of improved varieties under rational farming conditions could result in annual production of about 140 t/ha of yams. Increasing crop yields is a challenge for agriculture in the 21st century as the area available for cultivation is shrinking and becoming scarce while the population is expanding. Tree legumes are an alternative to synthetic fertilizers that further impoverish farmers and degrade the quality of their environment.

IV. CONCLUSION

The need to establish agricultural practices and land management methods capable of enhancing and maintaining soil fertility in the long term in the southern Cameroonian plateau is a major challenge. The objective of this study was to show the contribution of tree legumes to the production dynamics of yellow yam in the southern plateau of Cameroon. Soil fertilization using the litter of shrub legumes increased the yields of the local variety of *Dioscorea cayenensis* without changing its taste. This technique can be seen as a means of combating poor soil productivity in equatorial regions.

The difference in yields observed between the treatment levels is sufficiently large to conclude that the introduction of tree legumes into agrosystems is important for boosting agricultural production and improving the living standards of rural populations. Moreover, these results do not only concern the increase in yields, the litter of tree legumes also feeds the soil microorganisms for good mineralization and an improvement of soil fertility for sustainable and environmentally friendly agriculture.

Moreover, these results only cover two years and three different sites, namely Eloumden I, Eloumden II, and Ekoko. For better precision of the effects of each of the tree legumes, the research could be carried out in various agroecological zones of Cameroon with different combinations of tree legumes.

REFERENCES

[1] N. Njopkou. Positionnement géographique des activités économiques du Cameroun. Atlas National de développement physique du Cameroun, 71 p. 2014.
[2] N. Eoné. Evaluation des paramètres agrohydroclimatiques pour l'amélioration des rendements agricoles au Cameroun.Thèse de Doctorat. Université de Yaoundé I.116 P. 2019.
[3] H. Robain. Présentation des sols du Sud-Cameroun, organisation et mise en place à l'échelle de l'unité du paysage. In: Delneuf Michèle (ed), Essomba, J.M.(ed.), Froment, A. (ed.). Paléo-anthropologie en Afrique centrale : un bilan de l'archéologie au Cameroun. Paris. LeHarmattan, P. 133-142. (Etudes africaines). Un bilan de l'archéologie au Cameroun, Yaoundé (CMR), 1994/11.ISSN2-7384-7405-5. 1998.
[4] A. A. Adeniji,M. Lawa. Effects of replacing groundnut cake with Moringa oleifera leaf meal in the diets of grower rabbits. *Int. J. Mol. Vet Res*.,2(3): 8-13. https://doi.org/105376/ijmvr. 2012.02.0003.2012.
[5] D. Cornet. Influence des premiers stades de croissance sur la variabilité du rendement parcellaire de deux espèces d'igname (*Dioscorea* spp.) cultivées en Afrique de l'Ouest. Thèse de Doctorat unique ès Sciences agronomiques et écologiques, Institut des Sciences et Industries du Vivant et de l'Environnement (AgroParisTech), 174 p. [Google Scholar]. 2015.
[6] N. Sanginga. and A. Mbabu. Racines et tubercules (manioc, igname, pomme de terre et patate douce). Documents de référence. Banque africaine de développement, 35 p. 2015.
[7] N. Alkama, N.E.Noureddine, A. Haddadj, H. Sadji, S. Issad, S. Amrani. La pratique de l'inoculation en agriculture et en foresterie : une biotechnologie à notre portée. Communication orale présentée au 2e congrès de Biotechnologie. Tunisie. 2002.
[8] H. Jeder, M. Akrimi, M. Zouaghi, P. Delayudie, M. Gillis, M.S. Zaofouri.Diversité des Rhizobia associés aux légumineuses pastorales des régions arides de la Tunisie. In : Drevon, J.J. et Sifi, B. (eds). Fixation symbiotique de

l'azote et développement durable dans le bassin méditerranéen. INRA Paris. Les colloques N° 100: 163-172. 2003.

[9] J. Wéthé. Use of macrophyteses for domestic wastewaters treatment in developing countries. 2e journée scientifique en Sciences et Techniques de l'Environnement. Université Paris 12. ENPC, CEREVC, Paris. Mai, 2001.

[10] J. Wéthé. Urbanisation et protection de la ressource en eau : une approche par les Systèmes d'Informations Géographiques (SIG) appliqués à Yaoundé-Cameroun. Mémoire de fin d'études du 3e cycle, en vue de l'obtention du Diplôme d'Etudes Professionnelles Approfondies (DEPA), option : Gestion de l'Environnement. Université Senghor d'Alexandrie (Egypte). Avril 1999.

[11] M.C. Palada, B.T. Kang, S.L. Claassen. Effect of alley cropping with *Leucaena leucocephala* and fertilizer application on yield of vegetable crops. Agroforestry Systems 19: 139-147. https://doi.org/10.1007/BF00138504.1992.

[12] P. Letourmy. Experimentation Agronomique Planifiée (support de cours). 50p. 1999.

[13] D.S. Ngambeki,G.F. Wilson. Economic and on -farm evaluation of alley cropping with *Leucaena leucocephala* 1980-1983: Progrss report. Institut International d'Agriculture Tropicale, Ibadan, Nigéria, 45p.1984.

[14] F. Adifon, I. Yabi, I. Balogoun, J. Dossou, A. Saïdou. Caractérisation socio-économique des systèmes de culture à base d'igname dans trois zones agro-écologiques pour une gestion durable des terres au Bénin. *European Scientific Journal* 15(12) : 211–232. DOI : 10.1944/esj. 2019.v15n12p211. [Google Scholar] 2019.

[15] A.W. WAITT. Review of yam research in Nigeria 1920-1961. Place: Published, 1-18.1961

[16] A. S.Lithourgidis, C.A. Dordas, C.A. Damalas, and D.N. Vlachostergios.Annual intercrops: an alternative pathway for sustainable agriculture. 16 p.2011.

[17] M. R. Tshibingu, B.T. Mutamba, D.M. Kabongo, L.B. Longanza, T.M. Munyuli.Improvement of Biodegradation of lignin in a compost environment: A review. *Bioresource Technology*, 72: 169–183. http://doi.org/10.1016/S0960-8524(99)00104-2. 2000.

[18] A. Ngakou, and A. Ibrahima. Responses of Maize and Tomato Crops to Fertilization with Three Agroforestry Litter Species (*Annona senegalensis*, *Terminalia macroptera* and *Parkia biglobosa*) DOI: 10.9734/IJPSS/2020/v32i330262. http://www.sdiarticle4.com/reviewhistory/55898. 2020.

[19] A. Ngakou, L. Ngo Nkot, D.Gomoung,. and S.Adamou. Mycorrhiza-RhizobiumVigna Subterranea Dual Symbiosis: Impact of Microbial Symbionts for Growth and Sustainable Yield Improvement. *International Journal of Agriculture and Biology*, 14, 915- 921.2012.

[20] D. Fotio, A. Monkièdje , S. Miépi Ngouopiho , J. Nguefack, et P.H. Amvam Zollo. Évaluation des résidus des pesticides et de leurs effets sur la qualité des récoltes, du sol et de l'eau en zone périurbaine de Yaoundé à cultures maraîchères. *Actes de l'atelier de Présentation des opérations de recherche participative, 21-23 février 2006, Yaoundé, Cameroun du Pôle de Compétence en Partenariat (PCP) Grand Sud Cameroun*, 33-39.2006.

[21] B.T. Kang, B. Duguma. Nitrogen management in alley cropping systems. *ln* Kang B.T., van der Heide J., éd. Nitrogen management in farming systems in humid and subhumid tropics. Institute of Soil Fertility, Haren, Pays-Bas, 269-284. 17.1985.

[22] J. P. Laclau. Dynamique du fonctionnement minéral d'une plantation d' eucalyptus. Effets du reboisement sur un sol de savane du Littoral congolais. Conséquences pour la gestion des plantations industrielles. Institut National Agronomique Paris, Grignon.@fre. 2001.

[23] D.L. Heanes. Determination of organic C in soils by an improved chromic acid digestion and spectrophotometer procedure. *Commun. Soil Sci. Plant Anal*., 15: 1191-1213.1984.

[24] A. Boundonno, A.A. Rashad, and E. Coppola. Comparising test for soil fertility.11. The hydrogen peroxyde/sulfuric acid treatment as an alternative to the copper/selenium catalyzed digestion process for routine determination of soil nitrogen-Kjeldahl. Comminication in soil science and plant analysis 26 : 1607-1619.1995.

[25] J. M. Anderson ,&J.S.I.Ingram. (Eds).Tropical soil biology and fertility. *A handbook of methods* (2 nd ed). Wallingford: CAB International.1993.

[26] M. F. Trouslot. Analyse de la croissance de l'igname *Dioscorea* complexe *cayenensis rotundata*. Thèse de Docteur es Science. Serie E N° 326, Université de Clermont Ferrand II, Clermont Ferrand.1983.

[27] P. Duchaufour. Pédologie, sol, végétation, environnement 4e édition, Masson, Paris. 324p. 1995

[28] D. M. Essono, D. Nwaga, L.D. Kono. Phénologie fruitière de *Pericopsis elata* dans la forêt équatoriale camerounaise. Soil Biology and Agriculture in the Tropics 234-245. 2012

[29] V. Balasubramanian. Alley cropping: urn it be an alternative to chemical f e r t i l i z e r s in Ghana? Paper given at the Third National Maize Workshop held *at* I Cuadeso, I Cumssi, Ghana. Feb. 1-3, 1983. Mimeo. 22 p.1983.

[30] A.S.R. Juo, R. Lal.The effects of fallow and continuous cultivation on the chemical and physical properties of an alfisol. Plant and soil, 47: 567-568. 1977.

[31] B.T. Kang, G.F. Wilson, L. Sipkens. Alley cropping maize *(Zea mays* L.) and *Leucaena (Leucaena leucocephala* Lam.) in southern Nigeria. *Plant and Soil*, 63: 165-179.1981.

[32] B.T. Kang, et B. Duguma. Nitrogen management in alley cropping systems. International Institute of Tropical Agriculture, Nigeria. 269-284. 1985.

[33] E.O. Jaiyebo,A.W. Moore. Soil fertility and nutrient storage in different soil vegetation systems in tropical rainforest environment. *Tropical Agriculture*, 41, 129-130.1964.

[34] J.K. Obi,P. Tuley. The bush fallow and alley farming in the oil palm belt of South eastern Nigeria. Land Resources Division, Overseas Development Administtration, Londres, R.U. Miscellaneous Report 161p.1973.

[35] B.N. Okigbo, D.J. Greenland. Intercropping systems in tropical Africa. In Papendick, F.L. et al., ed., Multiple Cropping African Studies Association, Madison, WI. E.U. Special publication27: 63-101.1976.

[36] A. Budelman. Woody species in auxiliary roles ; live stakes in yam cultivation ; effect of the application of the leaf mulch of *Gliricidia sepium* on the early development ; leaf nutrient contents and tuber yield of the water yam (*Dioscorea alata*). W. Rosemary, 151 p.1991.
[37] A. Getahum, G.F. Wilson, B.T. Kang.The role of trees in farming systems in the humid tropics. *In* Mc Donald, L.H., ed., Agroforestry in the African humid tropics. United Nations University, Tokyo, Japan, 28-35.1982.
[38] B. Duguma. Studies of factors affecting establishment of selected trees species of potential importance in agroforestry. University of Ibadan, Ibadan, Nigeria. Thèse de doctorat 413p.1985.
[39] A. Young. Ten hypotheses for soil agroforestry research. NAIROBI, ICRAF, *Agroforestry* today, tome 1.13-16.1989.
[40] B. LEBUANEC. Absorption et exportation des éléments minéraux majeurs par l'igname. Third international sympodium on tropical root crops. IITA, Ibadan, Nigeria. *In* L'igname : plante à racine tropicale. Maisonneuve et Larose ; ACCT, série techniques agricoles et productions tropicales, Paris.1972.
[41] F.K. Arap-sang, D.A. Hoekstra, R. Okumu. Preliminary results of on station green manure trials with leaves from *Leucaena leucocephala*, *Cassia siamea* and *Terminalia brownii*, Dryland Agroforestry Project, Kenya Agriculture Research Institute, Kikuyu, Kenya Research Report 1.1985.
[42] J. Reganold. Sustainability of organic, Conventional, and Integrated Apple Orchards. Crop Management. Doi:10.1094/CM-2006-0921-16-PS. http://www.plantmanagementnetwork.org/pub/cm/symposium/organics/Reganold/2006.
[43] J. Tassin. Agroforesterie et conservation des sols dans les régions chaudes - Edition : Nature et Progrès - Montpellier, 140 p.1992.
[44] M.A. Razafindrakoto. Evaluation de l'efficience de diverses techniques biologiques de gestion conservatoire de la fertilité des sols. Doctorat d'Etat Es-Sciences Physiques, Université d'Antananarivo, 192 p. 2004.
[45] Y.F. Kouassi. Effets des jachères à *Acacia mangium* et *Acacia auriculiformis* sur les propriétés chimiques du sol et les rendements de l'igname (*Dioscorea* spp). DEA en sciences et gestion de l'environnement. Université d'Abobo-Adjamé, Côte d'Ivoire, 50 p. 2005.
[46] A. Bakayoko Gone, F. Kouamé Kra, M. Boraud N'takpé Kama. Culture de l'igname au Centre-Est de la Côte d'ivoire : contraintes, caractéristiques sociodémographiques et agronomiques. *J. Appl. Biosci*. 10701-10713.2017
[47] Dognimeton Soro, D. Dao, J. Robert, Carsky, R. Asiedu, A. Ayemou. Amélioration de la production de l'igname à travers la fertilisation minérale en zone de savane de Côte d'ivoire. J. Y. Jamin, L. Seiny Boukar, C. Floret. Cirad-Prasac, 7p. 2003.
[48] Dokou, La sécurité alimentaire des pays en développement : racines, tubercules, plantains et bananes. www.fao.org . 1984