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Plant diversity of oil palm plantations of different ages and under different farming practices in the Ngoas locality Yaounde-Cameroon

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ABSTRACT: The present study characterized the plant diversity of oil palm plantations in function of farming practices and their ages. The plant diversity of 7, 11 and 14 years old oil palm plantations evolving in different farming practices was inventoried using 1m x 1m quadrats for herbaceous species and the 20 m wide transects for woody species. The results obtained show that these stands are not very diversified: P7 presents 37 species, 34 genera and 27 families; P11, 27 species 26 genera, 18 families and P14, 31 species, 28 genera, 19 families. Only Ng13 had woody species individualized into trees and shrubs. The combination of manual and chemical weeding and irregular fertilization promotes the diversity of herbaceous species in the different stands. Age and farming practices influence the plant diversity of the stands.

KEYWORDS: Age, plant diversity, oil palm plantations, farming practices.

1 INTRODUCTION

Elaeis guineensis Jacq., the African oil palm is a plant species in the Arecaceae family. It is an indefinite growing monoecious monocotyledonous plant, listed on the IUCN Red List as a species of Least Concern [1]. There are three varieties of oil palm namely *Elaeis guineensis* Jacq. var. dura, *E. guineensis* Jacq. var. pisifera and *E. guineensis* Jacq. var. tenera. The tenera variety is the most cultivated throughout the world at the moment because it offers the best oil yield with a distribution of approximately 90% palm oil extracted from the pulp and 10% palm kernel oil extracted from the kernel [2].

China, India, Indonesia and the European Union are the main consumers of palm oil worldwide. Since most of them are not producers, their oil needs are met by imports from the countries that produce them [3]. In 2015, the world production was dominated by Asian countries, notably Indonesia (31000000 tons), Malaysia (19200000 tons) and Thailand (2100000 tons). Colombia was the leader in tropical America with 1000000 tons while Nigeria occupied the first place in Africa with 930000 tons [4]. According to a study carried out by WWF in Cameroon in 2012, the cultivation of oil palm does not only have advantages; adverse consequences, notably on the environmental can be associated with it [5]. Also, planting the oil palm is often done at the detriment of natural forests which are real carbon reservoirs and niches of biological diversity [6] - [7]. Oil palm is a heliophilous specie [2] that needs good sunshine to ensure better productivity. For this reason, a systematic cutting of trees very often precedes the establishment of its plantations.

Plant diversity has been the subject of several studies in Cameroon, in particular with regard to cocoa-based agro forests [8] - [9] - [10]. These studies were mainly concerned only with the productivity of these agro forests. This work is a continuation

of previous efforts, and aimed to study the different factors that influence the plant diversity of oil palm plantations in the locality of Ngoas. More specifically it focused on the inventory of the different species existing in the different plantations (1); and to analyze the influence of associated farming practices such as the frequency of weeding and fertilization on the plant diversity of the different palm plantations (2).

2 MATERIAL AND METHODS

2.1 DESCRIPTION OF STUDY SITE

This study was carried out in oil palm plantations of the locality of Ngoas, in the Lobo Subdivision located between longitude 758409 and latitude 433854, in the Lekie Division of the Centre Region of Cameroon, 30 km from the city of Yaounde. The study was realized in three plantations of 7, 10 and 13 hectares, aged 14, 16 and 7 years, respectively. The area is covered by partially disturbed semi-deciduous forest that resembles a secondary forest. Topographically, Lobo is located in the upper part of Nyong and Sanaga rivers basin. Plains and hills 400 to 800 m above sea level dominate the valleys. The soils of the area are tropical ferralitic soils (oxisols) [11]. The locality has a subequatorial climate with two distinct seasons; a rainy season from April to October, and a dry season from November to March. Rainfall in the area varies between 1200 and 1600 mm/year. Temperatures are between 22 and 26 ° C, with the hottest months being December and March.

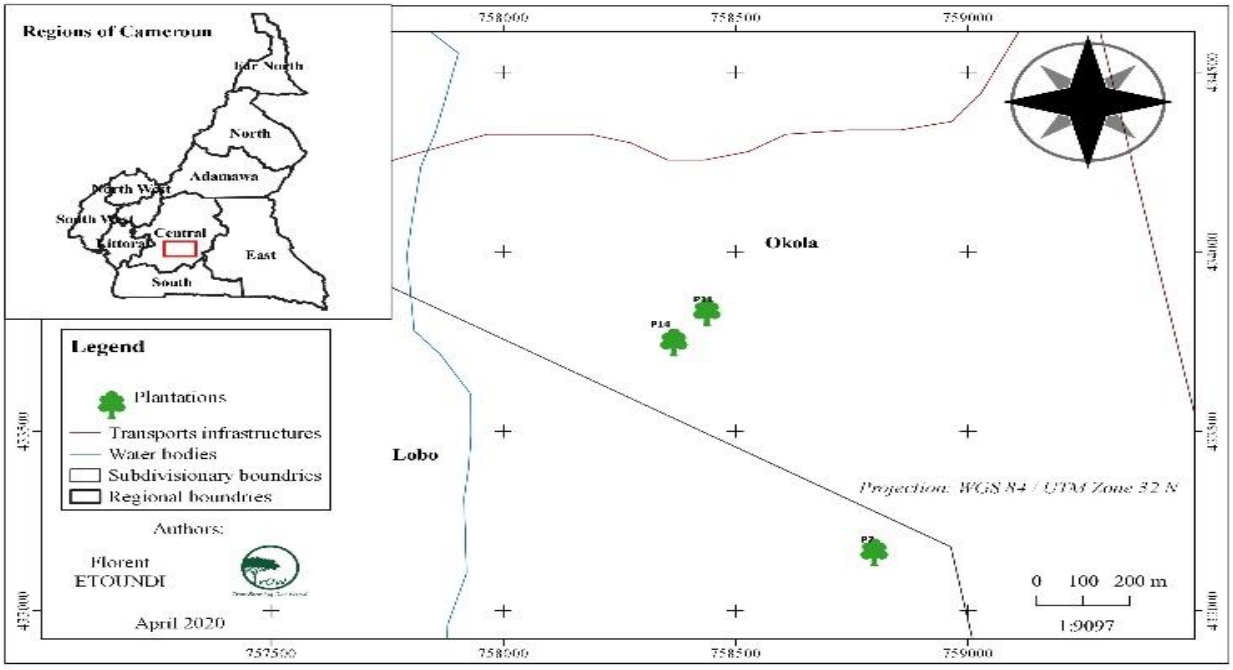

Fig. 1. Study site

2.2 DATA COLLECTION

The study was realized in three plantations aged 7 (P7), 11 (P11) and 14 (P14); and under different farming practices: manual weeding and combination of manual and chemical weeding; frequency of weeding; application and non-application of fertilizers. In each of these oil palm plantations, the plant diversity data were collected in quadrats of 1 m × 1 m placed at the center of the plots of 25 m × 25 m. These plots were installed in areas of high plant diversity from a floristic point of view. Twenty-four plots were installed in the three oil palm plantations. The coverage of inventoried species within plots was evaluated according to the scale of coefficients of dominance-abundance of Braun-Blanquet (1931) [12]. The coefficients assigned to the different species and their average coverage (RM) are:

- +: individuals of the species are very few or less abundant with a low spread, less than 1% of the soil surface area and at RM of 0.5%;
- 1: individuals abundant with a low degree of spread situated between 1 and 5 % of the soil surface area with RM of 3 %;
- 2: highly abundant individuals with a low coverage between 5 and 25 % of the considered area and with RM of 15 %;
- 3: individuals covering 25-50 % of the sampled areas irrespective of their number and with RM of 37.5 %;
- 4: individuals covering 50 - 75 % of the sampled area irrespective of their number and with RM of 62.5 %;
- 5: individuals covering more than 75% of the sampled area irrespective of their number and with RM of 87.5%.

The plant species were identified on the basis of their morphological characteristics. Those that could not be identified in the field were pressed in herbal press and taken to the National Herbarium of Cameroon for subsequent identification.

2.3 DATA ANALYSIS

The data were first entered into Excel spreadsheets of the Office 2013 program. Diversity indices were used, in particular the Shannon-Wiener index (H), given by the equation below made it possible to evaluate the species diversity of different milieus.

$$H = -\sum_{i=1}^{S} P_i log_2 \frac{n_i}{N} \qquad (1)$$

Here, i denotes a species of the study milieu and S, total number of species; ni denotes the number of individuals of the specie i and N is the total number of individuals of all the species. H varies between 0.5 and 4.5. Close to 0, this index reflects a low diversity and the dominance of a few species. On the other hand, an index value close to 4.5 reflects a high diversity of plant species present within the biotope. The Shannon index is often used alongside the Pielou's equitability or eveness index (J) to describe the alpha diversity. This index reflects the degree of diversity achieved compared to the theoretical maximum. It makes it possible to measure the distribution of individuals within species regardless of the species richness. Its value varies from 0 (case of dominance of one of the species) to 1 (even distribution of individuals among the species) [13]:

$$J = \frac{H}{H_{max}} \qquad (2)$$

H_{max} represents $log_2 S$ where S is the total number of species.

The Sørensen index (D), also called the Sørensen's similarity coefficient used by Kono et al. (2015) [14] and given by the equation below was also used to assess the similarity between the plant populations of the different oil palm plantations surveyed.

$$\mathrm{D} = \frac{2c}{S1+S2} \times 100 \qquad (3)$$

c: represents the number of common species between two habitats; S1 represents the number of species for Site 1; S2 represents the number of species for Site 2; D expresses the percentage of species common to two compared sampling units. For D > 50%, the sampled units compared belong to the same plant community.

The determination of life forms was done according to Raunkiaer (1930) [15] and the determination of morphological groups according to Yangambi (2005) [16]. The concepts of life forms or biological form and of morphological group can sometimes be confusing. Indeed, the morphological group is defined by Yangambi (2005) [16] as being an arrangement in space of the aerial organs of the plant with respect to each other and to the ground, an arrangement that can lead to the realization of well-defined structures. On the other hand, the biological group, designates the physiognomy that a species takes during its biological cycle in relation to its behavior towards environmental factors and in particular its ability to survive in unfavourable seasons [17]. The types of diaspores were defined according to Dansereau and Lems (1957) [18]. The phytogeographical groups were described in a like manner as Boupoya-Mapikou (2011) [19] according to the main phytochories of Africa and Madagascar [20] - [21].

Still using the R software, correlation tests, including the generalized linear model, the Spearman test and the Tukey test, were used to analyze the influence of associated farming practices on plant diversity.

3 RESULTS

3.1 PLANT COMPOSITION

A total of 68 species distributed in 62 genera and 42 families were inventoried in all the three oil palm plantations. The most abundant families were Asteraceae (11.76 %), Malvaceae (8.82), Fabaceae (8.82 %) and Poaceae (5.88 %). These families constituted 35.29 % of the total number of species for all three three oil palm plantations sampled. The number of species, genera and families identified in oil palm plantations in the locality of Ngoas are shown in Table 1. This result shows that plant species are irregularly distributed within the plantations.

Table 1. Number of species, genera and families identified in the oil palm plantations of Ngoas locality according to age

Parameters	P7	P11	P14	Total
Number of species	37	27	31	95
Number of families	27	18	19	
Number of genera	34	26	28	

3.1.1 PLANT DIVERSITY OF PLANTATIONS IN FUNCTION OF AGE AND FARMING PRACTICES

From the analysis of the floristic diversity patterns, the Shannon index obtained was 1.03, reflecting a low species diversity (Table 2). Pielou evenness was generally low, thus supposing the dominance of some species in the population.

Table 2 below shows the diversity indices applied to the result of herbaceous inventory of the three plantations.

Table 2. Variation of diversity indices in function of age and farming practices

age	Farming practices	Shannon (H)	Species richness	Pielou's evenness
P11	MW + CW; W 3 times /year; RF.	0,88 ± 0,56 a	7,83 ±2,14 ab	0,34 ± 0,15 a
P14	MW + CW; W 1 time / year; IF.	0,65 ± 0,32 a	9,00 ± 1,31 bc	0,23 ± 0,07 a
P7	MW; W 1 time / year; No F.	0,46 ± 0,26 a	4,67 ± 2,42 ab	0,47 ± 0,29 a

D: Weeding; M: Manual; C: Chemical; F: Fertilisation.

3.1.2 FLORAL CHARACTERISTICS OF OIL PALM PLANTATIONS IN FUNCTION OF AGE AND FARMING PRACTICES

Concerning herbaceous species, figure 2 shows that the 7 years old palm plantation, undergoing manual weeding and which has never been fertilized is dominated by Asteraceae with *Chromolaena odorata* being the most dominant species. Meanwhile in terms of woody species, the Fabaceae Family represent in P7 the most diverse plant family (*Albizia adianthifolia, Pterocarpus soyauxii, Tetrapleura tetraptera*). The 11 and 14 years old oil palm plantations undergoing a combination of chemical and manual weeding; regularly and irregularly fertilized were mainly dominated by Asteraceae and Poaceae (Figure 2). Representative species include: *Chromolaena odorata* (Asteraceae), *Ageratum conizoides* (Asteraceae), *Axonopus compressus* (Poaceae) and *Setaria pedicellatum* (Poaceae).

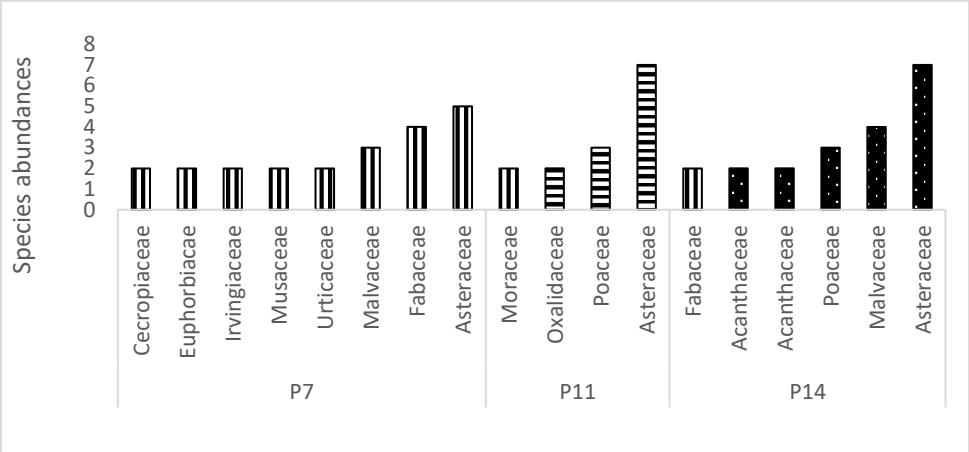

Fig. 2. Species abundances of families in the 7, 11 and 14 years old oil palm plantations according to farming practices

3.1.3 SIMILARITY IN PLANT COMPOSITION OF THE DIFFERENT PLANTATIONS

Among the two level of plant inventories carried out in the different plantations (trees/shrubs and herbaceous inventories), shrub and tree species were only encountered in P7. The similarity of Sorensen matrix indicates indices varying between 0.29 and 0.44 thus highlighting a floristic heterogeneity between the different populations (Table 3).

Table 3. Similarity of Sorensen matrix between the populations

	P11	**P14**	**P7**
P11	1		
P14	0,44	1	
P7	0,29	0,38	1

3.2 DIFFERENT FUNCTIONAL GROUPS

3.2.1 MORPHOLOGICAL GROUPS

In plantation P11, P14 and P7, two morphological groups were identified (woody and herbaceous plants).

Only plantation P7 presented two well-individualized morphological groups that is herbaceous and woody plants (individualized into trees or shrubs). In addition to the woody shrub and tree species (19 species) inventoried in P7, 57 herbaceous species and 21 woody species were identified at the seedling stage.

Concerning herbaceous plants, P14 was the most diversified plantation with 25 species and P7 the least diversified with 12 species while P11 had an intermediate diversity (20 species). Meanwhile, the number of woody species at the seedling stage was not very different in all the plantations. However, P7 was the most diverse with 8 species, P14 the least diverse with 6 species, while P11 had a diversity of woody plants at the intermediate seedling stage (7 species).

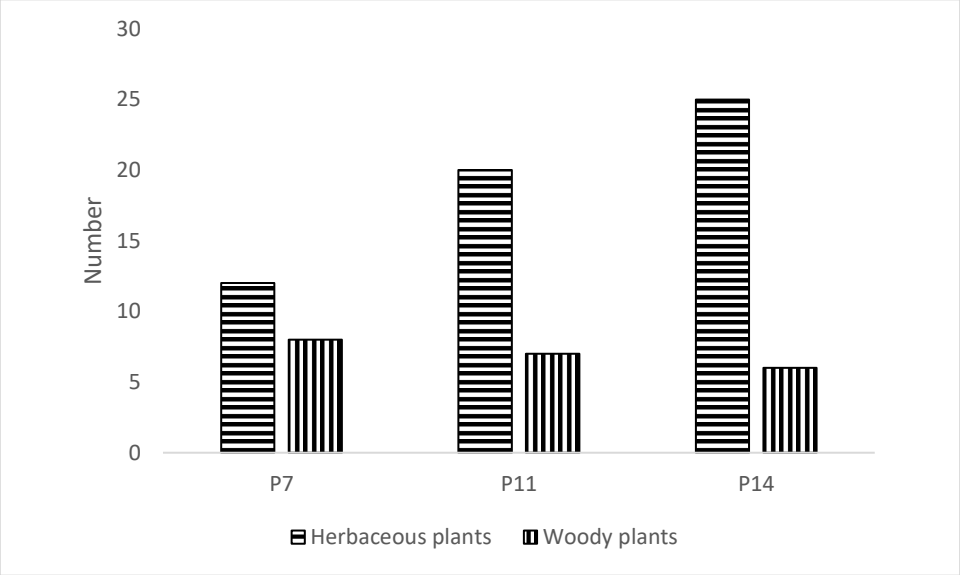

Fig. 3. Variation of morphological groups in the different plantations

3.2.2 TYPES OF LIFE FORMS

Figure 6 shows four life form in the oil palm plantation namely: Phanerophytes, Chamephytes, Hemicryptophytes and Geophytes. Phanerophytes were the most abundant in P7 (26 species) but almost nonexistent in P14 (1 specie). However, in P11 they had an intermediate abundance (7 species). Similarly, Chamephytes were represented by 19 species in P14, species in P7 and 16 species in P11. P7 was characterized by very low presence of Hemicryptophyte species (01) compared to P14 and P11 (4 and 3 species, respectively). Generally, Geophytes were very poorly represented with 01, 02 and 02 species in P11, P14 and P7, respectively.

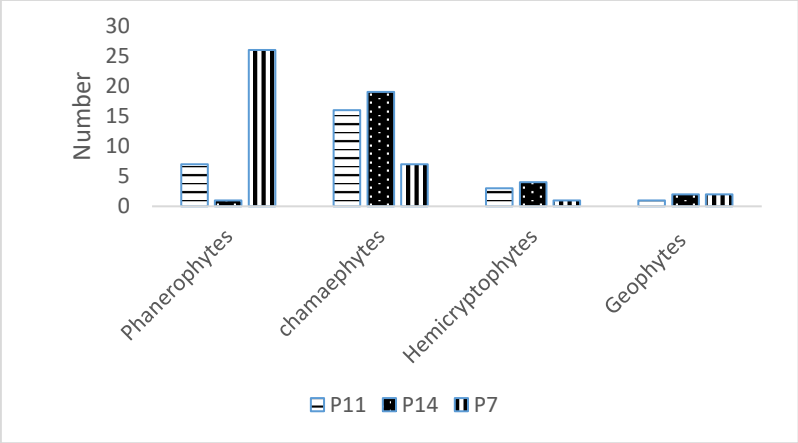

Fig. 4. Distribution of species within different life forms

3.2.3 TYPES OF DIASPORES

The types of diaspores found in the flora of oil palm plantations in the locality of Ngoas in Cameroon are distributed according to the model developed by Dansereau and Lems (1957) [19] as shown shown in Table VI.

Fig. 5. Types of diaspores in oil palm plantations

From figure 7 it appears that in the locality of Ngoas in Cameroon, the flora consists of autochore and heterochore species which are respectively, sclerochores and sarcochores. P14 and P11 were the richest in sclerochore species with 22 and 20 species, respectively against 09 species only in P7 which on the other hand presents the highest species richness in sarcochore species (28 species) compared to P11 and P14 where respectively 7 and 9 sarcochore species were inventoried.

3.2.4 PHYTOGEOGRAPHIC TYPES

The results, it reveal that in the oil palm plantations of the locality of Ngoas are found species with a wide distribution (pantropical (Pan), cosmopolitan (Cos), paleotropical (Pal), afrotropical (AT), afromalgaches (AM) and endemic Guineo-Congolese species (GC), Guinean (G) and Lower Guinean (BG).

Table 4. Phytogeographical types of plant species from oil palm plantations in the locality of Ngoas in Cameroon

	Species with large						Endemic Guineo-congolese species			
	Pan	Cos	Pal	AT	AM	Total	GC	G	BG	Total
P11	19	0	1	3	1	24	3	0	0	3
P14	21	1	1	2	0	25	5	0	1	6
P7	10	0	1	4	0	15	3	1	1	5
Total	50	1	3	9	1	64	11	1	2	14

Table 4 above reveals that species with wide distribution (64) are those which are more abundant in all three plantations, compared to the endemic Guinean-Congolese species (14). Among the widely distributed species, Pan (50) species are the most represented. Similarly, among the endemic Guinean-Congolese species, GC species are the most represented.

3.3 INFLUENCE OF FARMING PRACTICES ON PLANT DIVERSITY

Spearman's test used to assess the correlation between species richness and abundance shows a P-value (0.511) greater than 5% and a negative Rho (-0.1561027). This result indicates a non-significant and negative correlation between the two variables.

The evaluation of variation in species richness reveals that abundance (dof = 1; F = 0.7935; P-value = 0.3855) and altitude (dof = 1; F = 0.1651; P-value = 0.6895) do not influence the species richness of the different plantations. The average species richness according to the altitude was 7.9 ± 3.14 individuals while according to the abundance it was 6.8 ± 1.98 individuals.

The result of the correlation between species richness of the quadrats installed in the different plantations of *Elaeis guineensis* and annual fertilization (regular, irregular and no fertilization) shows a P-value (0.0023) <5% which indicates a significant correlation between the two variables. However, the result of the Tukey HSD test revealed a differences in mean values of species richness as a function of regularity, irregularity and lack of fertilization respectively as follows: 7.83 ± 2.13; 9 ± 1.30 and 4.6 ± 2.4 (figure 8).

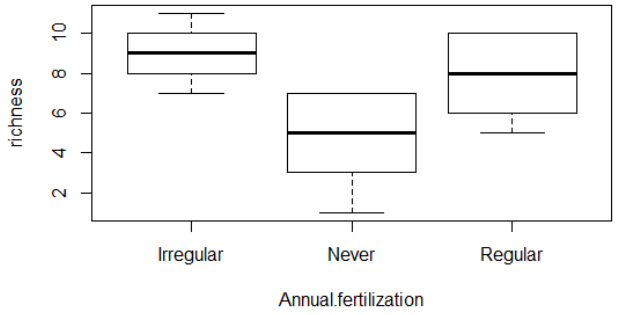

Fig. 6. Variation in species richness compared to annual fertilization

The linear model applied (p-value = 0.000808) shows the influence of the type of weeding on the species richness of the different environments. As a result, the plantation subjected to the combination of chemical and manual weeding are those which have the highest species richness (8.5 ± 1.74) compared to that of the manually weeded stand (4.6 ± 2.4). However, the linear model does not show any difference between the specific richness obtained under the two conditions (p-value = 0.14). The means value of species richness obtained under conditions A and B are respectively 8.66 ± 1.21 and 6.78 ± 2.88 as seen in Figure 9 below.

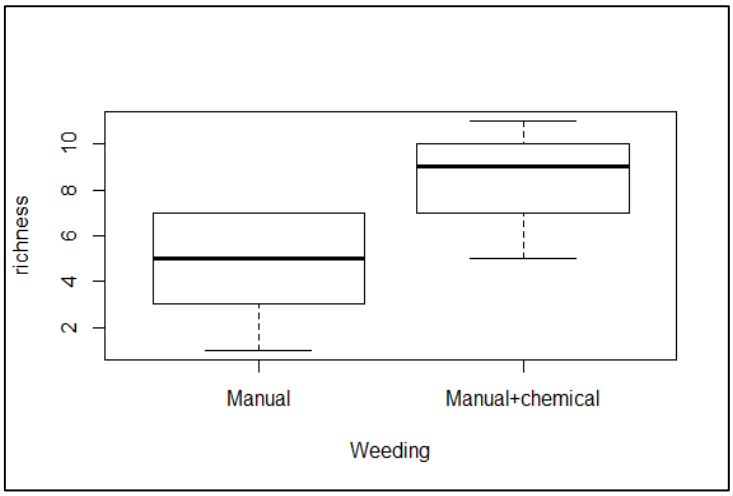

Fig. 7. Variation in species richness compared to the type of weeding

4 DISCUSSION

4.1 FLORA COMPOSITION DIVERSITY

For the three oil palm plantations P11, P14 and P7, the number of species obtained were 27, 31 and 37, respective, belonging to 26, 28 and 34 genera, and to 18, 19 and 27 plant families, respectively. This result obtained for the entire sample demonstrates a low plant species diversity for in oil palm plantations made evident by the values of the Shannon-Wiener coefficients (0.88 ± 0.56; 0.65 ± 0.32, 0.46 ± 0.26) which shows the species diversity of a given medium and the species richness (7.83 ± 2.14; 9.00 ± 1.31; 4.67 ± 2.42). This is confirmed by the abundance of families represented by single species. However, regarding the families, the abundance of species in the Asteraceae and Poaceae families reflects their presence in an open environment. On the contrary, in P7, the presence of the species of the family of Cecropiaceae represented by *Musanga cecropioides* and that of Euphorbiaceae represented by *Macaranga assas*, reveals that the plot was initially made up of a secondary forest. The Irvingiaceae and the Moraceae families provide information on the fact that we are in the Guinean-Congolese zone. The low Shannon indices of each stand justifies the dominance of some species [31] which in P11 are *Ageratum conizoides* (Asteraceae), *Axonopus compressus* (Poaceae), *Setaria pedicellatum* (Poaceae), et *Alternanthera sessilis*

(Amaranthaceae); in P14, *Axonopus compressus* (Poaceae) and *Setaria pedicellatum* (Poaceae); in P7, *Chromolaen aodorata* (Asteraceae) for herbaceous plants and *Theobroma cacao* (Malvaceae), *Persea americana* (Lauraceae) and *Musanga cecropioides* (Cecropiaceae) for ligneous species. The abundance of species in the Asteraceae, Poaceae and Malvaceae families testifies to the fact that the environment is disturbed [32].

4.2 FUNCTIONAL GROUPS

The cultivation of oil palm due to its heliophilic nature requires the suppression of all other woody shrubs and tree species [33]. The results suggest that the diversity of morphological groups depends on the age of the plantations. The older a plantation (P14), the more it is diversified in herbaceous species and very little in woody species even at the seedling stage. The youngest plantation (P7) is much more diverse in woody species (trees, shrubs and seedlings). However, seedlings that appears are those of species that colonise the surrounding forest. As a result, herbaceous plants represent the highest morphological type present in all stands (57 herbaceous species against 21 woody). Among the listed species, there are certainly woody species and herbaceous species but also there are among the herbaceous plants, woody plants at the seedling stage. Furthermore, it is important to note that the density of herbaceous species is higher in P14 and P11 which are 14 and 11 years old, respectively. The abundance of the herbaceous morphological type is in phase with that of the Chamephytes life form. In fact, in all the stands, Chamephytes are generally the most abundant compared to the Phanerophytes which are often much more represented in forest environment [31]. This could be explained simply by the heliophilic character of the oil palm. Indeed, several factors contribute to the break of dormancy of the seeds contained in the soil, in particular the variations of temperatures and atmospheric humidity, fire, the passage in the intestinal organs of animals, microbial activity in the soil, termites or other insects [34] - [35]. Under natural conditions, the luminosity and variation of temperature are the most important factors acting on the breaking of dormancy of seeds in the soil gene bank [36] - [37] - [38]. The systematic felling of trees during the installation of oil palm plantations leads to sudden variations in atmospheric temperature, humidity and light. This could lead not only to a break in dormancy of the seeds of woody species in a slowed-down situation in the soil bank but also the propagation of herbaceous species whose pioneering and heliophilic character is evident. Another perception of these results could make it possible to say that the variation in morphological types in oil palm plantations in the locality of Ngoas in Cameroon is much more linked to the age of the plantations. Indeed, the youngest plantation, P7 is much richer in woody species, compared to the other two, P11and P14 which are abundantly colonized by herbaceous species. Over time, the woody species at the seedling stage decrease with the different weedings at the detriment of herbaceous, heliophilous and more competitive species. These results also show that not all trees in oil palm stands may be cut at the same time, hence the abundance of woody shrub and tree species in P7.The age of the stands studied is an element which could explain the variation of several parameters. The density of the Phanerophytes is in this case a function of the age of the stand. In fact, the older the plantations, the less abundant the Phanerophytes within them.

This work presents results similar to those of Boupoya (2010) [39] who analyzed the flora and vegetation of intra forest clearings on hydromorphic soil in the Ivindo National Park in northeast Gabon and who obtained high abundances for geophytes, Chamephytes and Therophytes compared to the other life forms in the meadows which are open environments just like plantations. The mode of distribution of species in oil palm stands depends on the age of the plantations. Indeed, in P11 and P14, the sclerochore species are represented respectively at 74% to 70% compared to the sarcochore species which are respectively represented in the same plantations at 25% and 29%. In P7, the sarcochore species, represented at 75%, are the most represented. Species with a wide distribution are the most represented (82%) compared to endemic Guinean-Congolese species (17%). Among species with a wide distribution, pantropical species are the most represented (78.12%) justified by the wide distribution of herbaceous species which are generally more abundant in all the stands. On the other hand, for the endemic Guinean-Congolese species, the Guinean-Congolese species are the most abundant (78.57%), which testifies to the fact that the sites have not completely lost their original floristic specificity and on the other hand the belonging of the locality of study to the Guinean-Congolese region [40].

FARMING PRACTICES AND SPECIES DIVERSITY

There is a positive correlation between the species richness of the different stands and their annual fertilization. Depending on the regularity, the irregularity and the absence of annual fertilization, the values of the species richness were 7.83 ± 2.13; 9 ± 1.30 and 4.6 ± 2.4, respectively. It appears that stands that receive regular fertilization are floristically the richest compared to those that are irregularly fertilized and those that have never been fertilized. These results could suggest that a sporadic supply of fertilizers to the soils of oil palm plantations is beneficial for the specific richness of herbaceous species. This result is similar to the results obtained by Sweeney et al. (2008) [41] and Soares et al. (2016) [42] who evaluated the effect of nitrogen

fertilizers on the emergence and growth of some ruderal species and showed that the supply of these fertilizers in the soil promotes germination, growth and productivity of poor grass compared to unfertilized environments. However, germination depends on the environmental conditions as well as on the species considered. However, the high species richness of the plot under irregular fertilization suggest that the high presence of certain nutrients in the soil has an inhibiting action on the breaking of dormancy in some species on one hand and lowering of the concentration of the nutrients brought to the soil following their digestion or their leaching that leads to a beneficial competition which maintains the species richness of the environment on the other hand. According to Rahnavard et al. (2009) [43], the application of nitrogen fertilizers and NPK can reduce the density and biomass of weeds in growing media.

The frequency of annual weeding has no impact on the plant diversity of the different stands. On the contrary, the generalized linear model (p-value = 0.000808), made it possible to note that the plantations in which a combination of manual and chemical weeding were applied are the most diverse (8.5 ± 1.74 species) compared to the stand subject to manual weeding only (4.6 ± 2.4 species). We were expecting that the media subject to the combination of manual and chemical weed control in this case P11 and P14 should be the least diversified in terms of species compared to the media subjected to chemical weed control (P7). However, it seems that the application of herbicides could have favoured the emergence of monocots in P11 and P14 notably *Axonopus compressus* (Poaceae), *Setaria pedicellatum* (Poaceae) compared to dicots which were dominant in P7 and represented by *Ageratum conizoides* (Asteraceae) and *Chromolaena odorata* (Asteraceae).

5 CONCLUSION

The study of the plant diversity in oil palm plantations in the locality of Ngoas in Cameroon has shown that the different environments, although entirely modified by the installation of plantations still contain flora with a background of species woody (26.92%) even at the seedling stage. the Phanerophytes are still well represented (37.5%) although the chamephytes are more abundant (47.72%). This strong expansion of the Chamephytes results from the strong anthropization of the environment which has become open to the light rays. Most species are Sclerochore (53.68%). However, sarcochore species are represented (46.31%). The sclerochores are more encountered among herbaceous plants compared to the sarcochores which are encountered among woody species. Overall, the flora background is made up of species with wide distribution (64 species among which 50 pantropical species) compared to endemic Guinean-Congolese species (14 species, among which 11 Guinean-Congolese species). The results of this work have shown that, overall, oil palm plantations are poorly diversified environments in terms of plant species Indeed, the three oil palm plantations P7, P11 and P14 concerned by this study, contain 37 species, 34 genera and 27 families, 6 monocots and 31 dicots; 27 species, 26 genera, 18 families, monocots and 21 dicots; 31 species, 28 genera, 19 families 8 monocots and 23 dicots, respectively. The low values of the Shannon indices testify to the dominance of some species in the different plantations. The combination of manual and chemical weeding promotes the diversity of herbaceous species within the different stands. However, the frequency of weeding has no effect on species diversity. Also, irregular fertilization induces greater specific richness. These results can be used for the conservation of herbaceous plant biodiversity as well as the control of weeds in oil palm stands.

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