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Characterization of weeds in cashew plantations (*Anacardium occidentale* L.) in the Bafing region, in the North-West of Côte d'Ivoire

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Abstract

For the past five years, cashew has played an important role in the performance of the agricultural sector in Côte d'Ivoire. However, weeds represent one of the major constraints that compromise its production. The objective of this study is to characterize the weed flora and to identify the species most harmful to cashew cultivation in the Bafing region, precisely in the locality of Touba located in the North-West of the Côte d'Ivoire. Knowing the weed flora is necessary in order to carry out an effective fight against it. One hundred and twenty-four (124) surveys were carried out in cashew orchards in the localities of Kôssafinisso, Mandougou, Sesso, Têkor and Timinnnisso. The floristic inventory identified eighty two (82) weed species divided into sixty three (63) genera belonging to twenty five (25) families. By grouping according to botanical classes, the Dicotyledons represent 67% of the weed flora and the Monocotyledons, 33%. Poaceae (19%), Fabaceae (13%), Asteraceae (11%), Rubiaceae (9%), Malvaceae (6%), Cyperaceae and Euphorbiaceae (5% each) dominate the listed species. Regarding the biological types, therophytes and nanophanerophytes are the best represented with respectively 45% and 22% of species. The quantitative floristic analysis shows that the species most harmful to cashew cultivation are *Fleischmannia microstemon, Chromolaena odorata* and *Rottboellia cochinchinensis.*

Keywords: Cashew; Côte d'Ivoire; Harmfulness; Weed

1. Introduction

Introduced in Côte d'Ivoire since the independence period, the cashew tree (*Anacardium occidentale* L.) or cashew apple was first considered as a tree for reforestation between 1959 and 1960, then as a tree for fruit production, 1960 to the present day [1]. Today, the cashew nut sub-sector in Côte d'Ivoire has become an important agro-industrial sector for the Ivorian economy and a significant source of income for populations living in rural areas. Indeed, this crop occupies more than 350,000 producers and supports around 2.5 million people [2]. In addition, national production has grown considerably, from 235,000 tonnes in 2006 to over 968,676 tonnes of raw cashew nuts in FIRCA [3]. National production has more than doubled in a decade, making Côte d'Ivoire the world's leading cashew nut producer according to FIRCA [2]. Ivorian production represents nearly 20% of the world supply of raw cashew nuts. Despite this performance, orchard nut yields are still low because cashew cultivation is subject to many constraints (weeds, pests, diseases, etc.). These low yields are around 350 to 500 kg/ha [4] compared to those obtained in India, Vietnam, Brazil and Tanzania, between 1000 and 1500 kg/ha [5]. Weeds constitute a biological constraint that affects agricultural production and considerably reduces yields [6].

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Weed competition with crops for water, light, nutrients and space to grow can have a direct negative effect on yield. These losses are estimated at 9.7% of global agricultural production and range from 10 to 56% in Africa according to [7]. Recent studies have shown that weeds can cause between 15% and 97% of yield reduction [8].

Several efforts have been made to improve production, but the action of weeds is still a concern, especially since climate change and the shortening of fallow periods lead to the multiplication and abundance of problematic species. These species have always been harmful to crops, especially those in developing countries. The ability of these weeds to colonize the environment is a constant concern for the farmer. Difficulties in controlling weeds then become one of the main reasons forcing farmers to abandon old plots to create new ones [7]. However, to properly reason the fight against weeds, it is important to know the floristic composition that accompanies the crop established, both annual and perennial [6]. This justifies the purpose of the present study devoted to the knowledge of weed flora in cashew orchards in the Bafing region of Côte d'Ivoire.

1.1. Geographic location of the study area

This study was carried out in the north-west of Côte d'Ivoire, more precisely in the Bafing region located between the regions of Kabadougou to the north, Worodougou to the east, Tonkpi to the south and Guinea to the west. It is located 742 km from Abidjan, between latitudes 8° and 9° North and longitudes 7° and 8° 25 West. This region of Bafing has an area of 8650 km^2 and its capital is Touba. For this study, five localities were selected according to the presence of cashew crops, namely: Kossafinisso, Sesso, Mandougou, Têkor and Timminnisso (Figure1).

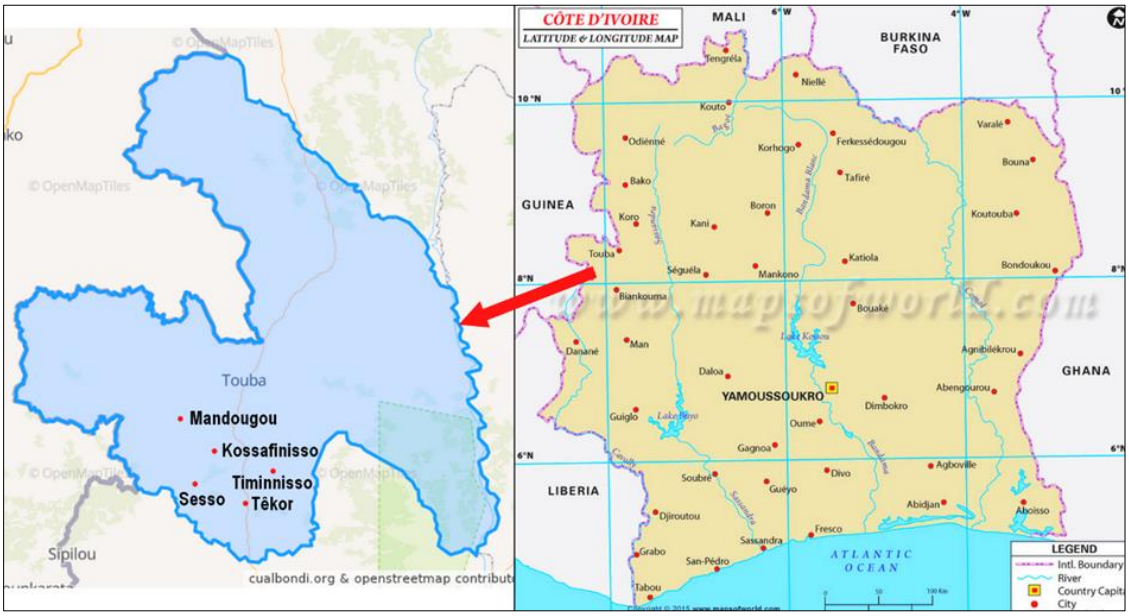

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Figure 1 Location of the Bafing region (study area)

2. Methodology

2.1. Floristic inventory

2.1.1. Sampling

Weeds were inventoried in plots of 10 m x 10 m each [9, 10] in the cashew orchards surveyed. The cashew tree crowns were layered in half. When the crowns of cashew trees never touch, we speak of separate crowns and when they touch, we speak of contiguous crowns (Juxtaposed and Closed). In the plantations with homogeneous crowns, ie a plantation presenting one of the two states, a single plot of 100 m^2 was installed and surveyed. On the other hand, in the plantations with heterogeneous crowns, made up of cashew tree crowns presenting the two types of crowns (separate and contiguous), two plots of 100 m^2 were installed and surveyed so as to have a plot in each type of cashew tree crown.

2.1.2. Realization of floristic surveys

Carrying out the floristic inventory consists of assigning abundance-dominance scores to the weed species observed. This makes it possible to estimate the agronomic importance of each weed encountered. Many authors establish the optimal observation area according to the type of crop. This area of 100 m^2 was chosen as the sampling unit for our work because, according to Guillerm [11], this area is the best suited for floristic surveys. All the species present on the defined surfaces are listed and then assigned an abundance-dominance index according to the rating scale of Le Bourgeois [12].

2.1.3. Investigation

An individual survey was conducted with individual farmers. This provided information on the phytoecological variables in Table 1.

Table 1 Nature of the ecological variables taken into account in the study

Factors	Modality of factors	Number of statements
Soil Texture	clayey	14
	Clay-sandy	62
	sandy	48
age of culture	1 to 5 years	56
	5 to 10 years	45
	10 to 15 years	23
Localities	Kôssafinisso	16
	Mandougou	63
	Sesso	16
	Têkor	7
	Timinnisso	22
Types of crowns	Separated	76
	Joined	48
Weeding methods	Manual	21
	Chemical	31
	Integrated	72

2.2. Data processing

2.2.1. Qualitative floristic analysis

Floristic composition

Floristic richness is the number of species within the limits of a territory [13]. It designates the number of taxa found in this environment, without judging either their frequency or their abundance, or even the size and productivity of the species encountered [14]. It also provides information on the number of genera and families, then species per family and species per genus. The floristic richness was determined by listing and then counting the species of each locality, all brought back to the study area.

Biological spectrum

The biological type classification model adopted in this study was that of Aké-Assi [15] itself adapted from the model of Raunkiaer [16]. Each species has been assigned the biological type to which it belongs. The percentages representing each biological type were calculated to establish the spectrum of biological types. The percentages were calculated using the formula below:

$$\mathbf{T}\text{B }(\%) = \frac{\text{Total species of same (TB)}}{\text{Total of all species}} \times 100$$

2.2.2. Quantitative floristic analysis

Similarity coefficient

It is used to compare the floristic lists obtained in different localities. For this purpose, the coefficient of Sorensen (1948) is used. It is calculated as follows:

$$\text{CS }(\%) = 100 \text{ x } (\frac{2\,c}{a+b})$$

With (a) and (b) the number of species recorded respectively in the two sampling units and c the number of species common to the two lists a and b. The value of the similarity coefficient (CS) is expressed as a percentage.

Generic family diversity index

It is an expression which makes possible to know the generic diversity of the various inventoried families. It gives an idea of the degree of floristic diversity of a studied flora and is calculated using the following formula:

With E = Number of species and G = Number of genus Idg=E/G

Weed frequencies

The frequency of a species is reflected in the regularity of its distribution in a plant community [17]. Absolute (Fa) or specific (Fs) frequency is the number (n) of times a species (e) was observed in (N) records representing a sample. The relative frequency (Fr) is the ratio of its absolute frequency (Fa) to the total number of records (N). From the relative frequency, the centesimal frequency (Fc) which is the relative frequency expressed as a percentage was defined as follows:

$$\text{Fc }(\%) = (100 \times \text{Fa})/\text{N}$$

Specific contribution due to the frequency of each species (Csf)

It is the expression of the contribution of a species to a given vegetation based on its absolute frequency; it is calculated using the formula proposed by [18].

$$\text{Cs F }(\%) = (100 \times \text{FS(e)})/(\Sigma^{1}{}_{n}\,\text{FS})$$

Where FS(e) is the absolute frequency of the species (e) and $\sum FS^{1}{}_{n\_}$ the sum of the absolute frequencies of all the species listed (n). This expression translates the aggressiveness of the species [17].

Weed damage potential

The harmfulness potential reflects the extent of the weed problems posed by the various weeds. The degree of harmfulness of the weeds is evaluated from the construction of the infestation diagram. This diagram consists of a cloud of points established from the centesimal frequencies and the average abundance/dominance indices of each species. The centesimal frequencies are shown on the abscissa and the average abundance/dominance indices on the ordinate. The average abundance-dominance index is calculated based on the number of surveys in which the species is present. This makes it possible to differentiate groups of species according to their degree of infestation, and therefore their agronomic importance.

2.2.3. Data organization

The data was organized in a matrix and then analyzed through CFA. XLSTAT software version 2016 was used.

2.3. Statistical analysis

The information concerning the different social and agronomic characters were analyzed using Excel software. For each character, percentage calculations have been established. The names of the species have been reduced by codifications in order to facilitate their insertion during the statistical analyses. Thus, the first three letters of the genus were associated with the first two letters of the specific epithet. Example, Ageco for *Ageratum conyzoides*

3. Results

3.1. Qualitative floristic analysis of cashew weeds

3.1.1. Floristic composition

The floristic surveys, carried out in 5 villages, made it possible to identify 82 species distributed among 63 genera belonging to 25 families (Table 2). Of the 25 families identified, 7 are dominant and include 56 species, i.e. 68% of all species. These are Poaceae (19%), Fabaceae (13%), Asteraceae (11%), Rubiaceae (9%), Malvaceae (6%), Cyperaceae and Euphorbiaceae (5% each)

The flora listed on all the localities in this study indicates that the class of Dicotyledons is the majority with 67% against 33% for Monocotyledons. This trend is practically identical in all localities (Table 2).

Table 2 Taxonomic distribution of weeds in cashew cultivation in the different localities of Bafing

Locality	**Kôssafinisso**	**Mandougou**	**Sesso**	**Têkor**	**Timinnisso**	**Study area**
Dicotyledons	18	36	15	15	24	55
	60%	65.45%	68.18%	71.43%	61.54%	67%
Monocotyledons	12	19	7	6	15	27
	40%	34.55%	31.82%	28.57%	38.46%	33%
Number of families	9	18	10	10	17	25
Number of genus	25	47	19	20	34	63
Number of species	32	55	23	22	39	82

3.1.2. Biological spectrum

In terms of biological types, weed flora is dominated by therophytes and nanophanerophytes throughout the study area with respective proportions of 45% and 22%. This trend is also observed in the five localities of the study area (Table 3).

Table 3 Biological spectrum of the weed flora of cashew orchards in the different localities

Localités	**Biological Types**						
	Th	**np**	**Ch**	**H**	**G**	**Lmp**	**mp**
Kôssafinisso	63%	20%	7%	7%	3%	0%	0%
Mandougou	40%	24%	14%	11%	7%	4%	0%
Sesso	59%	23%	4%	9%	5%	0%	0%
Têkor	47%	24%	5%	5%	9%	5%	5%
Timinnisso	41%	26%	10%	8%	8%	5%	2%
Study area	45%	22%	12%	9%	6%	4%	2%

Lmp: lianescent microphanerophyte, mp: microphanerophyte, np: Nanophanerophyte, Ch: Chamephyte, H: Hemicryptophyte, G: Geophyte, Th: Therophyte.

3.2. Quantitative analysis of cashew weed flora

3.2.1. Generic Diversity Index

The generic diversity index was only calculated for the predominant families. Overall, in the Bafing region, the generic diversity indices are low when referring to these families. In general, the Fabaceae and Asteraceae families are those with the lowest generic diversity index (Idg =1).

These families are therefore the most diverse. The other most diverse families are, in order, Poaceae, Cyperaceae and Euphorbiaceae (1.33 each), Malvaceae (1.67) and Rubiaceae (3).

When referring to each locality, the Fabaceae, Asteraceae and Cyperaceae families are among the families with the lowest generic diversity indices (Idg = 1.00).

In Kôssafinisso, in addition to Asteraceae, come in decreasing order of diversification, Poaceae (1.22), Euphorbiaceae (1.33), Rubiaceae and Malvaceae (1.5 each). In the plantations inspected at Kôssafinisso an absence of Cyperaceae and Fabaceae was noticed.

In the locality of Mandougou, the most diversified families are Fabaceae, Euphorbiaceae, Cyperaceae and Asteraceae (Idg = 1 each) then Poaceae (1.38) and Malvaceae (1.67).

In the locality of Sesso, Fabaceae, Asteraceae, Rubiaceae and Euphorbiaceae have the lowest indices of generic diversity (Idg = 1). The Poaceae (Idg = 1.12) then come the Malvaceae (1.5).

In Têkor, Fabaceae, Asteraceae and Euphorbiaceae are the most diversified with (Idg = 1) then, Malvaceae (2). Rubiaceae and Cyperaceae are absent in this locality.

In Timminnisso, Asteraceae, Cyperaceae and Euphorbiaceae have the lowest generic indices (Idg = 1 each), followed by Poaceae (1.43), Rubiaceae and Malvaceae (1.5 each) (Table 4).

Table 4 Weed families best represented in cashew cultivation in the different study localities, with their generic diversity index (Idg)

Families / Localities	Idg						
	Poaceae	**Fabaceae**	**Asteraceae**	**Rubiaceae**	**Malvaceae**	**Cyperaceae**	**Euphorbiaceae**
Kôssafinisso	1.22	0	1	1.5	1.5	0	1.33
Mandougou	1.38	1	1	2	1.67	1	1
Sesso	1.21	1	1	1	1	0	1
Têkor	1	1	1	0	2	0	1
Timinnisso	1.43	0	1	1.5	1.5	1	1
Study area	1.33	1	1	3	1.67	1.33	1.33

3.2.2. Similarity coefficient

Table 5 Coefficients of similarity between localities

Locality couples	**Species number**			**Cs (%)**
	a	**b**	**c**	
Mandougou-kôssafinisso	55	31	18	41.86%
Mandougou-Sesso	55	22	18	46.75%
Mandougou-Têkor	55	21	17	44.74%
Mandougou-Timinnisso	55	40	29	61.05%
Timinnisso-Sesso	40	22	15	48.39%
Timinnisso-Têkor	40	21	15	49.18%
Timinnisso-kôssafinisso	40	31	15	42.22%
Kôssafinisso-Sesso	31	22	14	52.83%
Kôssafinisso-Têkor	31	21	14	53.85%
Sesso-Têkor	22	21	13	60.47%

Taking into account the 50% threshold to decide on the floristic homogeneity of two localities, we see that the Mandougou-Timinnisso, Sesso-Têkor, Kôssafinisso-Têkor and Kôssafinisso-Sesso pairs have a homogeneous floristic composition. The Mandougou-kôssafinisso, Mandougou-Têkor, Mandougou-Sesso, Timinnisso-Sesso, Timinnisso-Têkor and Timinnisso-kôssafinisso pairs have a heterogeneous floristic composition (Table 5).

3.2.3. Specific contribution due to the frequency of each species

In the locality of Mandougou, 24 species out of the 55 inventoried have a Csf greater than 1. These weeds account for 85.45% of the weed vegetation in this locality.

In Timinnisso, out of 39 inventoried species, 17 species have a specific contribution (Csf) greater than 1. These weeds account for 79.01% of weed growth in cashew orchards.

In the locality of Kôssafinisso, 18 species out of 32 inventoried have a Csf greater than 1. These weeds account for 88% of the weed vegetation in this locality.

Twelve species out of 22 inventoried in Sesso have a specific contribution (Csf) greater than 1. These weeds account for 81.51% of the vegetation of weeds in cashew cultivation in the locality.

In the locality of Têkor, 11 species out of 22 inventoried have a Csf greater than 1. These weeds contribute 73.95% to the vegetation of weeds in this locality.

Of the 82 species of weeds identified in the entire study area, 27 appear to be aggressive for cashew crops with a contribution rate of 73.03%. The most aggressive in decreasing order are *Aframomum melegueta., Ageratum conyzoides* and *Andropogon gayanus*.

Considering each locality of study, the very aggressive species (because Csf > 4) are variable. In the locality of Mandougou, they are in decreasing order : *Chromolaena odorata, Rottboellia cochinchinensis, Fleischmannia microstemon, Andropogon gayanus, Croton hirtus* and *Spermacoce ruelliae*.

In Timinnisso, they are represented by *Rottboellia cochinchinensis, Chromolaena odorata, Croton hirtus, Fleischmannia microstemon, Euphorbia heterophylla, Spermacoce ruelliae* and *Echinochloa pyramidalis.*

In Kôssafinisso, *Rottboellia cochinchinensis, Chromolaena odorata, Fleischmannia microstemon, Synedrella nodiflora, Euphorbia heterophylla, Pennisetum polystachion, Ageratum conyzoides, Sida stipulata* and *Imperata cylindrica* have a very high aggressiveness.

At Sesso, the most aggressiveness species are *Chromolaena odorata, Croton hirtus, Fleischmannia microstemon, Pennisetum polystachion, Rottboellia cochinchinensis, Sida stipulata, Imperata cylindrica, Pueraria phaseoloides, Ageratum conyzoides, Andropogon gayanus, Pennisetum violaceum* and *Spermacoce ruelliae*.

In Têkor, *Chromolaena odorata, Andropogon gayanus, Fleischmannia microstemon, Rottboellia cochinchinensis, Spermacoce ruelliae, Croton hirtus, Imperata cylindrica, Pennisetum violaceum, Pueraria phaseoloides* and *Paspalum scrobiculatum* have the very high aggressiveness.

3.2.4. Harmfulness capacity

The combination of frequency and abundance-dominance of each species listed made it possible to establish the infestation diagram for the entire study area (figure 2) which gives the different groups of weeds. These are: general major weeds (more harmful species in the zone), general potential weeds (very ubiquitous species whose infestations are generally less than those of general major weeds), general weeds (frequent but never abundant species, in almost all settings), regional majors, general potentials, general, local majors, local and minor potentials.

Group 1 consists of general major weeds: these are the most harmful species on the scale of the entire cashew crop in the study area. This group is represented by 3 species which are *Fleischmannia microstemon, Chromolaena odorata* and *Rottboellia cochinchinensis* (figure 3).

The next group includes general potential weeds. It contains species whose infestation is less than that of the previous group. In this group, we have only one species : *Croton hirtus*

Group 4 contains the major regional weeds. These are species with a broad or medium ecological spectrum but often very abundant in regions favorable to their proliferation. *They consist of Imperata cylindrica, Pennisetum violaceum, Pennisetum polystachion, Pueraria phaseoloides, Andropogon gayanus* and *Synedrella nodiflora.*

Within the group of potential regional weeds, *Paspalum scrobiculatum, Echinochloa pyramidalis* and *Spermacoce ruelliae* make up group 5.

Group 6 consists of regional weeds. They do not constitute a hindrance to the culture. As species belonging to this group in our case, there are *Spermacoce ruelliae, Ageratum conyzoides* and *Sida stipulata.*

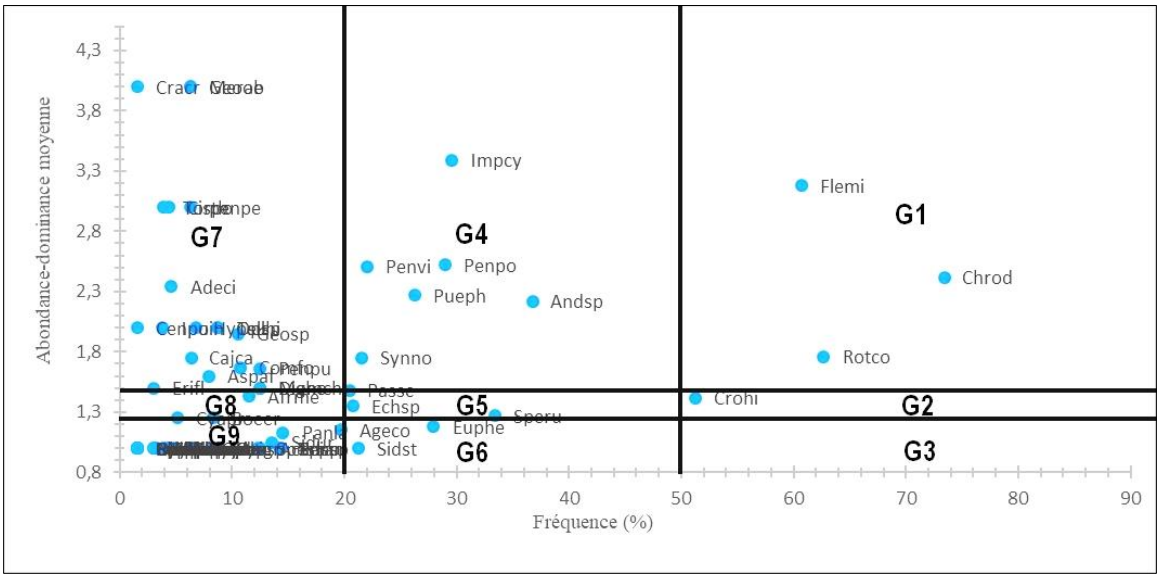

Figure 2 Diagram of weed infestation of cashew crops in Bafing

A: Fleischmannia microstemon; B: Rottboellia cochinchinensis; C: Chromolaena odorata

Figure 3 General major weeds of the cashew orchard in the Bafing region

The major local weeds constitute group 7. The species in this group have a frequency of less than 20%, so are infrequent. However, they are locally very abundant. These weeds are: *Adenia cissampeloides, Crassocephalum crepidioides, Cajanus cajan, Commelina forskalaei, Cissus populnea, Centrosema pubescens, Aspilia africana, Geophila obvollata, Ipomoea involucrata, Hyptis suaveolens, Tephrosia purpurea* and *Torenia thouarsii*. Species in this group are generally a major constraint to cultivation due to their high abundance.

Digitaria horizontalis, Aframomum melegueta, Erigeron floribundus, Momordica charantia, Boerhavia erecta and *Cyanotis axilaris* are the species that constitute the weeds of group 8. The weeds of this group are qualified as local potential weeds.

The last group is that of minor weeds represented by group 9. This group is very strongly represented. These species do not present a hindrance.

3.3. Ecological factors

Correspondence factor analysis (CFA) shows that the abundance of different species in culture environments is linked to the different ecological variables found there. This dependence between weeds and ecological variables is seen through figures 4, 5 and 6 and showing the distribution of species according to ecological variables.

The most significant ecological variables are soil types, crop age and weeding methods.

For the ecological variables "soil type", the results obtained show that for clayey soils, the species encountered are 17 in number. Among these, we can cite : *Imperata cylindrica, Ipomoea involucrata* and *Sida urens.*

For clay-sandy soils, the group of species encountered is made up of 41 species including *Croton hirtus, Aframomum melegueta* and *Ageratum conyzoides*.

For sandy soils, there are 14 species that have a strong affinity. Among them, we can cite *Pennisetum polystachion, Cyathula prostrata* and *Aspilia africana*. Certain species are found without distinction on all types of soil. These are *Paspalum scrobiculatum, Spermacoce ruelliae, Panicum laxum, Pueraria phaseoloides, Phyllanthus amarus, Panicum maximum Pennisetum violaceum* and *Solanum torvum* (figure 4).

Ecological variable "weeding method". For manually weeded orchards, there are 19 species with strong affinity. These include *Chromolaena odorata, Croton hirtus, Oldenlandia herbacea* and *Imperata cylindrica*.

There are 21 species with a strong affinity for chemically weeded environments. We can cite *Erigeron floribundus, Commelina forskalaei, Ageratum conyzoides* and *Synedrella nodiflora*.

The species encountered at the integrated management level are divided into 29 species including *Andropogon gayanus, Aspilia africana* and *Bidens pilosa*. The following species, numbering 10, are encountered indifferently on the three different weeding methods (manual, chemical and integrated). These are *Aframomum melegueta, Echinochloa pyramidalis, Eleusine indica, Euphorbia heterophylla, Fleischmannia microstemon, Panicum laxum, Paspalum scrobiculatum, Pennisetum polystachion, Pennisetum purpureum* and *Spermacoce ruelliae* (figure 5)

Ecological variable "orchard age": In orchards aged 0 to 5 years, the species inventoried are 33. We can cite *Brachiaria deflexa, Chromolaena odorata, Cyanotis axillaris* and *Cynodon dactylon*.

Seventeen species were encountered in orchards aged 5 to 10 years. We can cite *Aframomum melegueta, Andropogon gayanus, Bidens pilosa* and *Crassocephalum crepidioides*.

There are 21 species encountered in orchards aged 10 and over. Among them are *Aspilia africana, Cassia obtusifolia* and *Centrosema pubescens.*

The following eight species are encountered indifferently in the three orchard age categories: *Adenia cissampeloides, Ageratum conyzoides, Boerhavia erecta, Commelina forskalaei, Ampelocissus africana, Ipomoea involucrata, Panicum laxum* and *Triumfetta rhomboidea* (Figure 6).

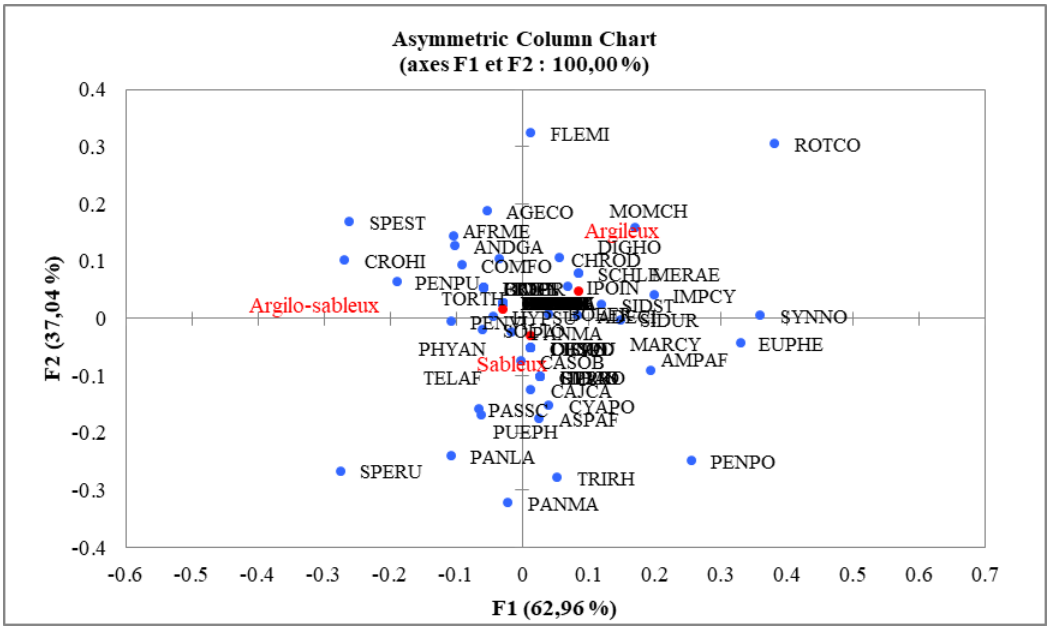

Figure 4 Distribution of species according to soil types in cashew orchards

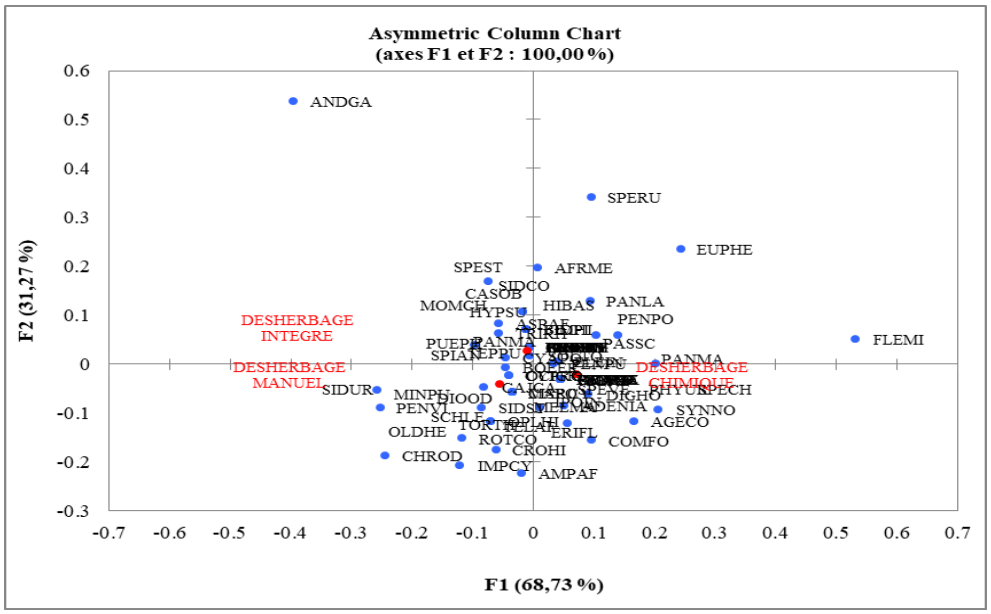

Figure 5 Distribution of species according to weeding methods in cashew orchards

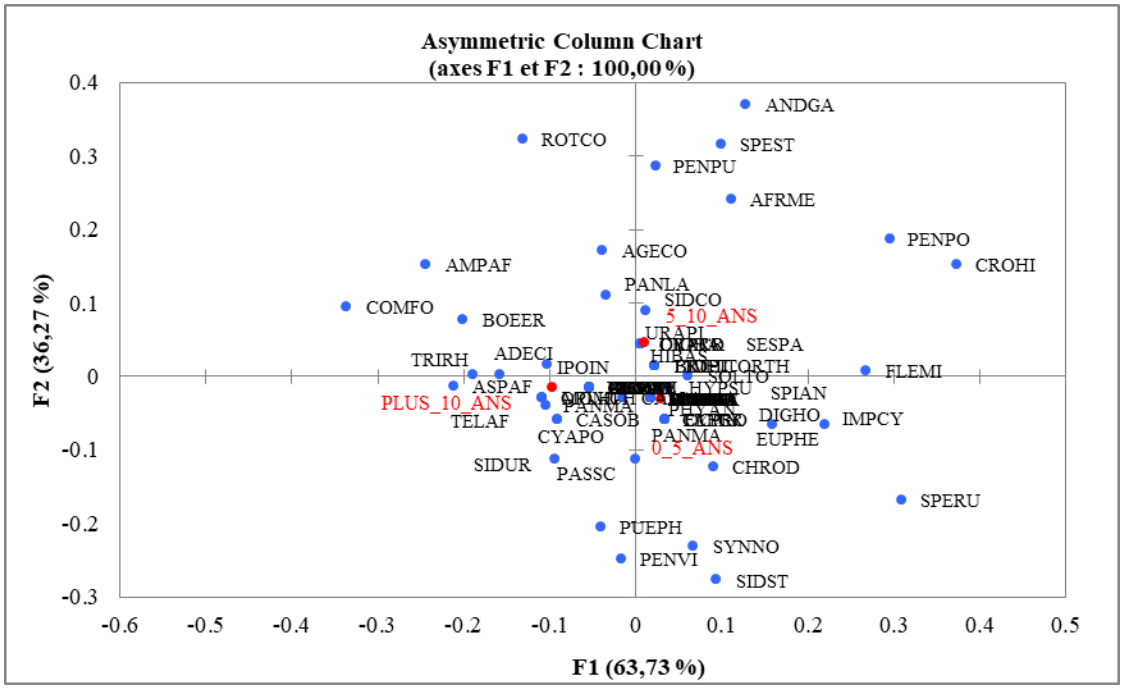

Figure 6 Distribution of species according to age of cashew orchards

4. Discussion

4.1. Qualitative state of the flora

The families best represented in this study are respectively the Poaceae, Fabaceae, Asteraceae, Rubiaceae, Malvaceae, Cyperaceae and Euphorbiaceae which include 68% of all the species of the flora listed. These botanical families are among those identified by [19] during their study. In addition, the works of [7] identified these same families as the most abundant weeds in their studies. In the work carried out by [20]. In the region of Belier, in the center of Côte d'Ivoire, between the six dominant families of weeds that he identified, four are common to those of our study. These are the Poaceae, Cyperaceae, Euphorbiaceae and Rubiaceae. These families are among the 10 families (Euphorbiaceae, Malvaceae, Asteraceae, Poaceae, Cyperaceae, Convolvulaceae, Fabaceae, Polygonaceae, Amaranthaceae and Solanaceae) comprising the most species considered as major weeds worldwide [21]. [22] explains the dominance of these families by the fact that the species that constitute them have a great capacity to adapt to very different environments. Poaceae, Fabaceae and Asteraceae are the best represented among the dominant families in the whole study area as well as in the different localities. The strong presence of Poaceae would be due to the dominance of the cultivation system practiced, namely monoculture. The study conducted by [23] showed that the Poaceae would be the main producers of the seed stock in monoculture soils.

In this work, the class of Dicotyledons is largely represented compared to that of Monocotyledons. This dominance of Dicotyledons confirms the results of several authors such as [24], [25], [20] and [26] who observed trends of approximately 2/3 of Dicotyledons and 1/3 of Monocotyledons in their work. [19] obtained 82.87% of Dicotyledons weed flora in their work in cashew cultivation. These results confirm the constancy of weed representativeness at each taxonomic level considered in Africa.

The spectrum of biological types indicates that Therophytes are more representative with a proportion of 45% of the species. [27] in rice cultivation in the Center of Côte d'Ivoire also reported a proportion greater than 50% of therophyte. [10] also highlighted the high proportion (over 60%) of the same biological type in the cotton-36 need for light of these different species in these study environments. The abundance of Therophytes in cashew orchards would be due to the fact that farmers associate food crops (rice, beans, sesame, yam and maize) with young cashew trees from 0 to 3 years old, to maintain the young orchard in a regularly weeded environment. This regular tillage promotes the development of heliophilous species including Therophytes. In addition, this dynamic of therophytes is all the more increased when the plot is perfectly exposed to the sun [28]. Therophyte weeds adapt in heavily disturbed areas and during unfavorable seasons. They are annual, and characteristic of regions under advanced cultural activity. In addition, therophytes,

preponderant in a field, is explained by a distribution of stock of weed seeds that is done each year. This situation is further amplified by the mode of sexual reproduction resulting in the production of seeds, thus facilitating dissemination. Dissemination is mainly by wind and insects. The reproduction strategy, as in the species of cultivated environments, results in a short cycle but with a high reproductive capacity. These adaptations are typical of plants linked to pioneer conditions: low competitive capacity, but ability to produce in a short time a large number of seeds which will colonize other disturbed sites. Temporary unstable environments, the first stages of wastelands of abandoned land are the favorite domain of these therophytes. In a cultivated plot, according to [29], the rate is on average 80% of therophytes. The group of therophytes is best adapted to withstand disturbances and it is to their life and reproduction strategy that they owe their success. They have a short lifespan, rapid growth, early sexual maturity and produce a large number of seeds. These monocarpic species in fact achieve a very high reproductive effort.

The chamephytes observed in the flora come from stump shoots. These strains of plants obtained by clearing before the establishment of crops have not been removed. The new individuals are emitted by these different organs of regeneration as soon as the conditions are favorable. The persistence of these biological types in the environment may also be due to the fact that tillage in cashew cultivation is superficial, therefore not being able to impact the viability of these strains. Also, the rudimentary farming system adopted by the farmers explains the persistence of these biological types in the environment.

4.2. Harmful species

Chromolaena odorata, Rottboellia cochinchinensis and *Flesichmannia microstemon* are the species identified as the most harmful. Their belonging to the group of general major weeds is explained by their different biological characteristics.

Rottboellia cochinchinensis is an erect, heavily tufted annual grass known to be a vigorous competitor and can reach a height of over 4 meters [30]. Here, in its exotic range, infestations are considered to be the most severe, possibly due to several contributing factors, including improved climatic compatibility, human intervention in the spread of the species, favorable agronomic practices and the absence of natural enemies that have co-evolved with the plant [31]. It has been reported as a weed of several crops in many countries by [30].

Concerning *Chromolaena odorata*, [32] reported that it is of greatest concern in the Center-East zone of Côte d'Ivoire. It has the ability not only to regenerate from its root, from stumps, but also has a very high seed production.

As for *Croton hirtus*, it is a species insensitive to the photoperiod and therefore capable of reproducing throughout the year. It owes its abundance and high frequency to its great ability to colonize environments [33]. It has a very short reproductive cycle, therefore insensitive to photoperiod. This insensitivity means that it can reproduce at any time of the year [34]. Added to this are the irritant properties that this species has because of the hairs that cover its stem and thus make manual weeding difficult. These species impose strong competition on cashew trees.

4.3. Weed distribution factors

Several factors influence the distribution of weeds. Soil type, weeding method and orchard age are the most important. Studies carried out by [35] and [12] revealed that after climatic factors, in particular rainfall, the main factor responsible for the distribution of weeds, the type of soil is the second factor. The preponderance of the type of soil in the distribution of species is explained by the fact that each type of soil has specific nutritional (hydric and mineralogical) conditions. The latter are favorable to the development of a well-defined group of plants.

The "weeding method" factor proved to be discriminating on the weed flora in the different inventoried plots. Indeed, the results obtained showed a good distribution of weeds at the level of the different types of weeding. This factor is more important on the weed flora of manually weeded plots in cassava cultivation in central Côte d'Ivoire [32]. This manual method promotes the vegetative propagation of species such as *Imperata cylindrica*, by cutting and spreading the rhizomatous organs. According to [36] combined weeding (manual and chemical or integrated) allows better control of weeds, because a chemical contribution after clearing makes it possible to control weeds which resist the machete. Some species appeared totally indifferent to the different weeding methods, such as *Aframomum melegueta, Echinochloa pyramidalis, Eleusine indica, Euphorbia heterophylla, Fleischmannia microstemon, Panicum laxum, Paspalum scrobiculatum, Pennisetum polystachion, Pennisetum purpureum* and *Spermacoce ruelliae*.

The “age of the cashew orchard” factor proved to be discriminating on the weed flora in the different inventoried plots. Cashew orchards over 10 years old are favorable to a greater number of species which develop there with low to medium cover. There is significant weed control by the overall covering of the cashew trees by their closed crowns. The shade of the cashew trees reduced emergence and led to the etiolation of some weed seedlings. This negative influence

of the shade of cultivated plants on weed flora was observed by [37] under banana plantations in the Dabou area in Côte d'Ivoire, by [28] in rubber cultivation and by [19] in cashew cultivation. The weed species in this orchard age category are mainly forest species that can withstand the shade of cashew [19].

In orchards from 0 to 5 years old which have separated crowns, the total availability of light for weeds is favorable to heliophilous pioneer species that can withstand the strong intensities and the long daily duration of the sun [38, 39] that develop there. The flora in this group of orchards is very weakly varied.

In cashew orchards of 5 to 10 years old where the intensity and duration of sunlight are intermediate, compared to the two previous groups of orchards, they are ultimately a result of those of said groups. It happens however that we meet in all age categories, some species that are totally indifferent to the intensity and duration of sunlight. This is the case of *Adenia cissampeloides, Ageratum conyzoides, Boerhavia erecta, Commelina forskalaei, Ampelocissus africana, Ipomoea involucrata, Panicum laxum* and *Triumfetta rhomboidea*.

5. Conclusion

This work aimed to know the weeds of cashew crops in the Bafing region in Côte d'Ivoire. From this study, it appears that the adventitious flora of this crop has 82 species distributed among 63 genera. The genera are grouped into 25 families, the best represented of which are in descending order: Poaceae, Fabaceae, Asteraceae, Rubiaceae, Malvaceae, Cyperaceae and Euphorbiaceae. The Dicotyledons are dominant with 55 species or 67% and the Monocotyledons, comprise 27 species, or 33% of the weed flora. The dominant biological types are therophytes with 45% of the species.

The species most harmful to the cashew tree are *Fleischmannia microstemon, Chromolaena odorata* and *Rottboellia cochinchinensis*. The most significant ecological variables are soil types, weeding methods and orchard age. These ecological variables act particularly on the composition of the weed flora by favoring the most competitive weeds and the best adapted according to the conditions. This work has made it possible to have a clearer knowledge of the characteristics of cashew weeds in the region of Bafing in the North-West of Côte d'Ivoire.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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