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(Research Article)

Characterization of the weed flora in maize (*Zea mays* L.) farms in the Adamawa region of Cameroon

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Abstract

In the Adamawa region of Cameroon, maize as the predominant crop, faces significant challenges, including weed management, which substantially compromises yields. This study aimed to characterize the weed flora of maize farms in the Vina division. The modified Braun-Blanquet phytosociological method was applied to 40 maize farms, with three 25 m^2 surveys per site, chosen according to vegetation homogeneity. A total of 74 weed species were recorded, distributed across 58 genera and 17 botanical families. Poaceae (27.02 %), Fabaceae (14.86 %), and Asteraceae (13.51 %) are the most represented families, accounting for 55.39% of the overall observed weed flora. Dicotyledons dominate, representing 62.2 % of the species, while the biological spectrum reveals a strong presence of Therophytes (50 %), indicating a high proportion of short-cycle annual species. High diversity indices (Shannon: 3.81; Simpson: 0.97) and low intersite similarity coefficients (< 50 %), reflect significant high floristic richness and marked heterogeneity between sites. The combined analysis of the infestation diagram and hierarchical classification made it possible to identify three groups of weeds according to their harmfulness. The group of major species, the most problematic for maize cultivation, notably includes *Spermacoce latifolia*, *Ageratum conyzoides*, *Eleusine indica*, *Galinsoga quadriradiata*, *Setaria barbata*, *Bidens pilosa*, *Commelina benghalensis*, *Mimosa pudica*, *Sida rhombifolia*, *Kyllinga squamulata*, and *Euphorbia hirta*. These results constitute an essential basis for implementing targeted management strategies adapted to the local agro-ecological context. However, their effective application in integrated weed management needs comprehensive complementary research on species ecology, their interactions with cropping practices, and their sensitivity to control methods.

Keywords: Weed flora; Maize; Pests; Management strategy; Infestation; Cameroon

1. Introduction

Maize (*Zea mays* L.) is currently the world's most produced cereal, with an estimated output of 1,188 million tonnes [1]. It constitutes an essential staple food for populations in sub-Saharan Africa [2], playing an essential role in food security. In this region, rising food and industrial demand necessitates an intensification of production, with requirements projected to grow by 40% by 2028 [3]. Cameroon is central to this challenge, particularly within the Adamawa region. However, despite a production of 153,000 tonnes in 2020 [4], the local supply remains insufficient to satisfy growing demand.

This inability to optimize yields results from numerous abiotic and biotic constraints. Specifically, weed pressure is predominant and represents one of the major challenges for maize producers in the region. Indeed, weeds are responsible for approximately 50% of yield losses [5], primarily due to severe competition with the crop for soil

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resources (water, nutrients) and light [6]. Furthermore, weeds are considered hosts for numerous insects, pests, diseases, and microorganisms, which consequently reduce crop production and yields [7,8].

Recent studies indicate that maize is a crop highly sensitive to weed competition. In fact, the absence of weeding can lead to a reduction in maize yields ranging from 35 to 87.5 % [9], resulting in significant economic losses estimated at 26.7 billion dollars per year in the United States alone [10]. For example, weed-free plots yield 4,256.5 kg ha−1 of maize, whereas higher weed densities cause yield reductions of 14 to 46 % [5]. Moreover, weeds can trigger stress reactions, affecting nutrient uptake and maize development during critical early growth stages [11]. Effective weed management is therefore crucial to ensuring profitable and quality production [12,13].

The reduction of the production constraints related to weed infestation requires knowledge on the floristic composition of the weeds in the maize fields. This prerequisite is essential for establishing effective Integrated Weed Management (IWM). However, despite the economic importance of maize in the Adamawa region, there is little or no scientific data on the weed species in maize fields. The objective of this study is to characterize the weed flora in maize farms in Adamawa. The results of this research will make it possible to identify the dominant species, assess their potential harmfulness, and provide an essential database for implementing management strategies adapted to the agro-ecological reality of the region.

2. Materials and methods

2.1. Study area

The present study was conducted in the subdivisions of Mbé, Nganha, Martap, and Ngaoundéré 3e, located in the Vina division, Adamawa region, Cameroon. Geographically, this area is situated between 6°30′ and 8°00 North latitude, and between 13°00′ and 14°30′ East longitude (**Figure 1**). This specific area corresponds to Agroecological Zone II of the Guinean High Savannas, which is characterized by a tropical high-altitude climate. This climate features a distinct dry season (November–March) and a rainy season (March–October), with average annual temperatures ranging between 20 and 26°C and an average annual rainfall of approximately 2,000 mm. While the dominant soils are deep ferralsols and lateritic soils depleted by leaching, the presence of more fertile volcanic soils near the volcanic massifs is crucial for supporting local agriculture [14].

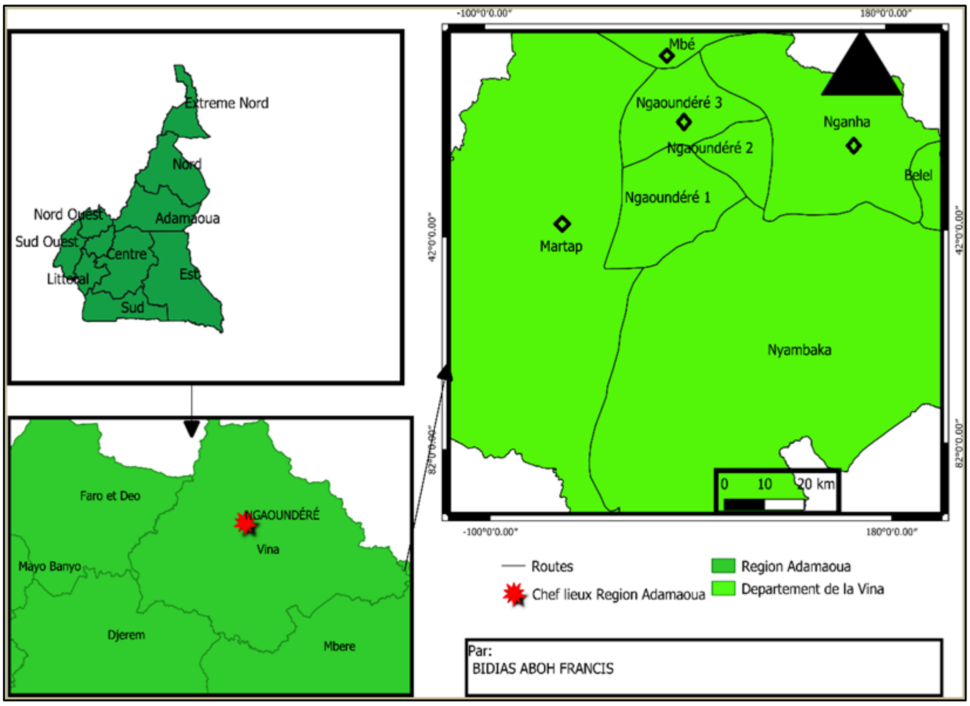

Figure 1 Location of the study area

3. Methodology

The study was carried out in four subdivisions of the Vina division, which were selected based on data from the Departmental Delegation of Agriculture for Rural Development identifying them as the main maize production basins. Floristic inventories were conducted comprehensively across these four subdivisions, spanning the period from August 2024 to September 2025.

A total of 40 agricultural farms specializing in maize cultivation were selected across the four subdivisions using a stratified sampling plan, following the methodology described by Cochran [15]. Each subdivision was treated as a stratum. Within each stratum, three villages were initially chosen to ensure coverage of the entire territory. Subsequently, at least three farms were randomly selected within each chosen village, yielding a total of ten farms per subdivision. This sample size is considered sufficient to reach species saturation on the species-area curve, thereby capturing nearly the entire species richness within the study area, in accordance with phytosociological principles [16].

3.1. Weed flora inventory

The method used for the weed flora inventory was inspired by the Braun-Blanquet approach [17], adapted to better suit the local context. This consisted of determining the minimal sampling areas based on the homogeneity of the vegetation. Three minimal areas, each with a surface area of 25 m^2 [17,18,19,20], were systematically delimited along the diagonal of each maize field, avoiding the edges [21]. All plant species present within these quadrats were then identified, resulting in a total of 120 sampling plots among the 40 surveyed farms.

The inventory procedure involved collecting samples following the traditional Braun-Blanquet approach, by assigning an abundance-dominance coefficient to each species encountered in the sampling areas, according to a scale ranging from 1 to 5, based on ground cover [22]:

- 1 = few individuals, or abundant but with low cover;
- 2 = very abundant individuals or covering 1/20 of the surface area;
- 3 = individuals covering between 1/4 and 1/2 of the surface area;
- 4 = individuals covering between 1/2 and 3/4 of the surface area;
- 5 = individuals covering more than 3/4 of the surface area.

Weed species not immediately identified in the field were collected and preserved as herbarium specimens. Their identification was subsequently conducted using the taxonomic keys from *Adventices tropicales* by Merlier and Montegut [23], and validated by comparison with reference specimens at the National Herbarium of Cameroon.

3.2. Data collection and analysis

3.2.1. Relative frequency

The Relative Frequency (Fr) of a given plant species is defined as the ratio of its Absolute Frequency (Fa), or the number of sampling plots where it is present, to the total number (N) of sampling plots carried out on a given site. It is expressed by the following equation:

$$\mathbf{Fr\ (\%) = (Fa / N).\ 100 \qquad (1)}$$

The Raunkiaer [24] histogram was used for the distribution of the relative frequencies of all inventoried species. The relative frequency classes according to Raunkiaer [24] are presented in Table 1.

Table 1 Relative frequency classes according to Raunkiaer

Class of Frequency	Relative Frequencies (%)
Classe I	0 à 20
Classe II	21 à 40
Classe III	41 à 60
Classe IV	61 à 80
Classe V	81 à 100

3.2.2. Specific contribution due to the frequency of each species

The Specific Contribution (Csi) due to the absolute frequency of a species i (Fai) expresses the aggressiveness or productivity of the species within the plot. It is obtained by the ratio of the species absolute frequency (Fai) to the sum of the absolute frequencies of all inventoried species (nFai), multiplied by 100:

$$\mathbf{Csi} = \boldsymbol{Fai/\textstyle\sum_1^n Fai} * \mathbf{100} \qquad \mathbf{(2)}$$

This specific contribution is interpreted as follows:

- **Csi < 1 %**: Accidental weeds whose depressive effect on the crop is more or less negligible;
- **1 < Csi < 4 %**: Potential major weeds whose depressive effect on the crop is relatively high; they are considered aggressive;
- **Csi > 4 %**: Highly productive major weeds whose depressive effect on the crop is particularly high.

3.2.3. Biological types

The biological types were identified in the field by the respective observation of the growth habits and the position of the renewal buds of the species in the inventoried weed flora. For this purpose, the Raunkiaer [25] classification was used. According to this classification, the following biological types were retained:

- **Phanerophytes (Ph)**: Woody plants whose renewal buds (survival organs) are borne by the perennial stem and are located above 50 centimeters from the soil. They are thus exposed to atmospheric conditions.
- **Chamaephytes (Ch)**: Woody or herbaceous plants whose renewal buds, located on persistent stems, are found at a low height above the ground, generally between 0 and 50 centimeters. These buds are protected from extreme conditions by their proximity to the soil, self-shading, or a layer of litter.
- **Hemicryptophytes (Hc)**: Plants whose renewal buds are located exactly at the soil surface level, after the complete or partial dieback of the above-ground part. These buds benefit from essential protection provided by the plant litter (dead leaves and debris) during the unfavourable season.
- **Therophytes (T)**: Annual plants whose entire life cycle (from germination to seed production) is completed within a single favourable season. The entire plant dies after fruiting. Consequently, they possess no perennial renewal buds. The species survives the unfavourable season (drought or cold) solely in the form of dormant seeds.
- **Geophytes (G)**: In these plants, survival is ensured by underground storage structures (bulbs, rhizomes, tubers) which allow the plant to completely escape climatic constraints (frost, drought).

3.2.4. Similarity coefficient

The Similarity Coefficient is used to establish the resemblance between the different floras of the studied subdivisions. The formula used is that of Sorensen [26], expressed as follows:

$$\mathbf{CS = 2\ c/a+b \times 100} \qquad \mathbf{(3)}$$

Where:

- **a** and **b** represent the number of species recorded in two distinct subdivisions, respectively.
- **c** represents the number of species common to both subdivisions.

The Similarity Coefficient ranges from 0 to 100 %. The two sites have totally different floristic compositions when c=0, and identical compositions when a=b=c. For a Similarity Coefficient greater than or equal to 50 %, the two subdivisions concerned are considered identical.

3.2.5. Floristic diversity indices

To assess the specific richness of the study area, the Shannon-Weaver diversity index and the Simpson diversity index were used. These indices are expressed as follows [27]:

- **Shannon-Weaver Index (H')**

$$\mathbf{H' = -\textstyle\sum_{i=1}^{S}\left(\frac{ni}{N}\right) ln\ \left(\frac{ni}{N}\right)} \qquad \mathbf{(4)}$$

Where:

- ni represents the number of individuals of a species in the sample.
- N represents the total number of individuals of all species in the sample.
- S represents the total number of species.

Interpretation:

- **H' = 0**: No diversity.
- **H' > 0** and low: Low diversity.
- **H' high**: High diversity.

- **Simpson Diversity Index (D)**

$$\mathbf{D = 1 - \sum_{i=1}^{S} Pi\ 2} \qquad \mathbf{(5)}$$

Where:

- Pi is the proportion of individuals of species i relative to the total number of individuals.
- S is the total number of species.

The Simpson diversity index ranges between 0 and 1:

- **D = 0** means there is no diversity.
- **D = 1** indicates maximum diversity.

3.2.6. Infestation diagram and weed classification

The Infestation Diagram is used to classify weed species based on their pressure on the maize crop [28]. It is based on two indicators: relative frequency and the abundance-dominance coefficient, calculated from the absolute frequency and the mean global cover across all sites [29]. This method translates the presence and dominance of species into a degree of infestation.

Weed species are positioned in a two-dimensional space, making it possible to identify those presenting both high frequency and high abundance-dominance, which are considered to have a strong potential for nuisance and impact on the plant community [28,30]. To refine this classification, a Hierarchical Ascending Clustering (HAC) was coupled with the diagram to group the species into homogeneous deleteriousness classes. This combined approach provides a solid basis for identifying the most problematic species and guiding weed management strategies.

3.2.7. Statistical analysis

The collected data were processed using Microsoft Excel 2013 for the calculation of relative frequencies, specific contributions, and diversity indices. Principal Component Analysis (PCA), complemented by Hierarchical Clustering under R (version 4.4.1), was used to group the weed species into harmfulness classes, thereby facilitating their ranking according to their potential impact on the maize crop.

4. Results

4.1. Floristic richness

The surveys conducted allowed for the recording of 74 weed species distributed across 58 genera belonging to 17 botanical families. Of the 17 families identified, three are dominant including 41 species, ie 55.39% of the recorded weed flora. These are Poaceae (27.02 %), Fabaceae (14.86 %) and Asteraceae (13.51 %) (Figure 2).

The class of Dicotyledons (62.2 %) is the most represented, with 46 species, compared to 37.8 % for Monocotyledons, with 28 species (Figure 3).

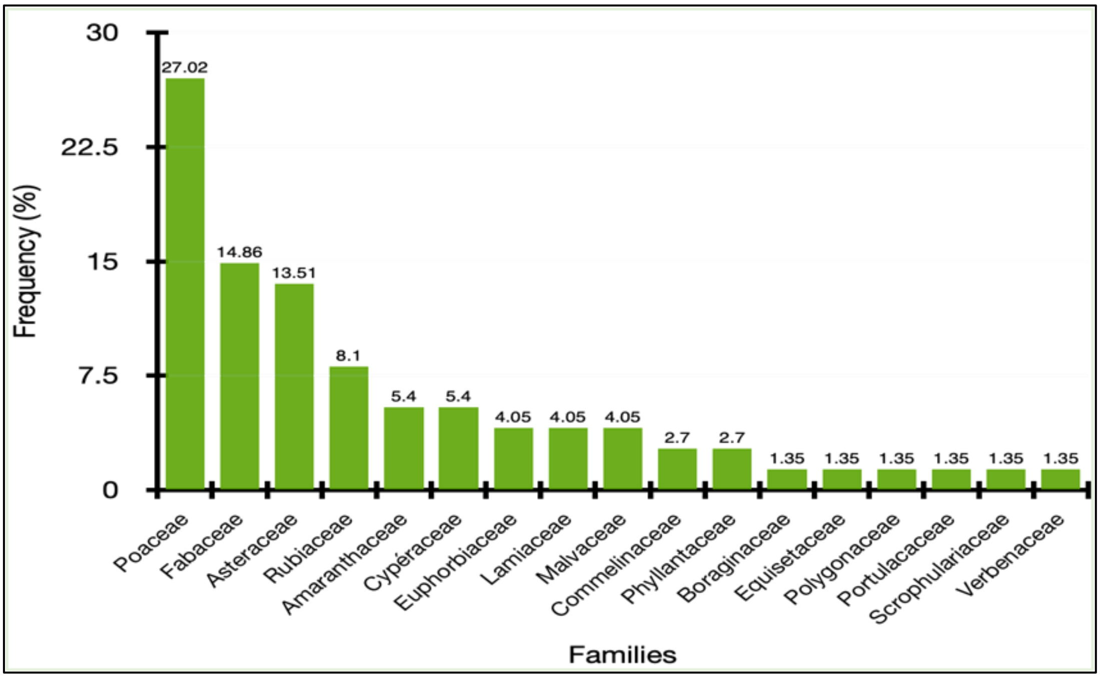

Figure 2 Botanical families of weeds inventoried in maize farms in the Vina division

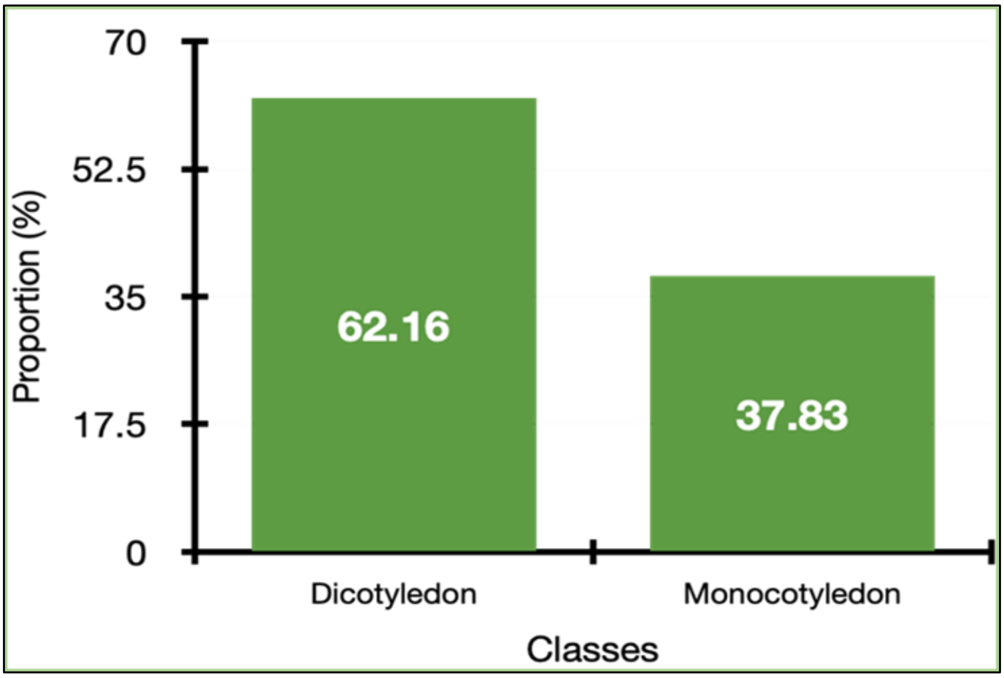

Figure 3 Biological Classes

4.1.1. Relative frequency classes

The data regarding weed species, categorized according to the relative frequency classes, allowed for the construction of a Raunkiaer diagram featuring five classes; I (59%), II (26%), III (8%), IV (5%) and V (1%) **(Figure 4)**.

These results show a large number of species with low frequency, visibly concentrated in Class I. Conversely, the weeds that could be harmful to the maize crop and against which control measures should be considered are found in Classes II, III, IV, and V (**Table 2**).

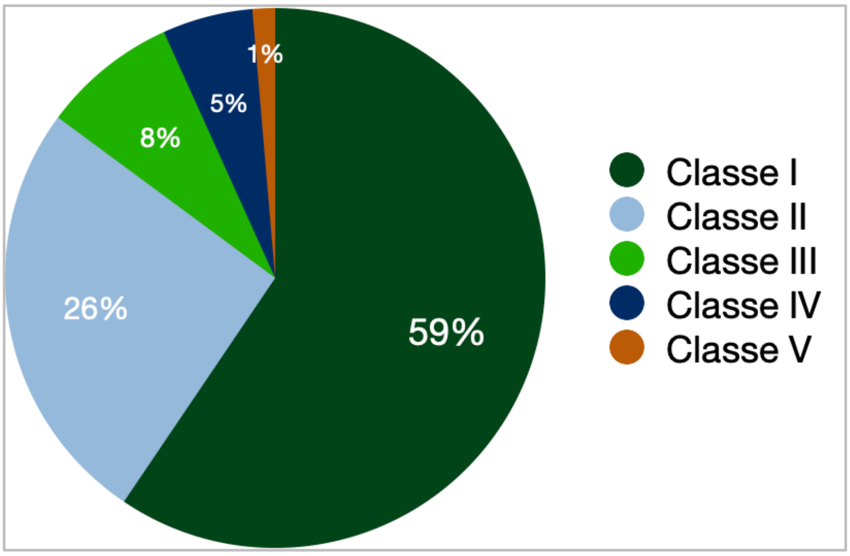

Figure 4 Relative Frequency Classes

Table 2 Relative Frequency Classes

Class	Species
I	*Acanthospermum australe, Achyranthes aspera, Agrostis stolonifera, Alternanthera sessilis, Amaranthus spinosus, Andropogon gayanus, Asparagus glycyphyllos, Bromus diandrus, Calopogonium mucunoides, Chenopodium ficifolium, Chloris gayana, Chloris virgata, Chromolaena odorata, Commelina diffusa Cynodon dactylon, Cyperus difformis, Cyperus eragrostis, Dactyloctenium aegyptium, Digitaria ciliaris, Equisetum sp, Eragrostis capensis, Erigeron floribundus Heliotropium indicum, Hyptis suaveolens, Indigofera hirsuta, Leucas martinicensis Mentha spicata, Micrococca mercurialis, Mitracarpus villosus, Parthenium hysterophorus, Phyllanthus amarus, Phyllanthus niruroides, Portulaca oleracea, Rumex abyssinicus, Sesbania pachycarpa, Spermacoce verticillata, Synedrella nodiflora, Tithonia diversifolia, Trifolium arvense, Trifolium nigrescens, Urena lobata, Verbena officinalis, Vicia faba*
II	*Brachiaria lata, Cyperus rotundus, Digitaria horizontalis, Digitaria sanguinalis, Echinochloa crus-galli, Euphorbia heterophylla, Imperata cylindrica, Mimosa pigra, Mitracarpus hirtus, Panicum maximum, Paspalum scrobiculatum, Rottboellia cochinchinensis, Setaria pumila, Sida acuta, Spermacoce stachydea, Sporobolus pyramidalis, Striga hermonthica, Stylosanthes hamata, Tridax procumbens*
III	*Bidens pilosa, Commelina benghalensis, Mimosa pudica, Sida rhombifolia, Kyllinga squamulata, Euphorbia hirta*
IV	*Ageratum conyzoides, Eleusine indica, Galinsoga quadriradiata, Setaria barbata*
V	*Spermacoce latifolia*

4.2. Biological types

The spectrum of biological types of weeds recorded in maize farms in the Vina division highlights the presence of five biological types. The flora is dominated by species that survive the unfavorable season as seeds, mainly Therophytes (50 %), followed by Hemicryptophytes (25 %), Chamaephytes (11 %), Geophytes (11 %), and finally Phanerophytes (3 %) (Figure 5).

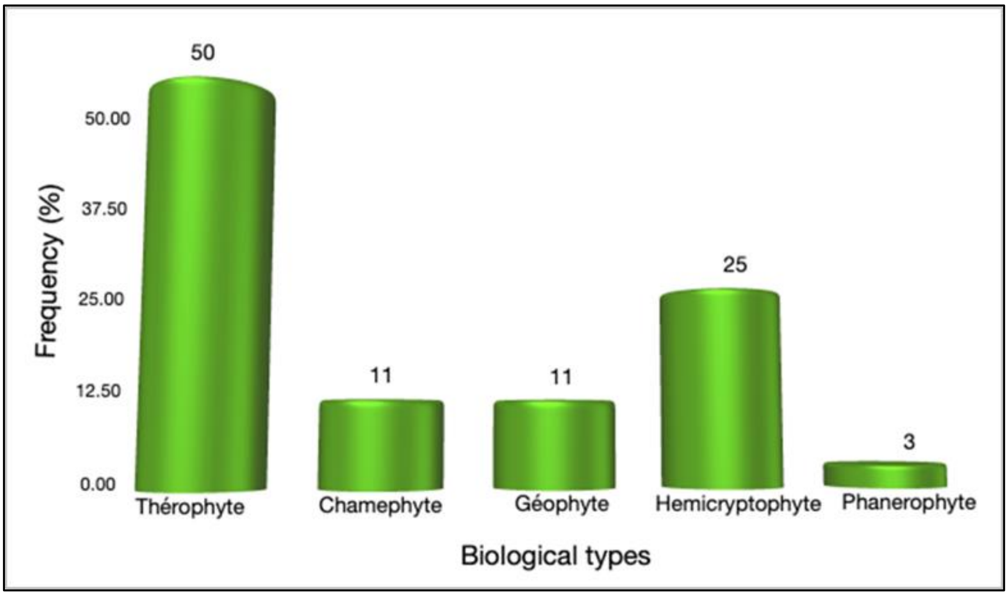

Figure 5 Biological types

4.3. Specific contribution and floristic classification

The Specific Contribution (Csi) due to the absolute frequency of each of the 74 inventoried weed species allowed for the distinction of three weed classes.

- Class of Weeds with Specific Contribution (Csi) Greater than 4 %

This class comprises the major species, considered highly aggressive to the maize crop, including: *Ageratum conyzoides, Eleusine indica, Galinsoga quadriradiata, Setaria barbata, and Spermacoce latifolia.*

- Class of Weeds with Specific Contribution (Csi) Between 1% and 4 %

This class concerns the potential major weeds, considered aggressive, and comprises: *Bidens pilosa, Brachiaria lata, Commelina benghalensis, Cynodon dactylon, Cyperus rotundus, Digitaria horizontalis, Digitaria sanguinalis, Echinochloa crus-galli, Euphorbia heterophylla, Euphorbia hirta, Imperata cylindrica, Kyllinga squamulata, Mimosa pigra, Mimosa pudica, Mitracarpus hirtus, Panicum maximum, Paspalum scrobiculatum, Rottboellia cochinchinensis, Setaria pumila, Sida acuta, Sida rhombifolia, Spermacoce stachydea, Spermacoce verticillata, Sporobolus pyramidalis, Striga hermonthica, Stylosanthes hamata, and Tridax procumbens*.

- Class of Weeds with Specific Contribution (Csi) Less than 1 %

This class consists of accidental weeds, considered minimally aggressive, such as: *Acanthospermum australe, Achyranthes aspera, Agrostis stolonifera, Alternanthera sessilis, Amaranthus spinosus, Andropogon gayanus, Asparagus glycyphullos, Asparagus racemosus, Bromus diandrus, Calopogonium mucunoides, Chenopodium ficifolium, Chloris gayana, Chloris virgata, Chromolaena odorata, Commelina diffusa, Cyperus difformis, Cyperus eragrostis, Dactyloctenium aegyptium, Digitaria ciliaris, Equisetum sp, Eragrostis capensis, Erigeron floribundus, Heliotropium indicum, Hyptis suaveolens, Indigofera hirsuta, Leucas martinicensis, Mentha spicata, Micrococca mercurialis, Mitracarpus villosus, Parthenium hysterophorus, Phyllanthus amarus, Phyllanthus niruroides, Portulaca oleracea, Rumex abyssinicus, Sesbania pachycarpa, Synedrella nodiflora, Tithonia diversifolia, Trifolium arvense, Trifolium nigrescens, Urena lobata, Verbena officinalis, and Vicia faba*.

4.4. Floristic composition and degree of infestation

The analysis of the weed flora in maize fields in the Vina Division allowed for the ranking of weeds according to their agronomic harmfulness, by combining relative frequency and the abundance-dominance index in an infestation diagram. To validate this classification, a Principal Component Analysis (PCA) was performed. This revealed that the first component alone explains 97 % of the total variance, indicating a strongly unidimensional structure of the data and thus confirming the hardiness of the established typology (**Figure 6**).

The combination of the infestation diagram with a hierarchical classification dendrogram made it possible to identify three major ecological groups of weed species, according to their level of competitiveness and harmfulness to maize cultivation (**Figure 7**).

4.4.1. Group 1: Major Competitive Weeds (11 species)

This group comprises the most competitive weed species, characterized by particularly high frequencies and abundances. They exert significant selection pressure on crops and constitute the main threat to maize yield. It includes: *Spermacoce latifolia, Ageratum conyzoides, Eleusine indica, Galinsoga quadriradiata, Setaria barbata, Bidens pilosa, Commelina benghalensis, Mimosa pudica, Sida rhombifolia, Kyllinga squamulata* and *Euphorbia hirta*.

4.4.2. Group 2: Potential Major Weeds (19 species)

Although less frequent and less abundant, these species possess a significant potential for causing harm. This potential is linked to their intrinsic biological characteristics, such as rapid growth rate, strong competitive ability for light and nutrients even at low density, or their ability to significantly enrich the soil seed bank for subsequent growing seasons (or their allelopathic potential). These species require special attention in term of management, as they are likely to become dominant and highly problematic following change in cultural practices or weed control technique. This group includes: *Brachiaria lata, Cyperus rotundus, Digitaria horizontalis, Digitaria sanguinalis, Echinochloa crus-galli, Euphorbia heterophylla, Imperata cylindrica, Mimosa priga, Mitrocarpus hirtus, Panicum maximum, Paspalum scrobiculatum, Rottboellia cochinchinensis, Setaria pumila, Sida acuta, Spermacoce stachydea, Sporobolus pyramidalis, Striga hermonthica, Stylosanthes hamata* and *Tridax procumbens*.

4.4.3. Group 3: Associated Companion Weeds (44 species)

This last group contains species with low frequency and low abundance, whose impact on maize productivity is considered negligible. Their presence nevertheless contributes to the floristic diversity of the agroecosystem, without representing a direct threat to the crop. This group consists of: *Acanthospermum australe, Achyranthes aspera, Agrostis stolonifera, Alternanthera sessilis, Amaranthus spinosus, Andropogon gayanus, Asparagus glycyphyllos, Asparagus racemosus, Bromus diandrus, Calopogonium mucunoides, Chenopodium ficifolium, Chloris gayana, Chloris virgata, Chromolaena odorata, Commelina diffusa, Cyperus difformis, Cyperus eragrostis, Dactyloctenium aegyptium, Digitaria ciliaris, Equisetum sp., Eragrostis capensis, Erigeron floribundus, Heliotropium indicum, Hyptis suaveolens, Indigofera hirsuta, Leucas martinicensis, Mentha spicata, Micrococca mercurialis, Mitrocarpus villosus, Parthenium hysterophorus, Phyllanthus amarus, Phyllanthus niruri, Portulaca oleracea, Rumex abyssinicus, Sesbania pachycarpa, Synedrella nodiflora, Tithonia diversifolia, Trifolium arvense, Trifolium nigrescens, Urena lobata, Verbena officinalis, Vicia faba, Cynodon dactylon* and *Spermacoce verticillata*.

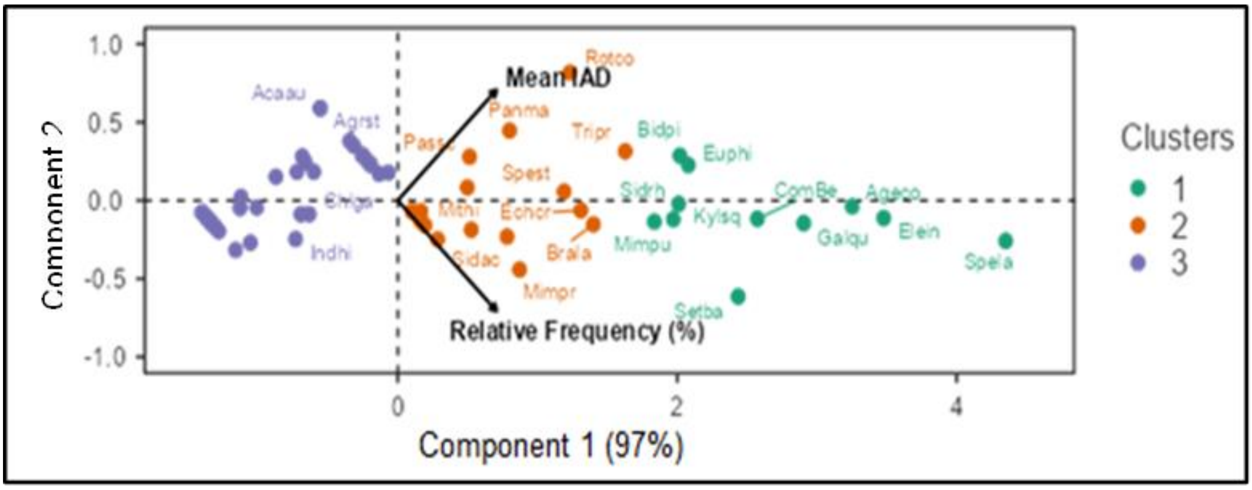

Figure 6 Weed Infestation Diagram

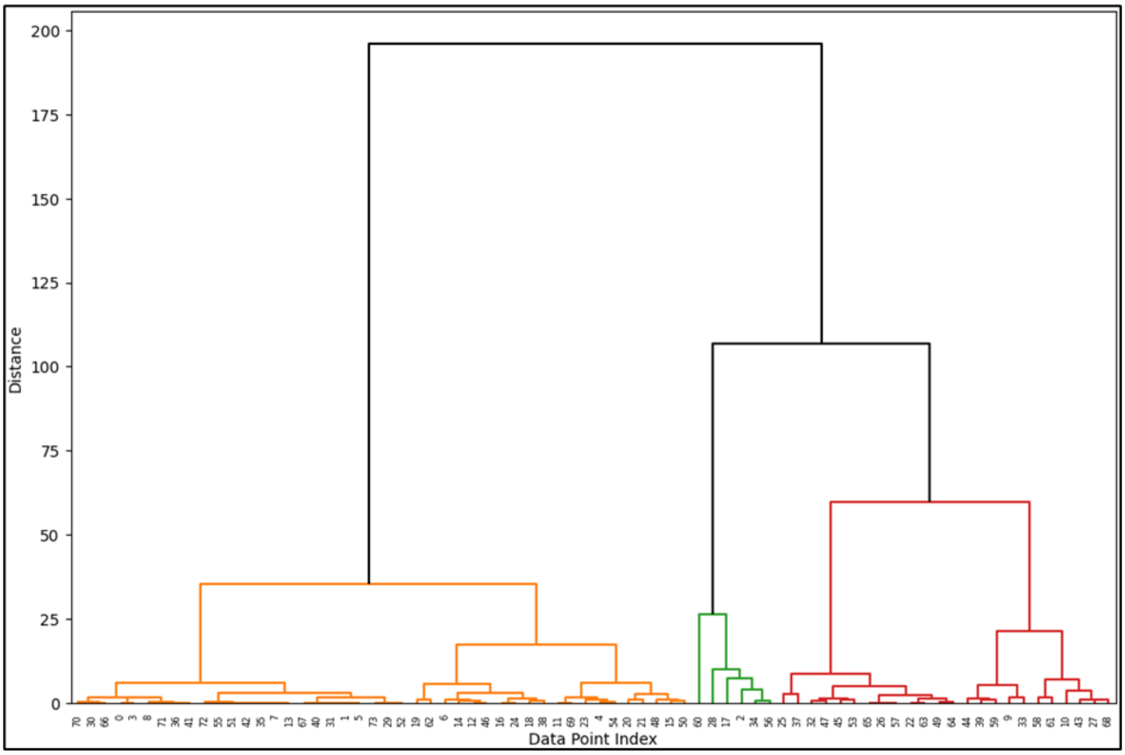

Figure 7 Dendrogram of Hierarchical Clustering with 3 Groups

4.4.4. Similarity coefficients

The similarity coefficient is used to establish the resemblance between the different flora of the studied subdivisions. It ranged from 20.83% to 37.5% (**Table 3**) with values of 25.80% between Ngaoundéré III and Mbé, 23.72% between Ngaoundéré III and Nganha, 37.5% between Ngaoundéré III and Martap, 23.25% between Mbé and Nganha, 20.83% between Mbé and Martap and 22.22% between Martap and Nganha.

These values are significantly below 50%, which ecologically indicates that the weed flora of the different subdivisions are not identical but highly distinct. The analysis of the table shows that the maize plots in different subdivisions are floristically heterogenous.

Table 3 Similarity coefficient between subdivisions

Subdivisions	Number of Species	Shared Species	Similarity Coefficient (CS)
Ngaoundéré III Mbé	39 23	8	25,80%
Ngaoundéré III Nganha	39 20	7	23,72%
Ngaoundéré III Martap	39 25	12	37,5%
Mbé Nganha	23 20	5	23,25
Mbé Martap	23 25	5	20,83%
Martap Nganha	25 20	5	22,22%

4.4.5. Diversity indices

Table 4 shows the floristic diversity indices for the Vina Division. The Shannon-Weaver Index (H) had a value of 3.81. This relatively high value indicates a high abundance of weed species in the study area. Similarly, the Simpson index had a value of 0.97. This value, very close to 1, also indicates very high species diversity and low dominance by any single species.

Table 4 Floristic diversity indices

Diversity Index	Value
Shannon-Weaver	3,81
Simpson	0,97

5. Discussion

5.1. Floristic richness

The distribution of inventoried weeds by class revealed that Dicotyledons (62.2%) were the dominant class. The dominance of dicots can be explained by their vast distribution range and their adaptability to disturbed ecosystems, particularly in agricultural environments. Their capacity for rapid establishment in agricultural landscapes contributes to their prevalence [31]. Indeed, numerous authors have reported similar proportions, finding approximately 2/3 dicotyledons and 1/3 monocotyledons among the total inventoried weeds [32,33]. Furthermore, the predominance of dicotyledons could also be attributed to various agricultural practices, notably tillage methods. According to Sanou *et al.,* [33], intensive soil tillage may have a detrimental impact on the development of certain monocotyledonous weeds, particularly through the burial of seeds or the fragmentation of perennial storage organs.

However, it is crucial to nuance this statement. The influence of soil tillage is complex and depends on the specific species and the technique utilized. For example, a recent study has shown that reduced tillage, by keeping seeds near the surface, suppresses broadleaf weeds while allowing grasses to prosper [34]. This confirms that changes in soil tillage primarily affect the competitive balance between the two major weed groups. In addition, environmental factors such as soil composition and nutrient availability also play a role in weed species distribution [35]. A study on heavy metal accumulation in weed species also highlights the adaptability of dicotyledons in contaminated environments [36].

The families Poaceae, Fabaceae, and Asteraceae proved to be preponderant in the maize plots studied. These families are consistently among the ten principal weed families worldwide, as reported by Miderho *et al.,* [28]. Our results corroborate findings obtained in other similar agroecosystems, particularly in maize fields in South Western Cameroon [21], in rice fields in Burkina Faso and Côte d'Ivoire [30,33], sorghum plots in Senegal [32], cotton farms in Burkina Faso [37], coffee crops in Congo [27], and sugarcane plantations in Côte d'Ivoire [38].

The predominance of these families is explained by effective reproductive strategies. Poaceae primarily propagate through seed production (80% of species), disseminated by wind, water, and insects. Fabaceae adopt an opportunistic life strategy, characterized by rapid growth and reproduction. As for Asteraceae, their proliferation is favored by the massive production of small, lightweight seeds, such as the species *Bidens spinosa* which is capable of producing between 3,000 and 6,000 easily wind-dispersed seeds [39]. The high diversity indices (Shannon: 3.81; Simpson: 0.97) and the low similarity coefficients (< 50%) confirm a high species richness of weeds in the Vina division.

5.2. Biological types

The analysis of biological types reveals a clear dominance of Therophytes (50%) within the surveyed plots, which serves as a strong ecophysiological indicator of habitat disturbance and opportunistic species strategies. The resulting crude biological spectrum (Therophyte > Hemicryptophyte > Geophyte > Chamaephyte) is typical of weed communities in cultivated environments, aligning with previous regional observations [20]. These annual plants, which survive the unfavorable season as seeds, are particularly well-adapted to the marked seasonality and recurrent agricultural disturbances of the Guinean High Savannas in the Adamawa region of Cameroon. Their r-selection reproductive strategy characterized by a short cycle, rapid growth, and massive seed production is typical of pioneer species. These traits grant them a superior capacity to rapidly colonize disturbed sites and maximize reproduction before the onset of environmental stress [28].

Furthermore, this biological dominance is significantly amplified by the cultural practices inherent to maize production. The necessity for frequent tilling and weeding, typical of intensive agricultural systems in tropical Africa, subjects the soil to constant disturbance. These agronomic interventions exert a selective pressure that discourages perennial species, such as Geophytes, while strongly favoring annual, sun-loving (heliophilic) species that quickly establish themselves on bare soil [40]. High representations of Therophytes have been consistently observed in similar climatic and cultural contexts [28,30,32].

The strong representation of Therophytes, including species such as *Spermacoce latifolia*, *Ageratum conyzoides*, and *Bidens pilosa*, has direct consequences for weed management. These monocarpic species make a very high reproductive effort, contributing massive amounts of seeds annually to the soil seed bank [38]. Their effective dissemination (often by wind or insects) ensures rapid re-infestation, which complicates sustainable management strategies and necessitates heightened vigilance in planning cultural operations.

5.3. Floristic composition and degree of infestation

The combined analysis of the weed infestation diagram and a hierarchical classification dendrogram allowed for the identification of three distinct ecological groups based on their potential detrimental effect on the maize crop. The Major Weeds group constitutes the primary threat to production. It is composed of highly competitive species such as *Spermacoce latifolia*, *Ageratum conyzoides*, *Eleusine indica*, *Galinsoga quadriradiata*, *Setaria barbata*, *Bidens pilosa*, *Commelina benghalensis*, *Mimosa pudica*, *Sida rhombifolia*, *Kyllinga squamulata*, and *Euphorbia hirta*. Their high abundance is likely favored by local edaphoclimatic conditions, granting them a marked competitive advantage for resources.

Previous studies confirm that species within this group, notably *Bidens pilosa*, *Commelina benghalensis*, *Ageratum conyzoides*, and *Sida rhombifolia*, can cause considerable yield losses, ranging from 10% to 100% depending on the species and zone [9, 21,41]. This threat is further substantiated by the analysis of the specific contribution of each species, where those exceeding 4% particularly *Ageratum conyzoides*, *Eleusine indica*, *Galinsoga quadriradiata*, *Setaria barbata*, and *Spermacoce latifolia* play a more significant role in competition with the maize crop. Conversely, the remaining ecological categories, designated as "Potential" and "Associated Companion" species, do not represent a direct threat, although they may still exert an indirect negative impact, especially by serving as potential hosts for pests and diseases.

The severity of the threat posed by the Major Weeds group lies in the convergence of their aggressive biological traits. These species, mostly Therophytes employing an r-selection strategy, combine rapid growth and the development of dense foliar cover (*Spermacoce latifolia, Ageratum conyzoides*), which generates severe and early competition for light, a factor limiting juvenile maize growth [42]. Furthermore, the group's grasses (*Eleusine indica, Setaria barbata*), often equipped with a C4 metabolism and vigorous root systems, exert significant pressure on water and nutrient resources [43]. This competitive efficiency, combined with massive seed production that ensures annual re-infestation, justifies their status as the primary threat to maize yields in the studied region.

However, the evaluation of this contribution must be interpreted cautiously, as it reflects only one aspect of the potential aggressiveness (i.e., abundance). Other factors, such as establishment rate, renewal capacity, seed production, and tolerance to environmental conditions, must be integrated for a more comprehensive assessment. Thus, while these species deserve priority attention in control strategies, their optimal aggressive potential should be confirmed by complementary studies integrating these various parameters.

6. Conclusion

This study aimed to characterize the weed flora of maize crops in the Vina division, Adamaoua region. The results reveal a dominance of dicotyledons, which represent 62.2% of the recorded species. The most represented families are Poaceae (27.02%), Fabaceae (14.86%), and Asteraceae (13.51%), accounting for 55.39% of the weed flora combined. The biological spectrum highlights a predominance of Therophytes (50%), indicating a high presence of short-cycle annual species. The combined analysis of the infestation diagram and hierarchical classification successfully identified three groups of weeds based on their level of detrimental potential. The Major Weeds group gathers the most problematic species for maize cultivation, notably *Spermacoce latifolia, Ageratum conyzoides, Eleusine indica, Galinsoga quadriradiata, Setaria barbata, Bidens pilosa, Commelina benghalensis, Mimosa pudica, Sida rhombifolia, Kyllinga squamulata,* and *Euphorbia hirta*. These results, based on species occurrence and dominance, constitute a fundamental initial step for understanding the local weed flora and for species prioritization. However, the development of effective and adapted integrated management strategies cannot be limited to these statistical indicators alone. A complete evaluation of detrimental potential imperatively requires complementary investigations focusing on the biological and ecological characteristics of the identified species (mode of action, allelopathic potential, and intrinsic competitiveness). This approach is essential to determine the actual impact of these weeds on maize productivity and to more precisely target control methods.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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