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FLORISTIC DIVERSITY AND ECOLOGICAL STRUCTURE OF THE WEEDS ASSOCIATED WITH COWPEA CULTIVATION (*VIGNA UNGUICULATA* L. WALP.) IN SMALLHOLDER FARMING SYSTEMS IN THE DEPARTMENT OF MBOUR (SENEGAL)

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ABSTRACT

Cowpea (*Vigna unguiculata*) is a major food legume of Sahelian rainfed farming systems, whose productivity remains limited by weed pressure that is poorly documented at the crop scale. This study aims to characterize the floristic diversity and ecological structure of the weeds associated with cowpea in smallholder farming systems, in the department of Mbour. Ten floristic surveys were carried out in smallholder farming conditions, then analyzed by hierarchical ascending classification (Pearson index), complemented by the biological and chorological spectra. The inventory recorded 37 species distributed across 10 botanical families, very largely dominated by the Poaceae (40.5%), ahead of the Fabaceae, Cyperaceae, Rubiaceae and Malvaceae. A core of 10 constant species, present in 90 to 100% of the surveys, notably including *Cyperus rotundus*, *Digitaria ciliaris* and *Spermacoce verticillata*, structure most of the assemblage alongside a majority of occasional species. The flora is dominated by therophytes (73.0%) and by species with a wide biogeographic distribution (pantropical and African), reflecting a heavily disturbed environment. These results call for priority to be given, in integrated management strategies, to the core of ten constant species, in particular the geophyte *Cyperus rotundus*, and for weeding interventions to be timed to the emergence peaks of annual species.

Keywords*:* *Vigna unguiculata*, Weed flora, Phytosociology, Agrobiodiversity, Senegal.

1 INTRODUCTION

Among the food crops that structure smallholder production systems, cowpea (*Vigna unguiculata* (L.) Walp.) occupies a prominent place [1]. In Senegal, it is widely grown and, alongside millet and groundnut, constitutes one of the pivotal crops of the rainfed systems of the Groundnut Basin. A staple food crop and a major source of protein for rural populations [2], it also provides households with appreciable income and, as a nitrogen-fixing legume, contributes to soil fertility in rotation and intercropping systems with millet [3].

However, despite this importance, cowpea productivity remains strongly constrained by various biological pests, among which weeds constitute one of the main factors of yield loss, ahead of diseases and animal pests [4], [5], [6]. In West African legume-cereal systems, weed control remains particularly difficult [7]. Indeed, through their competition for water, light and mineral nutrients, weeds can cause, in smallholder farming conditions, yield losses exceeding 30%, depending on the area and level of infestation [8], [3]. Weed management therefore appears to be a decisive factor for improving cowpea productivity.

This issue is all the more important given that the possibilities of resorting to herbicides remain limited in many smallholder contexts, owing in particular to their cost, their limited availability and the environmental concerns they raise [9]. Rational weed control requires a detailed knowledge of the floristic composition of weed communities, whose structure varies according to the cropping system [10] and determines the choice of intervention methods.

Knowledge of the weed flora specifically associated with cowpea cultivation in Senegal remains fragmentary. Available studies mainly concern cropping systems combining millet and cowpea [3] or more northerly, drier areas of the Groundnut Basin [11].

This study therefore aims to inventory and characterize the floristic diversity and ecological structure of the weed communities associated with cowpea cultivation in smallholder farming systems, in the coastal zone of Senegal (Department of Mbour).

2 MATERIAL AND METHODS

2.1 Study area

This study was carried out at Nianing, located 91 km southeast of the capital Dakar, around 14°.20 N and 16°.55 W. The study area is located in the department of Mbour, more precisely in the region of Thiès. It is bounded to the north by Mbour, to the south and east by the Saloum estuary, and to the west by the Atlantic Ocean. It belongs to the coastal North Sudanian domain [12]. It is under the influence of the harmattan for 7 to 8 months and of the monsoon for 5 to 6 months. Recorded rainfall ranges between 500 and 1000 mm. The rainy season runs from June to October and accounts for almost all of the annual rainfall (99.21% of the total). The dry season is characterized by low or absent rainfall. It runs from November to May.

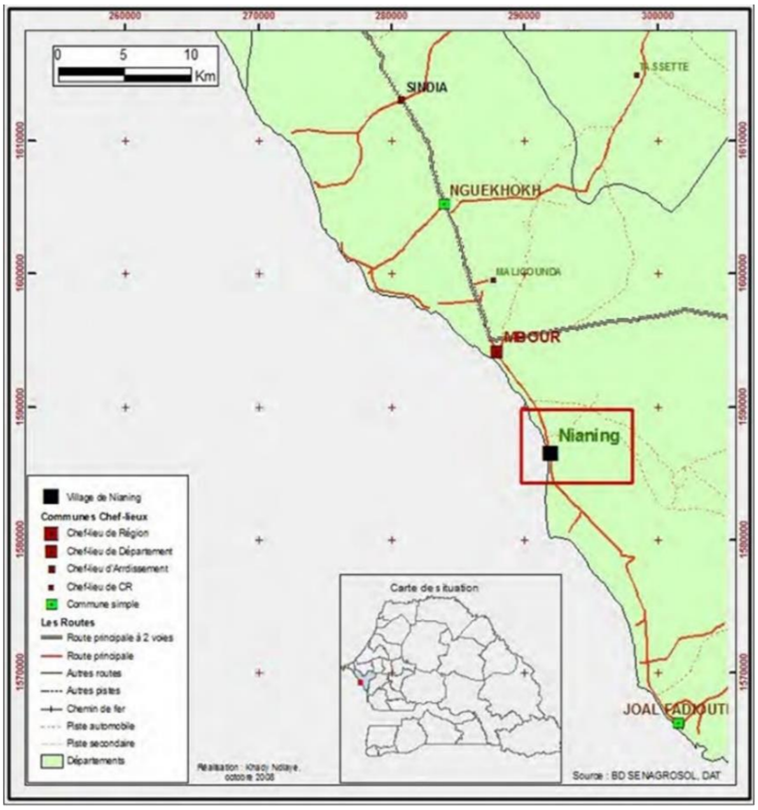

Figure 1: Location of the study site (Source: BD SENAGROSOL, DAT).

The vegetation is of the wooded-to-shrub savanna type, sometimes with monospecific stands, and displays formations typical of the Sudano-Sahelian domain. The herbaceous layer is dominated by grasses, which make up the pastures [13].

2.2 Floristic inventory in the market-garden plots

Floristic surveys were carried out in smallholder farming conditions in the Department of Mbour. Ten surveys were carried out on 2 plots. Within each plot, five 4 m × 4 m (16 m^2) quadrats were arranged randomly in order to standardize the floristic observations. All weed species present in the quadrats were systematically recorded and logged on floristic inventory sheets. Botanical specimens of taxa not identified in the field were collected, dried in newspaper, and then kept for the purpose of building a reference herbarium. Taxonomic identification was carried out in the field, on the basis of direct observations [14]. Species not identified in the field were placed in the herbarium for identification at the Laboratory of Botany and Biodiversity of the Department of Plant Biology. The floras of Senegal [15], [16], [17] and [18] were used for the taxonomic identification of the species. The nomenclature used is that of [19] and [20]. The contribution (C_i) of each family in genera and species to the total flora was expressed as a percentage of the total number of genera and species recorded (n = 37) according to the following formula:

$$C_i\ (\%) = \frac{N_i}{N}\ x\ 100$$

Where N_i = number of genera or species of family i ; N = total number of genera or species recorded.

The biological spectrum of the inventoried flora was established on the basis of the classification of [21] and [22], who distinguished the following 6 biological forms: phanerophytes (P), chamephytes (C), hemicryptophytes (H), geophytes (G), therophytes (T) and parasitic plants (Par.). The chorological spectrum was drawn up according to the biogeographic classification of [23] and [22]. The following species types were identified: African species (Af), Afro-Asian species (As), Afro-Asian and Australian species (Asu), Afro-Malagasy species (Ma), Afro-Malagasy and Asian species (Mas), cosmopolitan species (Cosm) and pantropical species (Pt). The biological spectrum (Raunkiaer types) and the chorological spectrum (biogeographic affinities) were established in the same way, by relating the number of species in each category to the total flora, according to the following formula:

$$S_i\ (\%) = \frac{N_i}{N}\ x\ 100$$

Where S_i = biological or chorological spectrum; S_i = number of species in a category i ; N = total number of species recorded.

2.3 Statistical data analysis

Presence-absence data for the species recorded in the 10 plots were entered into a species × survey matrix, then processed using Excel spreadsheet software. To explore the floristic affinities among the 10 surveys, a hierarchical ascending classification (HAC) was performed on the presence-absence matrix, based on a binary similarity index (Pearson index), making it possible to construct a dendrogram grouping the species according to their affinities.

3 RESULTS

3.1 Structure of the weed flora associated with cowpea cultivation

The inventory carried out over the 10 surveys recorded 37 species distributed across 10 botanical families. The Poaceae family clearly dominates with 15 species (40.5% of the flora), followed by the Fabaceae (6 species, 16.2%), the Cyperaceae and the Rubiaceae (4 species each, 10.8%) and the Malvaceae (3 species, 8.1%). These five families alone account for nearly 87% of the recorded flora, while the five remaining families (Capparidaceae, Commelinaceae, Nyctaginaceae, Phyllanthaceae, Rhamnaceae) are each represented by a single species.

Analysis of presence frequencies across the surveys reveals a core of constant species (class V, present in 90-100% of surveys), comprising 10 species (27% of the flora): *Bulbostylis coleotricha, Cyperus esculentus, C. rotundus, C. squarrosus* (Cyperaceae), *Cenchrus biflorus, C. unisetus, Digitaria ciliaris, D. horizontalis* (Poaceae) and *Spermacoce chaetocephala, S. verticillata* (Rubiaceae), together with *Eragrostis aspera* (90%). Conversely, 12 species (32.4%) appear in only a single survey (class I, accidental species), among which several woody species (*Vachellia tortilis, Ziziphus mauritiana, Leptadenia lanceolata*) likely originating from the surrounding woody vegetation.

Table 1: Floristic composition of the recorded weed species.

Families	Accepted scientific name	Codes	BT	GD	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
Capparidaceae	*Cleome viscosa* L.	CLV	Th	Mas	0	0	0	0	0	0	0	0	0	1
Commelinaceae	*Commelina ramulosa* (C.B.Clarke) H.Perrier	COR	Th	Mas	1	0	1	1	0	0	0	1	0	1
Cyperaceae	*Bulbostylis coleotricha* (Hochst. ex A.Rich.) C.B.Clarke	BUC	Th	Af	1	1	1	1	1	1	1	1	1	1
	Cyperus esculentus L.	CYE	Ge	Cosm	1	1	1	1	1	1	1	1	1	1
	Cyperus rotundus L.	CYR	Ge	Cosm	1	1	1	1	1	1	1	1	1	1
	Cyperus squarrosus L.	CYS	Ge	Pt	1	1	1	1	1	1	1	1	1	1
Fabaceae	*Alysicarpus ovalifolius* (Schum.) Leonard	ALO	Th	Pt	1	0	0	0	0	0	0	0	0	0
	Indigofera astragalina DC.	INA	Th	Af	1	1	1	0	0	0	1	1	1	1
	Indigofera sphaerocarpa A.Gray	INS	Ch	As	0	0	0	0	1	1	0	1	1	0
	Senna obtusifolia (L.) H.S.Irwin & Barneby	SEO	Ch	Pt	1	1	1	0	0	0	1	0	0	0
	Sesbania pachycarpa DC.	SEP	Th	Asu	0	0	0	0	0	1	0	0	0	0
	Vachellia tortilis (Forssk.) Galasso & Banfi	VAT	mph	As	0	0	0	0	0	0	0	0	1	0
Malvaceae	*Corchorus tridens* L.	COT	Th	Asu	1	1	1	1	1	0	1	1	0	1
	Hibiscus sabdariffa L.	HIS	Th	Pan	0	0	0	1	0	0	0	1	0	0
	Leptadenia lanceolata (Poir.) Goyder *subsp. lanceolata*	LEL	mph	Af	0	0	1	0	0	0	0	0	0	0
Nyctaginaceae	*Boerhavia erecta* L.	BOE	Th	Pt	0	1	0	0	0	0	0	0	0	0
Phyllanthaceae	*Phyllanthus reticulatus* Poir.	PHR	Th	Af	0	0	0	0	0	0	0	1	0	0
Poaceae	*Cenchrus americanus* (L.) Morrone	CEA	Th	Asu	0	0	0	0	0	0	0	1	0	0
	Cenchrus biflorus Roxb.	CEB	Th	As	1	1	1	1	1	1	1	1	1	1
	Cenchrus unisetus (Nees) Morrone	CEU	Hc	Af	1	1	1	1	1	1	1	1	1	1
	Cenchrus violaceus (Lam.) Morrone	CEV	Th	Asu	0	0	0	0	0	0	0	1	0	0
	Chloris pilosa Schumach.	CHP	Th	As	1	1	1	1	1	1	1	0	0	1
	Dactyloctenium aegyptium (L.) Willd.	DAA	Th	Pan	0	0	0	1	0	1	0	0	0	1
	Digitaria ciliaris (Retz.) Koeler	DIC	Th	Pt	1	1	1	1	1	1	1	1	1	1
	Digitaria horizontalis Willd.	DIH	Th	Ma	1	1	1	1	1	1	1	1	1	1
	Eleusine indica (L.) Gaertn.	ELI	Th	Pan	0	0	1	1	0	0	0	0	0	0
	Enteropogon prieurii (Kunth) Clayton	ENP	Th	Af	0	0	0	0	0	0	1	0	0	1
	Eragrostis aspera (Jacq.) Nees	ERA	Th	As	0	1	1	1	1	1	1	1	1	1
	Eragrostis multiflora Trin.	ERM	Th	As	0	0	0	0	0	0	0	0	1	0

	Eragrostis tenella (L.) P.Beauv. ex Roem. & Schult.	ERT	Th	Pt	1	1	1	1	0	0	0	0	0	1
	Setaria parviflora (Poir.) Kerguélen	SET	Hc	Pan	0	0	0	0	0	0	1	1	1	0
	Sorghum bicolor (L.) Moench	SOB	Th	Af	0	0	0	0	0	0	0	0	1	0
Rhamnaceae	*Ziziphus mauritiana* Lam.	ZIM	mph	As	0	0	0	0	0	0	1	0	0	0
Rubiaceae	*Kohautia grandiflora* DC.	KOG	Th	Af	1	1	1	0	1	0	1	1	0	0
	Spermacoce chaetocephala DC.	SPC	Th	Af	1	1	1	1	1	1	1	1	1	1
	Spermacoce stachydea DC.	SPS	Th	Pan	0	0	0	1	0	0	1	1	0	1
	Spermacoce verticillata L.	SPV	Th	Af	1	1	1	1	1	1	1	1	1	1

Legend: BT = Biological type; GD = Geographic distribution.

Table 2 confirms the predominance of the Poaceae both at the generic level (7 genera, i.e. 29.2% of the genera) and at the specific level (15 species, 40.5%). They are followed by the Fabaceae (5 genera, 20.8%; 6 species, 16.2%). Conversely, the Malvaceae (3 genera, 3 species) and the five monospecific families show a genus/species ratio of 1, indicating more limited diversification.

Table 2: Contribution of families and genera.

Families	Genera	Genus contribution (%)	Number of species	Family contribution (%)
Capparidaceae	1	4.17	1	2.70
Commelinaceae	1	4.17	1	2.70
Nyctaginaceae	1	4.17	1	2.70
Phyllanthaceae	1	4.17	1	2.70
Rhamnaceae	1	4.17	1	2.70
Malvaceae	3	12.50	3	8.11
Cyperaceae	2	8.33	4	10.81
Rubiaceae	2	8.33	4	10.81
Fabaceae	5	20.83	6	16.22
Poaceae	7	29.17	15	40.54
10 families	24	100.00	37	100.00

3.2 Floristic classification of the weed species

The hierarchical ascending classification (HAC) reveals three floristic groups reflecting varying degrees of similarity in weed composition among the surveys. Class 1 is characterized by the presence of a ubiquitous core of 10 species common to all plots (r = 1). These are *Bulbostylis coleotricha*, *Cyperus esculentus*, *C. rotundus*, *C. squarrosus*, *Cenchrus biflorus*, *C. unisetus*, *Digitaria ciliaris*, *D. horizontalis*, *Spermacoce chaetocephala* and *S. verticillata*. These species make up the base floristic assemblage of the cowpea weed flora. Two subgroups can also be distinguished within this same class, each associated with a single survey. The first combines *Vachellia tortilis, Eragrostis multiflora* and *Sorghum bicolor*, three species found exclusively in survey R9. The second combines *Phyllanthus reticulatus, Cenchrus americanus* and *Cenchrus violaceus*, exclusively present in survey R8, which represents the richest survey of the study (22 species, i.e. nearly 60% of the total). These two subgroups, however, show a much lower similarity index with respect to the core of 10 constant species (r = 0.10).

Class 2 groups species of intermediate frequency, whose similarity index with the core of 10 constant species from class 1 ranges from 0.30 to 0.90 (r_{avg} = 0.55). The species concerned are *Eragrostis aspera* (r = 0.90), *Corchorus tridens* and *Chloris pilosa* (r = 0.80 each), *Indigofera astragalina* (r = 0.70), *Kohautia grandiflora* (r = 0.60), *Commelina ramulosa* and *Eragrostis tenella* (r = 0.50), *Indigofera sphaerocarpa, Senna obtusifolia* and *Spermacoce stachydea* (r = 0.40 each), *Dactyloctenium aegyptium* and *Setaria parviflora* (r = 0.30 each). The internal cohesion of this class remains moderate, with a mean pairwise similarity index of 0.37 among its species.

Class 3 brings together the most individualized species of the flora, with a very low similarity index to the core, ranging between 0.10 and 0.20 (r_{avg} = 0.13). These are *Hibiscus sabdariffa, Eleusine indica* and *Enteropogon prieurii* (r = 0.20 each), then *Cleome viscosa, Sesbania pachycarpa, Leptadenia lanceolata, Ziziphus mauritiana, Alysicarpus ovalifolius* and *Boerhavia erecta* (r = 0.10 each). Unlike the subgroups of class 1, the mean pairwise similarity index is very low (r = 0.05), with most species sharing no survey in common at all.

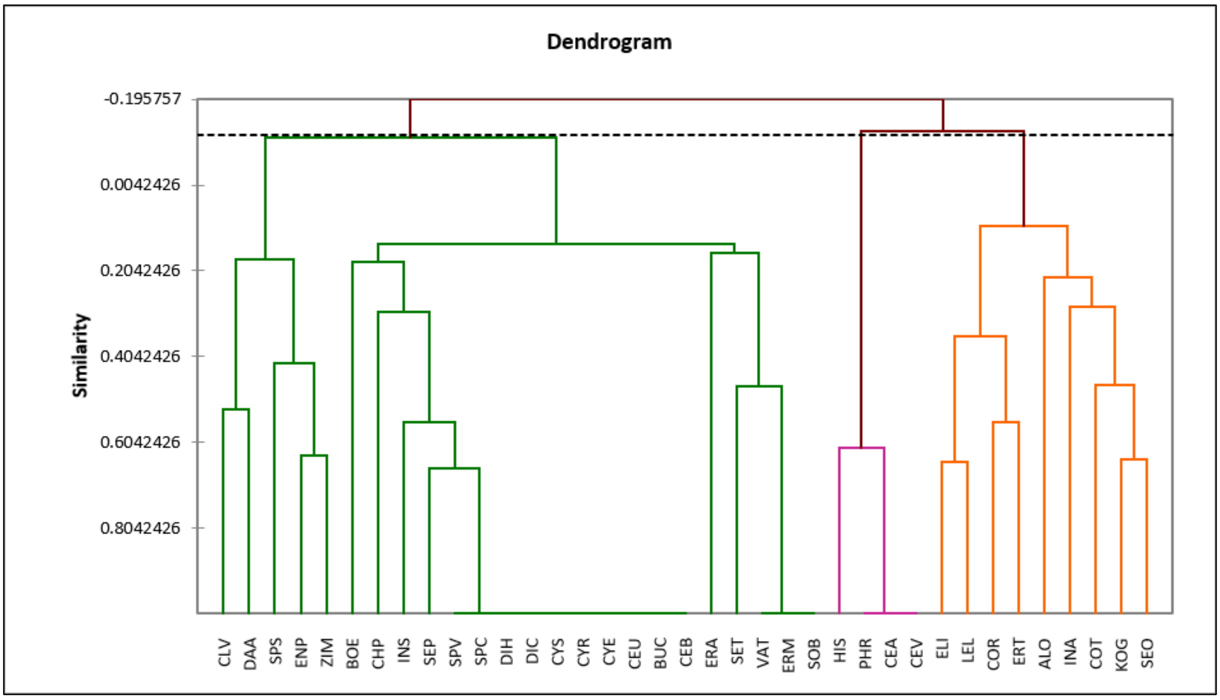

Figure 2: Dendrogram of the hierarchical ascending classification of weed species based on their presence/absence similarity.

3.3 Biological and chorological spectra of the weed flora

The biological spectrum of the cowpea weed flora is very largely dominated by therophytes (27 species, 73.0%). They are followed by geophytes and microphanerophytes (3 species each, 8.1%), and by chamephytes and hemicryptophytes (2 species each, 5.4%).

Pantropical species dominate the chorological spectrum with 11 species, or 29.7% of the total. They are followed by African species (10 species, 27.0%) and Afro-Asian species (7 species, 18.9%). The other categories (Afro-Asian and Australian, Afro-Malagasy, Afro-Malagasy and Asian, cosmopolitan) together total less than 25% of the flora.

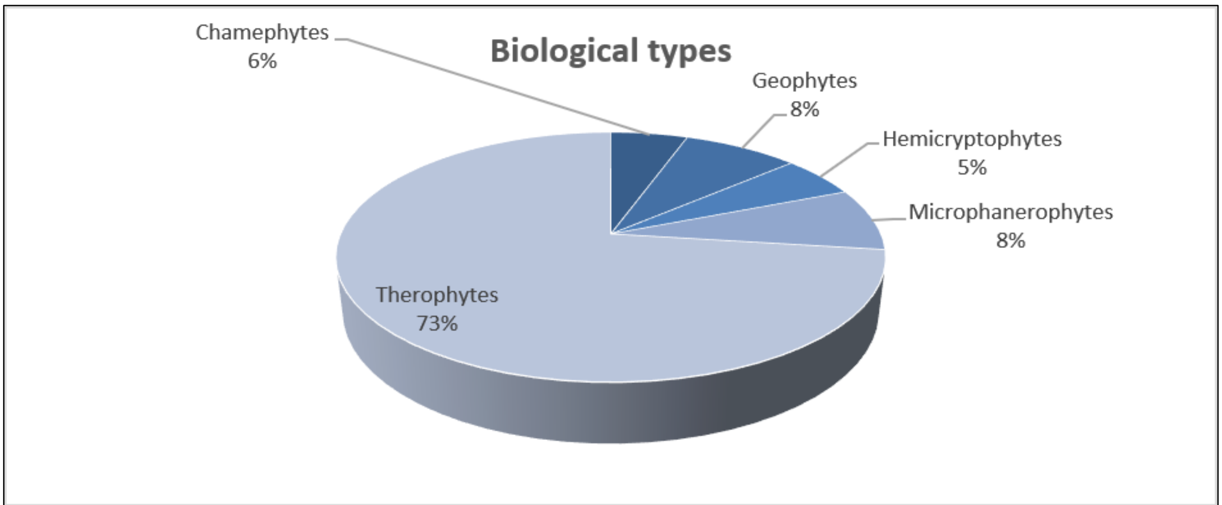

Figure 3: Biological types of weed flora.

Table 3: Biogeographic affinities of weed flora.

Biogeographic affinities	Number of species	Proportion (%)
African species (Af)	10	27.03
Afro-Asian species (As)	7	18.92
Afro-Asian and Australian species (Asu)	4	10.81
Afro-Malagasy species (Ma)	1	2.70
Afro-Malagasy and Asian species (Mas)	2	5.41
Cosmopolitan species (Cosm)	2	5.41
Pantropical species (Pt)	11	29.73

Overall, these results depict a weed flora that is relatively low in diversity (37 species, 10 families) but strongly structured: it is dominated by a restricted core of families (Poaceae, Fabaceae, Cyperaceae, Rubiaceae, Malvaceae) and by an assemblage of constant species with a wide ecological amplitude, while the majority of recorded species occur only occasionally. This structure, combined with a marked dominance of therophytes and of species with a wide geographic distribution (pantropical and African), directly informs the discussion points developed below.

4 DISCUSSION

The inventory carried out in the farmers' cowpea plots of the department of Mbour revealed a clear dominance of the Poaceae (40.5% of the flora), ahead of the Fabaceae, the Cyperaceae, the Rubiaceae and the Malvaceae. This taxonomic structure is consistent with what is generally reported for cultivated agrosystems in Senegal, where the Poaceae are among the most diverse and most frequent families of the weed flora, whatever the crop considered [24].

These authors recorded 121 species distributed across 51 genera, including *Cenchrus*, *Digitaria* and *Eragrostis*, also dominant here. This convergence suggests that the grass predominance observed on cowpea reflects a trait shared across cultivated Sahelian fields, where the openness of the canopy and the frequency of cultural disturbances favor short-cycle heliophilous species. Conversely, the low representation of weedy Fabaceae (16.2%, six species) is consistent with niche exclusion between cowpea and weeds of its own botanical family [7]. [11] recorded 92 species in the northern zone of the Groundnut Basin, a difference in richness attributable to the agroclimatic position of that zone and to a greater sampling effort; several common structuring genera (*Cenchrus*, *Cyperus*, *Digitaria*) nonetheless support the hypothesis of a common core of weedy grasses and sedges associated with cowpea.

The constant presence, in 100% of the surveys, of three geophytic Cyperaceae (*Cyperus esculentus*, *C. rotundus* and *C. squarrosus*) deserves particular attention, a finding that echoes that of [25] for food crops in the southern Groundnut Basin. *Cyperus rotundus* is indeed considered one of the most problematic weeds in the world [26], and recent work on its germination ecology confirms the difficulty of eliminating it by tillage alone [27]. The same constancy characterizes two *Digitaria* species (*D. ciliaris* and *D. horizontalis*) and two *Cenchrus* species (*C. biflorus* and *C. unisetus*), confirming the status of these taxa among the most widespread grasses in West African cultivated fields [16], [18] and [24].

The biological spectrum is very largely dominated by therophytes (73.0% of species), a constant feature of the weed flora of annual Sahelian agrosystems, found both in Burkina Faso [22] and in most weed floras described in Senegal [25], [28] and [29]. Recent work carried out in Benin confirms the sensitivity of weed community structure to tillage intensity [10]. The disturbance regime thus appears to be a major determinant of the biological physiognomy of weed communities, and repeated manual weeding would favor conditions for the development of short-cycle therophytes. Biogeographically, the co-dominance of pantropical (29.7%) and African (27.0%) species illustrates the open, human-disturbed nature of the environment, favorable to the establishment of widely distributed species [30]. This weed pressure, which adds to the other biological pests limiting cowpea cultivation [6], confirms the value of integrated management suited to the means of family farms, where access to herbicides remains limited [9].

5 CONCLUSION

This study provides a first structured inventory of the weed flora associated with cowpea cultivation in smallholder farming systems in the department of Mbour. A restricted but constant assemblage, dominated by the Poaceae and a few geophytic Cyperaceae, structures most of the weed infestation alongside a majority of occasional species. This flora, predominantly therophytic and with a wide biogeographic distribution, reflects a determinism that is above all agroecological, shared with other rainfed crops of the Groundnut Basin. These results provide a scientific basis for prioritizing, in weeding strategies, the most constant and hardest-to-eliminate species. They should be supplemented by surveys incorporating an abundance-dominance coefficient and covering more localities, in order to better rank the actual harmfulness of the species and guide technical practices suited to Senegalese family farms.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare no conflict of interest.

Authors' Contributions

AN contributed to the development of the experimental protocol, data analysis, and manuscript preparation. NKGS contributed to the statistical analysis of the data. KN supervised the work.

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