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Diversity of Weed Plants in Market Garden Crops of the Mountainous Zone in the West of Côte d'Ivoire

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Abstract

Weed plants, commonly called "weeds", represent a major constraint for Ivorian market garden production. This study aims to assess the diversity and harmfulness of weeds in the market gardens of the mountainous zone in the West of Côte d'Ivoire. The characterisation of the weed flora was carried out in 32 market garden crop plots in the Departments of Man and Biankouma. It combined itinerant surveys and plot surveys within 119 quadrats of 4 m² using the Braun-Blanquet phytosociological method. In total, 14 market garden crops were identified, including cabbage (19%), lettuce (19%), parsley (10%), etc. The inventories identified 63 weed species, distributed across 53 genera and 24 families, with a predominance of Poaceae, Asteraceae and Fabaceae. On average, 7.83 ± 2.55 species per quadrat were recorded. The similarity index between the Departments of Man and Biankouma is 75.24%, indicating a strong floristic similarity. Four identified species groups (G1, G4 and G5) represent an agronomic constraint in the mountainous zone. The most harmful weeds are *Eleusine indica*, *Portulaca oleracea*, *Ageratum conyzoides*, *Ipomoea lacunosa*, *Trianthema portulacastrum*, *Cyperus microiria* and *Acmella oleracea*. They should be subject to targeted management to reduce their impact on yields.

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Introduction

Market garden crops encompass agricultural practices dedicated to the production of vegetables, small fruits, and aromatic herbs (Sui Bi, 2019). This sector plays a key role in food and nutritional security, while representing a vital source of income for many rural and peri-urban families in West Africa (Adeoluwa et al., 2021). These crops offer a diversity of foods rich in essential nutrients, including vegetables with recognised nutritional and medicinal virtues (Olaniyi et al., 2010). According to WHO and FAO (2003), a daily consumption of 400 g of fruits and vegetables is recommended to strengthen immune defences due to their contribution of vitamins, mineral salts, and trace elements.

However, market garden production in West Africa faces multiple constraints. Producers encounter numerous difficulties such as access to quality seeds, inputs, irrigation water, and post-harvest conservation equipment (Zougmoré et al., 2020). To these constraints are added climate hazards, losses due to diseases and pests, as well as high weed pressure which compete with crops for water, nutrient, and light resources (Dembélé et al., 2021).

Weeds, or "bad herbs", are spontaneous uncultivated plants that develop within a cultivated area. Their influence on agricultural systems is ambivalent (Caussanel, 1989). On one hand, they contribute to biodiversity, stabilise soils, enrich organic matter, and can serve as biological control against certain pests; on the other, when they proliferate, they become a threat to crops and reduce yields. Some weeds also act as intermediate hosts for pathogens or insect vectors of diseases (Wisler & Norris, 2005). In the Department of Man in the West of Côte d'Ivoire, market garden crops face increased phytosanitary and ecological pressure. PRO2M (2019) reports low productivity linked to low fertility soils, parasitic diseases, and a high proliferation of weed plants. For sustainable crop management, better knowledge of the weed flora is essential. The objective of this study is to assess the diversity and harmfulness of weeds in the market gardens of the Departments of Man and Biankouma to enable the development of integrated management strategies adapted to local realities.

Materials and Methods

Study Site

The investigated plantations belong to the Departments of Man and Biankouma located in the mountainous zone in the West of Côte d'Ivoire (Fig. 1). These Departments are included in the District of Mountains between latitudes 8°4' and 6°34' North and longitude 5°24' and 7°3' West, covering an area of 12,284 km². The climate is tropical and the vegetation belongs to the mountain sector of the Guinean domain, formerly composed of humid dense mountain forests (Guillaumet et Adjanohoun, 1971). The current vegetation is composed of perennial crops (Coffee, cocoa, rubber, etc.), food crops, and market garden crops (CNRA, 2019). For this study, 32 market garden crop plots, typically found in low-lying areas, without distinction of crop type, were studied.

Floristic inventories

Two inventory techniques allowed for data collection. The first was the itinerant inventory, also called "field tour" (Maillet, 1981). It involved traversing the plot in different directions, noting all encountered weeds, and allows for identifying the maximum number of weed species. Next, quadrats of 2m X 2m (4m²) were drawn randomly in each plot, inside which all weeds were noted and their abundance-dominance determined according to the method of Braun-Blanquet (1932). The latter assesses the extent of weed infestation by visual observation of the counting and coverage of weeds (Le Bourgeois, 1993). The weed infestation gradient of each species is quantified by assigning an abundance-dominance index (Table 1).

Identification of weed species

The plant samples collected during the inventories were identified at the University of Man and confirmed by comparison with specimens from the National Floristic Centre. The nomenclature used combined Aké-Assi (2000, 2001), then updated by APG IV (APG, 2016) and the online database of the Conservatory and Botanical Gardens of the City of Geneva.

Data processing and analysis

Floristic diversity

Plant diversity helps to translate the richness and regularity of the population. The Shannon (1948) index was used to assess the heterogeneity and diversity of the orchards. Its mathematical expression is:

$$H' = \sum_{i=1}^{s} \frac{Ni}{N} . log2(\frac{Ni}{N})$$

Where, S: total number of species, Ni: number of individuals of the species, N: total number of individuals of all considered species. The higher the value of the H' index, the greater the diversity.

Sørensen similarity index

The Sørensen (1948) similarity index quantifies the similarity between plots and belongs to the group of β diversity indices. This index highlighted the floristic resemblance between the plots of the visited Departments. The mathematical expression of the

Sørensen coefficient is:

Ks = (2c / a + b) x 100

Where, Ks: Sørensen similarity coefficient, a: number of species in list a (survey A), b: number of species in list b (survey B), c = number of species common to surveys A and B that one wants to compare. The values of the Sorensen similarity coefficient vary from 0 to 100. The more the compared floristic lists have species in common, the more Ks tends towards 100.

Relative and percentage frequency

The frequency of a species is defined by Raunkiaer (1905) as the number of observations of the species in a set of floristic surveys.

The absolute frequency (Fa) or specific frequency is the number of times (n) a species (e) was observed in (N) surveys during sampling: **Fa = n**

The relative frequency (Fr) is the ratio of the absolute frequency (Fa) to the total number (N) of surveys, the formula is: **Fr = Fa / N**

The percentage frequency (Fc) is the expression of the relative frequency (Fr) as a percentage, the formula is: **Fc = Fa (e) / N x 100.**

Mean Abundance-Dominance Index

The mean abundance-dominance index of species (e) (I-ADavg. of species (e)) defines the ratio of the sum of the abundance-dominance scores of the species (Σ I-AD of species (e)) to its absolute frequency (Fa), this index is calculated according to the following formula:

$$\text{I- ADavg.} = \frac{\sum AD}{Fa}$$

Infestation level

Two parameters are used to construct the infestation diagram: the mean Abundance-Dominance index (I-ADavg) and the relative frequency (Le Bourgeois, 1993). The Infestation Diagram is a graphical representation of the relative frequency as a function of the mean abundance-dominance. It consists of a scatter plot that allows for distinguishing major weeds. The EPPO code, a coding system that uses the first 3 letters of the genus and the first two letters of the species, was used for coding the species. Several groups of weeds can be identified according to the classification of Le Bourgeois (1993). These are:

- Major general weeds (G1 with Fr > 0.5 and ADavg > 1.5): Very abundant and very frequent species, they are the most harmful in the studied area, can colonise all ecological environments and possess a high invasion potential due to their strong competitiveness, they require intensive control;

- Potential major weeds (G2 with Fr > 0.5 and 1.25 < ADavg < 1.5). Very frequent and less abundant species; these species are very ubiquitous and harmful but their infestation is lesser than major weeds, they require increased monitoring to avoid their expansion;

- General weeds (G3 with Fr > 0.5 and ADavg. < 1.25): Very frequent species in the inventoried environments but not abundant; they are very ubiquitous with a limited impact that can be managed mechanically;

- Major regional weeds (G4 with 0.2 < Fr < 0.5; ADavg.>1.25): Very abundant species with an average frequency; they have a broad ecological amplitude whose presence is linked to a local ecological factor; this is the original vegetation. They pose localised problems under specific pedoclimatic conditions;

- Major local weeds (G5 with 0.2 < Fr < 0.5; ADavg < 1.5): Abundant species with an average frequency; they have an average ecological amplitude but often show punctual abundance, they become a more or less important agronomic constraint on cultivated plots;

- Potential regional weeds (G6; 0.2 < Fr < 0.5; 0.75 < ADavg < 1.25): Species with low abundance and average frequency; they have an average ecological amplitude and do not constitute an agronomic constraint;

- Regional weeds (G7 with Fr < 0.2 and ADavg > 1.5): Species with broad or average ecological amplitude but do not constitute an agronomic constraint;

- Potential local weeds (G8 with Fr < 0.2 and 1.25 < ADavg < 1.5): Local, infrequent species with average abundance; they possess a very narrow ecological amplitude in certain localities but are not an agronomic constraint;

- Accidental weeds (G9; Fr < 0.2 and ADavg < 1.25): Infrequent and not abundant species, they are rare, foreign, or pioneer, do not constitute an agronomic constraint.

In general, weeds in groups G1 and G2 are the most aggressive and require intensive control measures to preserve yields. Those in groups G3 to G5 present moderate harmfulness and require targeted interventions. Groups G6 to G9 are of little concern and mainly play an ecological indicator role.

Statistical data analysis

The collected data were analysed using EXCEL software and XLSTAT 2013 software was used for drawing the infestation diagram. The Chi-square test was used to identify diversity differences between the weeds of the two Departments. Significance was observed at $p < 0.05$.

Results and Discussion

Floristic richness and diversity of weeds in market garden crops of the mountainous zone

The floristic inventories carried out in the market garden crop plots of the mountainous zone identified 63 weed species, distributed across 53 genera and 24 botanical families (Fig. 2). On average, 7.83 ± 2.55 species per quadrat were recorded across all sites. The calculated Shannon diversity index is 1.59 ± 0.33. These results indicate significant floristic richness and abundant plant diversity. Compared to our results, the work of Kouman et al., (2024) in rice plots in the Department of Man recorded 88 species distributed across 72 genera and 37 families, while that of Mango et al., (2022) in cassava crops in the peri-urban area of Abidjan in the South of Côte d'Ivoire recorded 152 weed species distributed across 123 genera and 46 families. All these results testify to the diversity and preponderance of weeds in market garden and food crops in Côte d'Ivoire. Regarding the dominance of families in the studied plots, Asteraceae (10 species) are the most represented (Fig. 2), followed by Poaceae (9 species) and Fabaceae (7 species), which conforms to the results of Coulibaly et al., (2022) in rice systems of the Department of Man. This floristic structure is frequent in disturbed agricultural areas, where Poaceae and Asteraceae dominate due to their ecological plasticity and high seed production (Jacques-Félix, 1962).

The analysis of the biological spectrum (Fig. 3) shows a clear dominance of therophytes (72%), followed by hemicryptophytes (11.7%). These biological types dominate highly disturbed environments, where intensive agricultural practices such as repeated ploughing, irregular manual or chemical weeding, create an environment conducive to their rapid establishment (Benabderrahmane et al., 2017). This type of flora has also been reported by Ouédraogo et al., (2013) in rice systems in Burkina Faso, albeit in different water contexts. For Akobundu et al., (2001), high vegetative regeneration capacities of species presenting underground reserve organs make them particularly persistent. These so-called "problematic" species are difficult to eliminate by mechanical means alone.

At the departmental scale, the estimated floristic richness is 49 weed species recorded in market gardens in Man compared to 52 species in Biankouma. Data processing shows that several weed species, corresponding to 60.13% of the inventoried species, were found simultaneously in both Departments of the study area.

The Sorensen similarity index calculated between the Departments of Man and Biankouma is 75.24%, indicating a strong floristic similarity. The comparison of floristic diversities by the chi-square test shows that there is no significant difference between the diversity of weeds in the two zones and in the different practised market garden crops ($p = 0.17$). These results indicate the existence of a common base of weeds, but also a floristic diversity modulated by local conditions. Indeed, the Departments of Man and Biankouma both belong to the Mountain Sector of the Guinean domain (Guillaumet and Adjanohoun, 1971). These results are strategic for proposing common and locally differentiated management measures.

Harmfulness of weeds

Frequency, Abundance-Dominance

The results of frequencies and mean abundance-dominance in the study area highlight the preponderance of certain species (Table 2). The most frequent weeds are *Eleusine indica* (L.) Gaertn. (Fc = 69%; Fig. 4), *Portulaca oleracea* L. (48%, Fig. 5), *Cyperus microiria* Steud (40%). The weeds with the greatest abundance-dominance are *Acmella oleracea* (L.) R.K.Jansen (4.13), *Echinochloa crus-galli* L. P. Beauv. (2.63), *Digitaria sanguinalis* L. Scop. (2.59), *E. indica* Table 2 presents weeds with a frequency greater than or equal to 15%. They represent 27% of the inventoried species. The analysis of frequencies and the abundance-dominance index shows that *E. indica* is the major weed of market garden crops in the mountain zone. It is followed by *P. oleracea*, *C. microiria* and *Ageratum conyzoides* L. The species with the highest frequencies and abundance-dominance are substantially the same in Man and Biankouma.

These are *E. indica*, *C. microiria*, *P. oleracea*, *A. conyzoides* for the Department of Man, while in Biankouma, they are *E. indica*, and *A. oleracea*, *P. oleracea* and *P. angulata*. These results align with those of Soro et al., (2019) who describe *E. indica* as a dominant species in the market garden systems of Yamoussoukro. These results show the preponderance of this species in market gardens in Côte d'Ivoire. However, discrepancies may appear, favoured by the difference in study regions, types of crops, climatic, edaphic pressure, etc. (Zouzou et al., 2021)

Table.1 The modified Braun-Blanquet scale

Indices	Signification
1	Rare individuals, not abundant or abundant, but with low coverage
2	Very abundant individuals or covering 1/20 of the sampled plot
3	Individuals covering ¼ to ½ of the surface, any abundance
4	Individuals covering ½ to ¾ of the surface, any abundance
5	Individuals covering more than ¾ of the surface, any abundance

Table.2 Frequencies and abundance-dominance of major weeds in the study area

		Total		Biankouma		Man	
Nom Scientifique	**EPPO Code**	**Fc**	**ADavg**	**Fc**	**ADavg**	**Fc**	**ADavg**
Eleusine indica (L.) Gaertn.	ELEIN	**69%**	**2,58**	92%	**3,06**	62%	**2,4**
Portulaca oleracea L.	PTLOL	**48%**	**2,08**	61%	1,55	44%	**2,3**
Cyperus microiria Steud.	CYPMI	**40%**	**2,42**	-	-	52%	**2,4**
Ageratum conyzoides L.	AGECO	**39%**	1,84	36%	1,31	39%	2
Amaranthus viridis L.	AMAVI	**35%**	1,51	-	-	39%	1,5
Thranthema portulacastrum L.	TRIPO	**31%**	**2,33**	25%	1,67	32%	**2,5**
Phyllanthus amarus Schumach. & Thonn.	PHUAM	**28%**	1,26	-	-	30%	1,2
Alternanthera sesselis (L) R. Br. ex DC	ALTSE	**25%**	**2,24**	-	-	32%	**2,2**
Cleome rutidosperma DC.	CLERT	**25%**	1,42	-	-	28%	1,5
Physalis angulata L.	PHYAN	24%	1,47	61%	1,68	-	-
Ipomoea lacunosa L.	IPOLA	20%	2,2	25%	**2,67**	18%	2
Euphorbia heterophylla L.	EUPHE	19%	1,32	47%	1,35	-	-
Galinsoga parviflora Cav.	GALPA	19%	1,32	-	-	18%	1,3
Digitaria sanguinalis L. Scop.	DIGSA	18%	**2,59**	25%	**3,33**	16%	**2,2**
Echinochloa crus-galli L. P. Beauv.	ECHCR	18%	**2,63**	-	-	17%	**2,5**
Craton hirtus L'Hèr.	CRAHI	16%	1,29	58%	1,33	-	-
Acmalla oleracea (L.) R.K.Jansen	ACMOL	15%	**4,13**	64%	**4,13**	-	-
(- : Absence); Fc: percentage frequency; ADavg: Mean Abundance-Dominance							

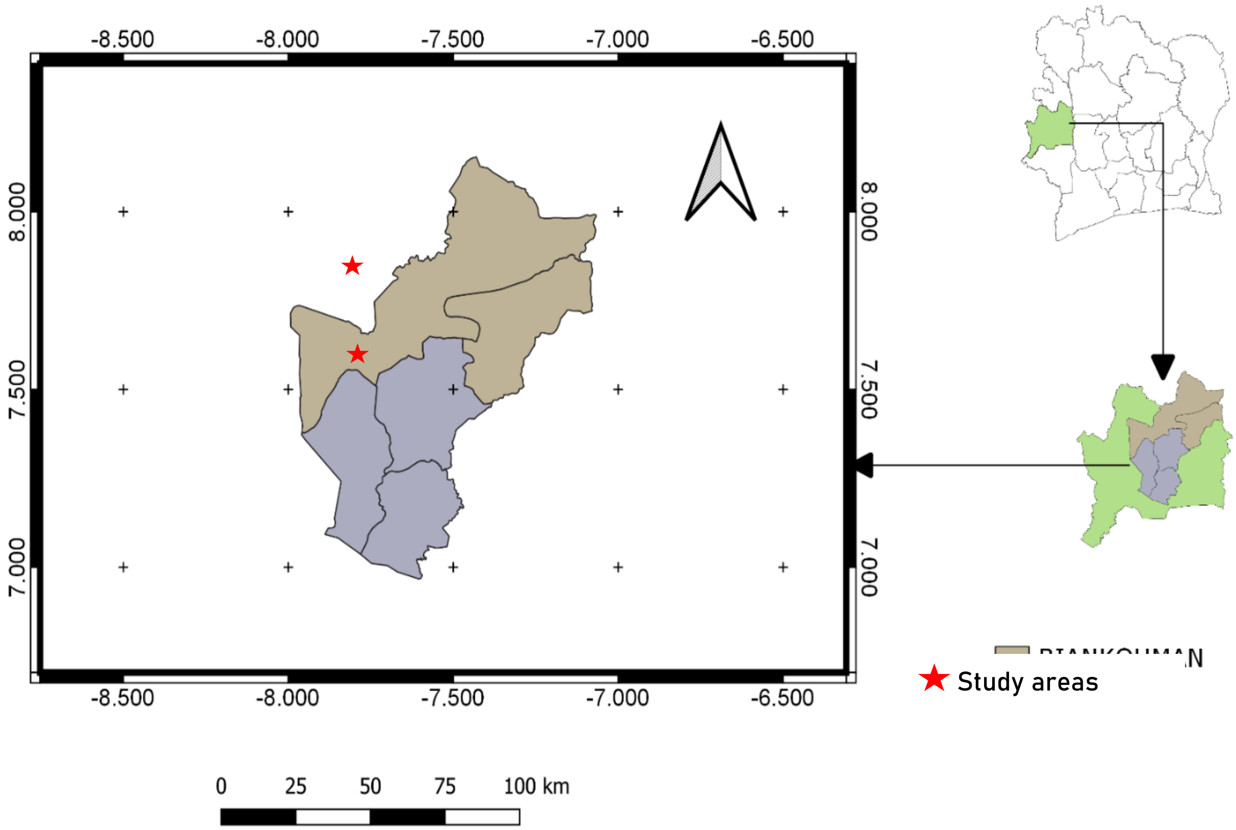

Fig.1 Location of the study areas

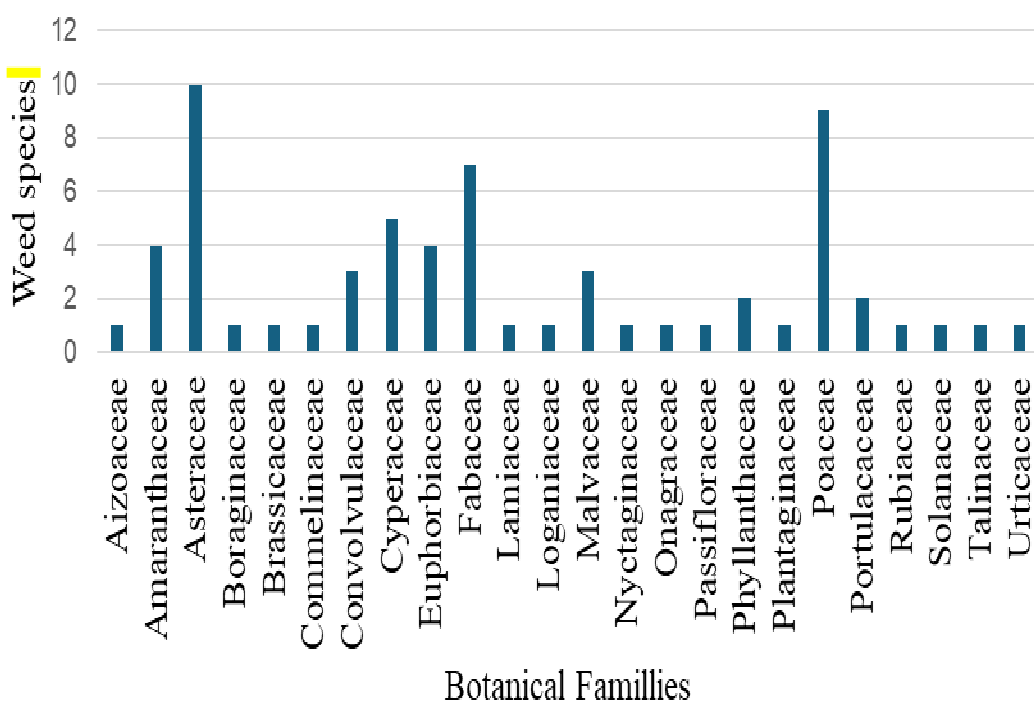

Fig.2 Botanical families of weed species in the inventoried plots

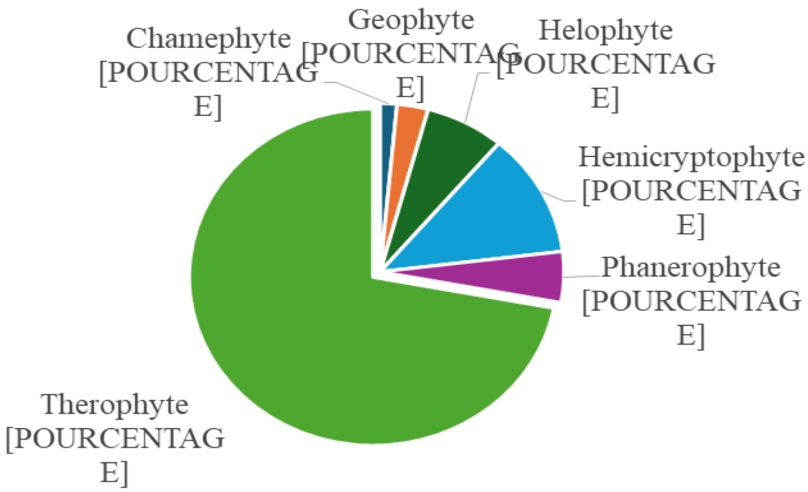

Fig.3 Biological type of weed species in the inventoried plots

Fig.4 Individual of *Eleusine indica* (L.) Gaertn.

Fig.5 Individual of *Portulaca oleracea* L.

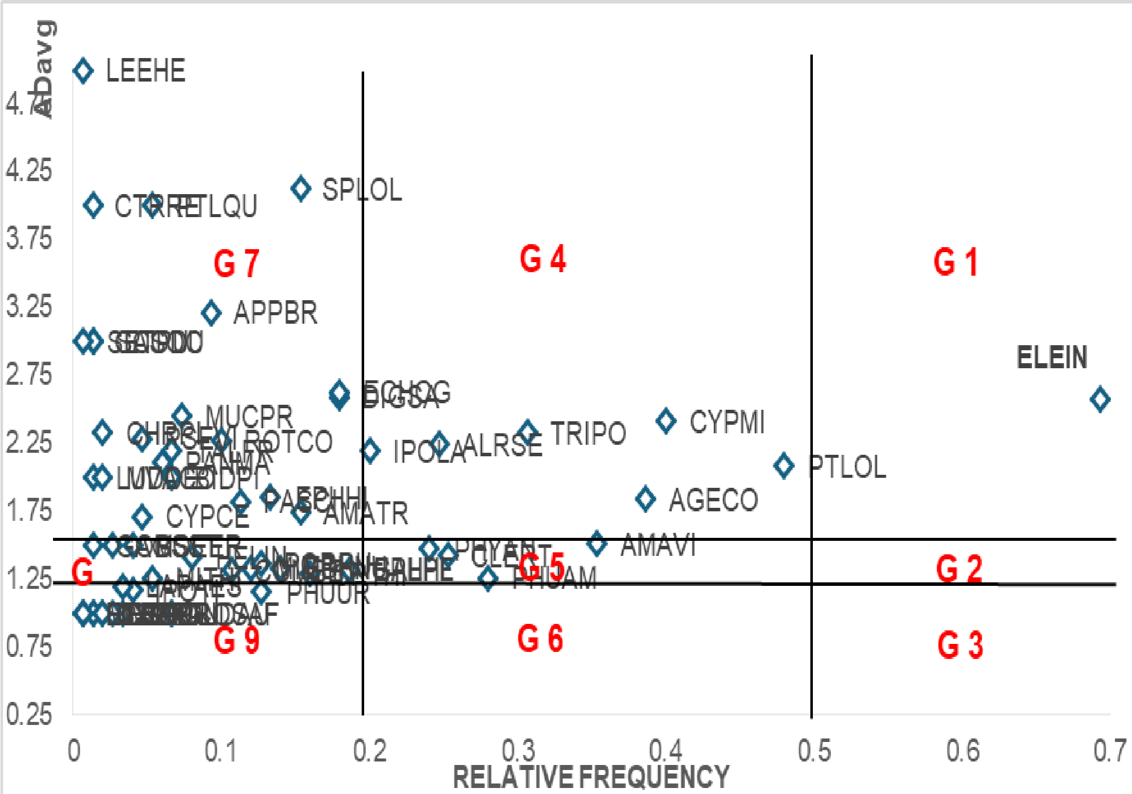

Fig.6 Infestation diagram of market garden crops in Study area.

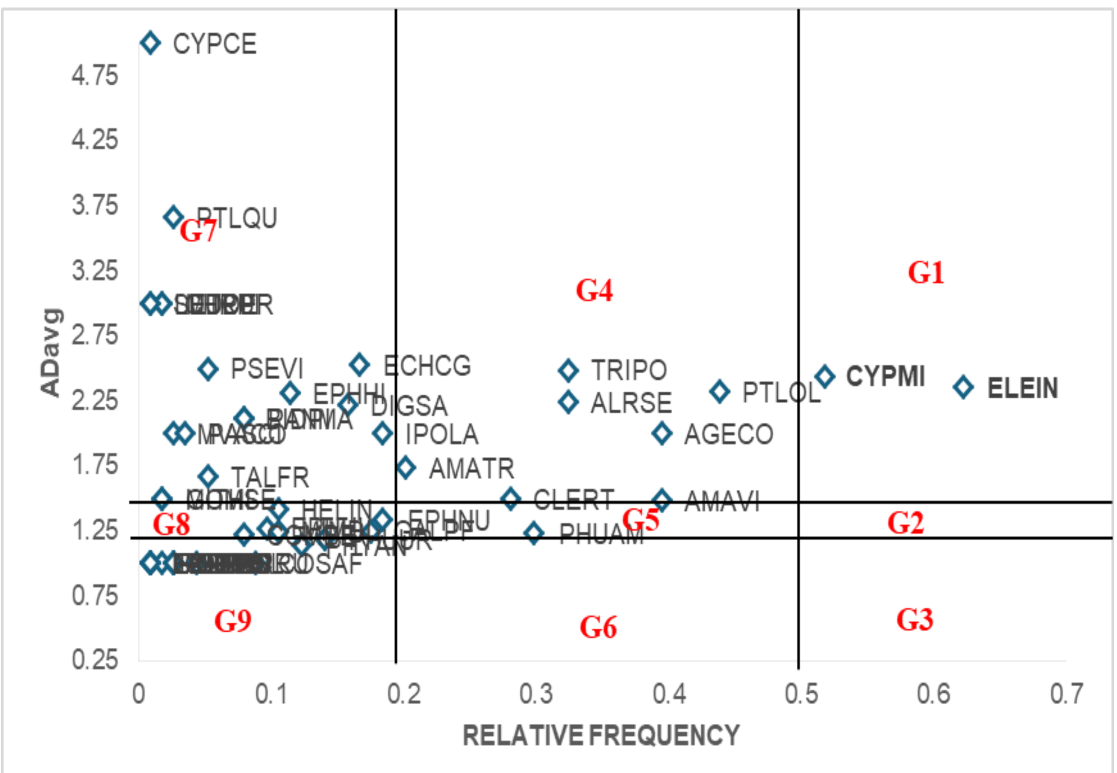

Fig.7 Infestation diagram of market garden crops in the Department of Man

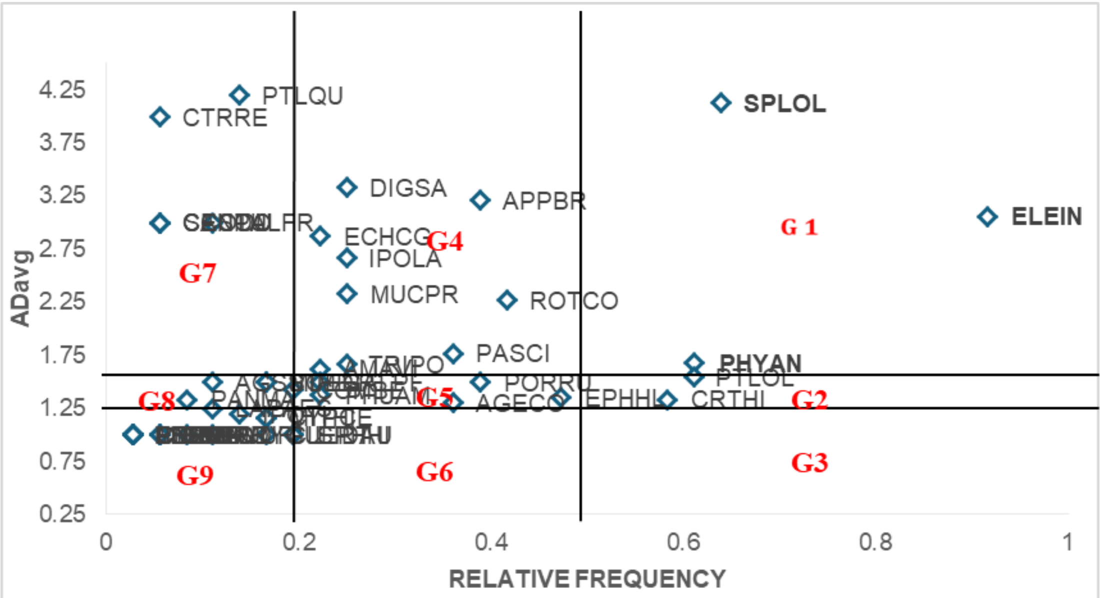

Fig.8 Infestation diagram of market garden crops in the Department of Biankouma.

Weed infestation level

The analysis of the infestation diagram of the species recorded in the market garden crops of the mountainous zone and the studied plots revealed six groups of harmful weeds out of the 9 listed. These are: G1, G4, G5, G7, G8 and G9 (Fig. 6), according to Le Bourgeois (1983). The work of Kouman et al., (2024) had identified 7 groups in the rice plots of the Department of Man. In our study, three groups represent an agronomic constraint (G1, G4 and G5). Group G1, consisting of major general weeds, is represented exclusively by *E. indica*, identified as the most harmful weed in the entire study area.

It is considered harmful by several weed science researches (Mango et al., 2022; Kouman et al., 2024). Its preponderance could be due to its resistance to several herbicides (Seng et al., 2010; Jalaludin et al., 2010; Heap, 2011). Group G4 includes several species very present in the plots: *P. oleracea*, *Ipomoea lacunosa* L., *Trianthema portulacastrum* L., *A. conyzoides*, *C. microiria* and *Alternanthera sessilis* (L.) R.Br. ex DC. Group G5 is represented by *Phyllanthus amarus* Schumach. & Thonn. and *Cleome rutidosperma* DC., observed in several plots with moderate infestation. Group G7, which groups nearly 40% of the recorded species, includes among others *Leersia hexandra* Sw., and *Crotalaria retusa* L. Group G8 brings together species such as *Gomphrena serrata* L., *Agrostis stolonifera* L. and *Boerhavia erecta* L., observed locally. Finally, group G9 groups weakly represented weeds, not considered harmful. Among these are *Phyllanthus urinaria* L., *Mitracarpus hirtus* (L.) DC and *Heliotropium indicum* L. The most harmful species in the study area are therefore *E. indica*, *P. oleracea*, *A. conyzoides*, *I. lacunosa*, *T. portulacastrum*, *C. microiria*, *A. sessilis* and *A. oleracea*. These harmful species should be subject to targeted management to reduce their impact on yields. However, all weeds, regardless of their status, should be given particular attention. They maintain competition with crops and can be carriers of parasites (Prieto et al., 2012; EPPO, 2025).

At the departmental scale, the analysis of the infestation diagrams (Fig. 7 and 8) identified six (6) and seven (7) groups of harmful weeds, respectively in the Department of Man and Biankouma. In total, three groups (G1, G4 and G5) represent agronomic constraints in the Department of Man compared to four (G1, G2, G4 and G5) in Biankouma. Group G1 is dominated in both zones by *E. indica*, identified as the most constraining weed in the entire study area. In Biankouma, this group also includes *A. oleracea*, *Physalis angulata* L. and *P. oleracea*, while in Man, it includes *C. microiria*. Group G2, observed only in Biankouma, is represented by *Croton hirtus* L'Hér., a dominant species in certain plots. Group G4 is well represented in both zones. In Man, it includes *A. conyzoides*, *P. oleracea*, *A. sessilis*, *Amaranthus tricolor* L. and *T. portulacastrum*. In Biankouma, this group is more diversified, with 11 species, including *D. sanguinalis*, *Amphicarpaea bracteata* (L.) Fernald and *E. crus-galli*. The comparative analysis of infestations in the Departments of Man and Biankouma reveals a strong dominance of some very harmful weeds, notably *E. indica,* present in both zones as the most harmful species. The floristic assemblage of harmful species is greater in Biankouma. Several plots present species with a high abundance-dominance potential which corresponds to a high infestation level according to the typology of Le Bourgeois (1993). Among these species, *A. oleracea*, a species less documented in the classical weed literature, showed strong dominance in several plots where it presents a recent invasion for the populations. This result could be the result of climate change or modification of the floristic landscape linked to specific microclimatic conditions (cultivation techniques, drainage, soil texture, rainfall, etc.). For Koulibaly et al., (2006) and Coulibaly et al., (2018), significant coverage in market garden systems can lead to a significant yield decrease and require urgent intervention to avoid a decline in quality and productivity.

In conclusion, this study aimed to assess the diversity and harmfulness of weeds in the market gardens of the mountainous zone in the West of Côte d'Ivoire. The inventories identified 63 weed species, distributed across 53 genera and 24 botanical families, with a predominance of Poaceae, Asteraceae and Fabaceae. The calculated diversity index is 1.59 ± 0.33.

The similarity index between the Departments of Man and Biankouma is 75.24%, indicating a strong floristic similarity between the weed floras. Three identified species groups (G1, G4 and G5) represent an agronomic constraint in the mountainous zone. The most harmful species in the study area are therefore *E. indica*, *P. oleracea*, *A. conyzoides*, *I. lacunosa*, *T. portulacastrum*, *C. microiria*, *A. sessilis* and *A. oleracea*. These species must be subject to targeted management to reduce their impact on yields. The implementation of adapted control strategies, integrating cultural, mechanical, and phytosanitary methods, therefore appears essential to sustainably improve the productivity of market garden systems.

Competing interests

The authors declare that they have no conflict of interest regarding this manuscript.

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