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Impacts of weed control methods on weed dynamics in rainfed rice cultivation in the Niakara Department in northern Côte d'Ivoire

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Abstract

Introduction: Rice accounts for approximately 10% of national food production and has become the staple food for the majority of Ivorians. Unfortunately, the proliferation of weeds in the fields is one of the main factors limiting its production. This study aims to identify the main weeds and evaluate the effectiveness of two weeding methods on weed management in rain-fed rice cultivation.

Methods: A survey was conducted among 70 producers to identify problematic weeds. A trial was then set up on 14 plots belonging to producers. This enabled the effect of chemical weed control and the combination of chemical and manual weed control on weed growth dynamics and the agronomic importance of major weeds to be assessed.

Results: The study identified 22 problematic weeds. The most common family is Poaceae. Therophytes (63.64%) and grasses (81.82%) are the most problematic biomorphological types. *Rottboellia cochinchinensis* (Poaceae) and *Setaria pumila* (Poaceae) are the most frequently cited invasive species. The results on weed management methods reveal that chemical weed control and the combination of chemical and manual weed control significantly reduced weed flora. Major weed flora decreased significantly.

Conclusion: This study highlights the need to implement more effective and efficient integrated weed management strategies for sustainable agriculture.

Keywords: Weed Proliferation; Rain-Fed Rice Cultivation; Sustainable Agriculture

1. Introduction

Rice (Oryza sp.) ranks third among cereal crops after wheat and corn in terms of production, with global production estimated at 533.8 million tons in 2024 (Rice Outlook, 2024) [1]. It is the staple food for more than half of the world's population, with annual per capita consumption estimated at 76.9 kg in Asia, 27.2 kg in Africa, and 19.2 kg in Europe (FAO, 2022) [2]. In African agricultural systems, rice plays a fundamental role in people's sources of income and contributes to reducing poverty among producers (Totin et al., 2013) [3].

In Côte d'Ivoire, rice is the fourth most important food crop after yams, cassava, and plantains, accounting for approximately 10% of national food production. This staple food has become the main food source for the vast majority

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of Ivorians (Gala bi et al., 2011; Kotchi et al., 2018) [4] [5]. According to Ouédraogo et al. (2021), [6] nearly 675,324 households are involved in rice production in Côte d'Ivoire, of which 26,634 are involved in irrigation, 374,038 in lowland rice, and 274,651 in upland rice. In addition, domestic production in 2024 was estimated at 1.55 million tons of milled rice. Unfortunately, this production is unable to meet domestic demand, estimated at 2.8 tons of milled rice (Le point Afrique, 2025) [7]. To make up for this shortfall, the country imports large quantities of milled rice, the cost of which continues to rise. According to Gurdev (2013) [8], rice production is expected to increase by 40% by 2030 in order to meet population demand. Indeed, insufficient rice production can be explained by unfavorable socioeconomic conditions, but above all by biotic constraints (Oerke and Dehne, 2004) [9]. Rice productivity in general, but particularly rain-fed rice production, is severely affected by weeds, which can cause crop losses ranging from 50 to 100% in some cases (Mishra and Singh, 2007; Rao et al., 2007) [10] [11]. According to FAO STAT, (2016) [12], in rain-fed rice cultivation, without effective and timely control, competition from weeds can reduce the yield. In addition to their harmful effect on the crop, weeds can also serve as alternative hosts for pathogens and crop pests between seasons (Rézaul, 2000) [13].

To combat weeds, this study aims to identify problematic weeds and evaluate the effectiveness of two traditional weeding methods in rain-fed rice cultivation, with a view to developing weed management strategies that can optimize rice productivity.

2. Materials and methods

2.1. Study area

This study was conducted in the department of Niakaramadougou, in northern Côte d'Ivoire, at geographical coordinates 8° 39' 37''north and 5° 17' 28'' east. In this area, seven rice-producing villages were selected based on their distance from Niakaramadougou and the village's involvement in rice production (Figure 1). These are Fononkaha, Badiokaha, Kafiné, Niakaramandougou, Tortya, Adamakaha, and Panakaha.

2.2. Study materials

The study materials consist of plants of the different rice varieties grown by the producers and weeds, as well as survey forms to collect information on problematic weeds, phytosociological survey forms, and weed coverage rating forms to record the names of species and the level of weed coverage on the plots of selected producers

2.3. Data collection

A survey was conducted among 70 rice producers. On the pre-established questionnaire, the main question asked of producers for this study concerned the problematic weeds encountered during the crop cycle. Next, a trial was conducted on 14 plots belonging to producers. This trial consisted of marking out a 900 m^2 plot in the middle of the selected producer's plot. Seven plots were used for the first treatment (T1) and the other seven for the second treatment (T2). Each plot is considered a repetition. The treatments are as follows

- T1: two chemical weedings, with the first carried out after sowing;
- T2: first chemical weeding and second manual weeding, with the first carried out after sowing.

None of the plots underwent any special treatment beforehand. Floristic surveys were carried out in each plot two weeks before treatment and two weeks after weed emergence.

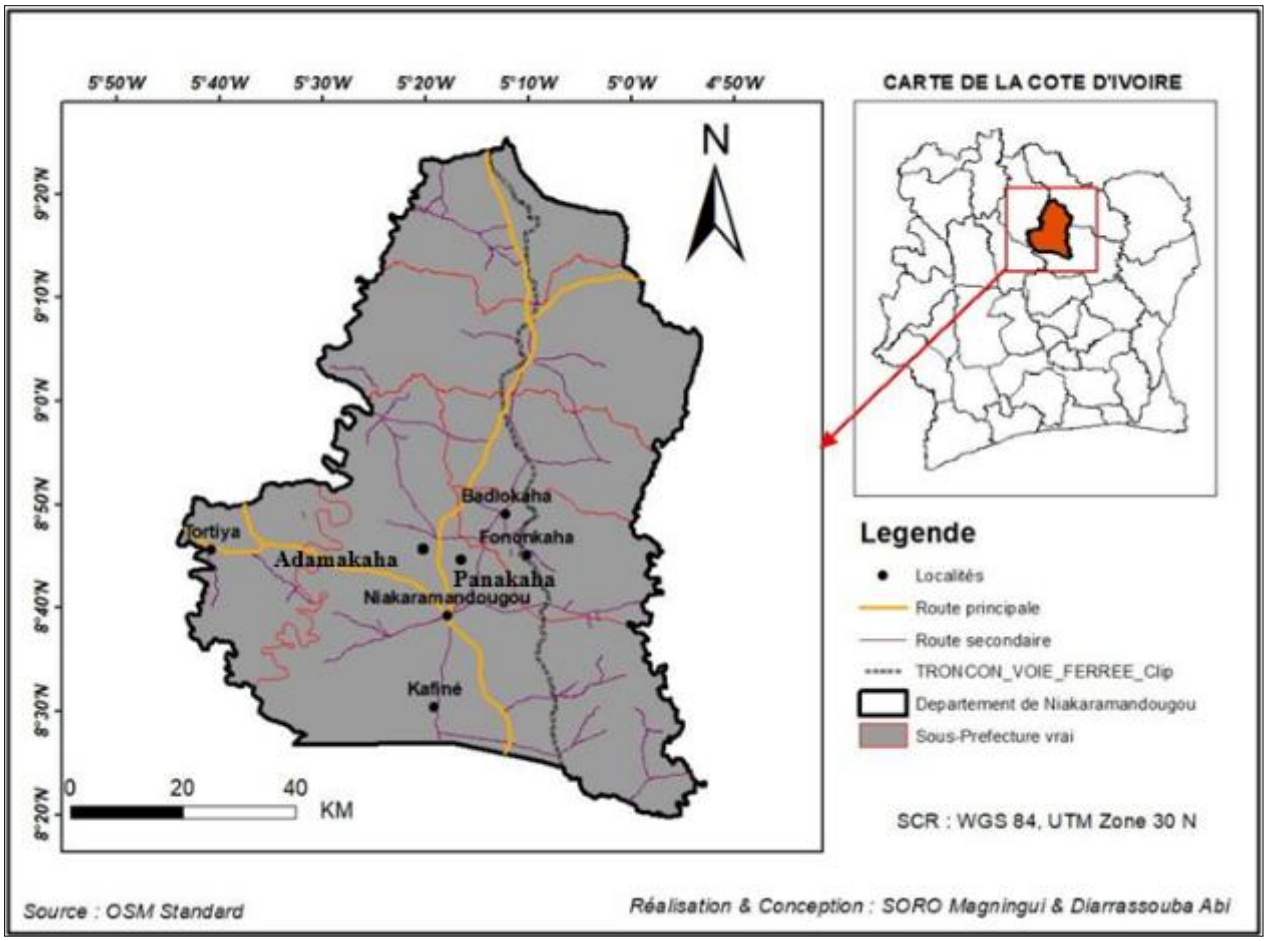

Figure 1 Map showing the location of the study area

An abundance-dominance score was assigned according to the weed cover rating scale (Table 1) adopted from Le Bourgeois (1993) [14]. The Bayer principle was adopted in this study for the coding of taxa. This is a 5-letter coding system that combines the first 3 letters of the genus with the first 2 letters of the specific epithet (Boraud, 2000 and Ipou, 2005) [15] [16].

2.4. Analysis of survey data

The problematic weeds were recorded using an Excel spreadsheet. The frequency of citation (1) for each problematic weed was determined. With regard to biomorphological types, the percentages representing each biological and morphological type were calculated and used to construct histograms of biological and morphological types. The biological type classification model adopted is that of Aké Assi (2001; 2002) [17 ;18], itself adapted from Raunkiaer's model (1905) [19].

$$Fc = \frac{Fa\,(e)}{N} \times 100 \qquad (1)$$

Fc: Citation frequency; Fa (e): Number of times the species has been cited; N: Number of producers

Table 1 Scale adopted for quantifying grass cover (Le bourgeois, 1993) [14]

Indices	Significations
1	Rare individuals, few in number or abundant, but with low coverage
2	Very abundant individuals or covering 1/20 of the sampled area
3	Individuals covering ¼ to ½ of the surface, abundance unknown
4	Individuals covering ½ to ¾ of the surface, abundance unknown
5	Individuals covering ¾ or more of the surface, abundance unknown

2.5. Dynamics and degree of weed infestation during the crop cycle

The weed flora before and after treatment was recorded. Weeds were classified according to family, biological type, and morphological type. The average abundance-dominance (2) of each weed was calculated using the following formula :

$$\text{AD moy (e)} = \frac{\sum \text{AD de l'espèce}}{\text{N}} \quad (2)$$

With AD moy (e): Average abundance-dominance of the species, AD: Abundance dominance, N: Total number of surveys.

(1) and (2) made it possible to establish the agronomic importance of weeds before and after treatment. Different groups of weeds are defined as follows

- Group 1: species that are both frequent (frequency > 0.5) and abundant (average A/D > 1.5) are classified as "major general weeds";
- Group 2: species that are frequent (frequency > 0.5) and of average abundance (1.25< average A/D < 1.5) are referred to as "potential general weeds";
- Group 3: species that are frequent (frequency > 0.5) but never abundant (average A/D < 1.25) are weeds to be monitored due to their widespread distribution during cultivation practices. They are referred to as "general weeds";
- Group 4: moderately frequent species (0.2 < frequency < 0.5) with a wide ecological range whose presence is linked to a regional ecological factor (soil, climate, topography) and which are abundant, known as "major regional weeds";
- Group 5: species that are common but locally very abundant with a narrow ecological range, known as "major local weeds";
- Group 9: species that are uncommon (frequency < 0.2) and not very abundant, which are rare, foreign, or pioneer species known as "minor weeds"; they do not pose a threat to crops.

There are intermediate levels between the "minor" species group and the 'major' species group; these are "regional potential," "regional," and "local potential" species.

In this study, the evaluation of the effectiveness of weed control methods (treatments) focused on species in groups 1, 2, 3, and 4.

3. Results

3.1. Analysis of the flora of problematic weeds

Investigations carried out among 70 rice producers in their fields identified 22 problematic weeds, divided into 19 genera and 8 botanical families. The most represented family is Poaceae. Eight weeds were mentioned by 20% or more of respondents (Table 2). At the end of the survey, the problematic species identified by producers were grouped into

five biological types, with therophytes predominating, accounting for 63.64% of biological types (Figure 2). Regarding morphological types, two types were observed: herbaceous plants (81.82%) and shrubs (18.28%).

Table 2 Weeds most frequently cited by rice farmers in the Niakaramadougou department

N°	Species	Families	Centésimal frequency
1	*Ageratum conyzoides*	Asteraceae	20,00
2	*Commelina benghalensis*	Commelinaceae	30,00
3	*Digitaria horizontalis*	Poaceae	22,86
4	*Eleusine indica*	Poaceae	21,43
5	*Imperata cylindrica*	Poaceae	25,71
6	*Oryza barthii*	Poaceae	27,14
7	*Rottboellia cochinchinensis*	Poaceae	50,00
8	*Setaria pumila*	Poaceae	31,43

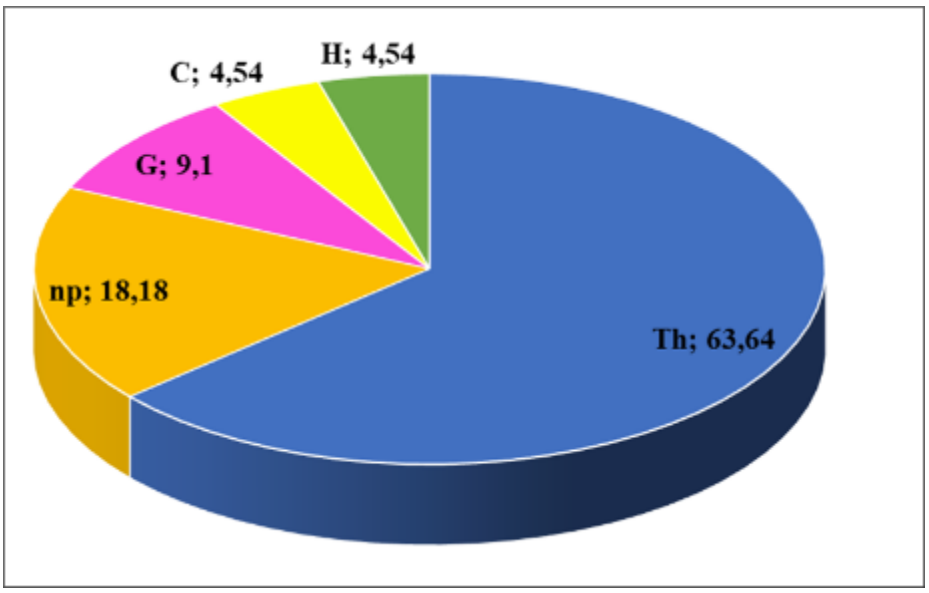

Figure 2 Biological spectrum of restrictive weeds

Th: Therophytes; np: nanophanerophytes; G: Geophytes; C: Chamephytes; H: Hemicryptophytes

3.2. Effects of the two weeding methods on the dynamics and agronomic importance of weeds

3.2.1. Two chemical weed control treatments during the growing cycle (T1)

Floristic surveys carried out on the plots before chemical weed control (post-emergence) identified 58 species, divided into 38 genera, 19 botanical families, 7 biological types, and 3 morphological types. The most represented family is Poaceae (16 species). As for biological types, therophytes (44.83%) and nanophanerophytes (26.86%) were the most represented. The majority of the species identified were herbaceous plants (72.41%) and shrubs (24.14%). In terms of the infestation diagram before chemical weed control, Figure 3 shows five groups of weeds. These are weeds from groups G1, G2, G3, G6, and G9. The weeds from the three main groups are:

- **G1:** *Rottboellia cochinchinensis* (ROTCO), *Ageratum conyzoides* (AGECO), *Commelina benghalensis* (COMBE), *Setaria pumila* (SETPU), *Physalis angulata* (PHYAN) and *Brachiaria mutica* (BRAMU) ;

- **G2:** *Eleusine indica* (ELEIN), *Acmella uliginosa* (ACMUL), *Imperata cylindrica* (IMPCY) and *Oryza barthii* (ORYBA) ;
- **G3:** *Phyllanthus amarus* (PHYAM), *Crotalaria retusa* (CRORE)*, Chromolaena odorata* (CHROD) and *Digitaria sanguinalis* (DIGSA).

After chemical weed control, the floristic list of the plots contained 35 species, divided into 31 genera and 15 botanical families, 7 biological types, and 3 morphological types. The predominant family remained the Poaceae family (14 species). All other families present before weed control were significantly reduced in terms of species. In terms of dominant biomorphological types, no major differences were observed. Therophytes (74.28%), nanophanerophytes (22.86%) and herbaceous plants (77.14%) are the most common. No new weed species appeared on the plant list after chemical weed control.

The potential harmfulness of weeds, as shown in the infestation diagram (Figure 4), also presents the same five groups of weeds as before weeding. However, a significant reduction in each species group is observed. Group 1 (G1), which initially had 5 species, now has 4 species, followed by a decrease in the average abundance and dominance of each species.

The species in groups G2 and G3 were reduced to two weeds, respectively *Commelina benghalensis* (COMBE) and *Digitaria insularis* (DIGIN) for group G2 and *Acmella uliginosa* (ACMUL) and *Chromolaena odorata* (CHROD) for group G3. The species *Digitaria insularis* (DIGIN), initially in group G6, is now in group G2. The species *Digitaria sanguinalis* (DIGSA) has been significantly reduced.

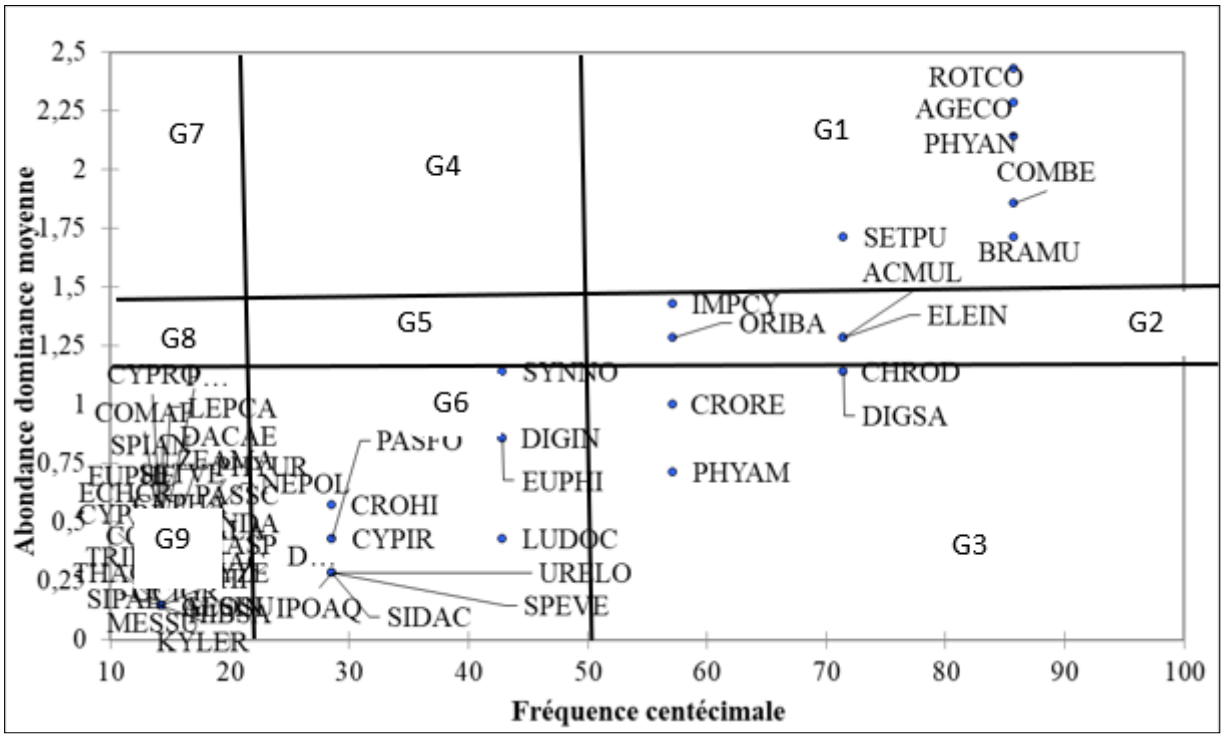

Figure 3 Diagram showing weed infestation before chemical weed control on the plots

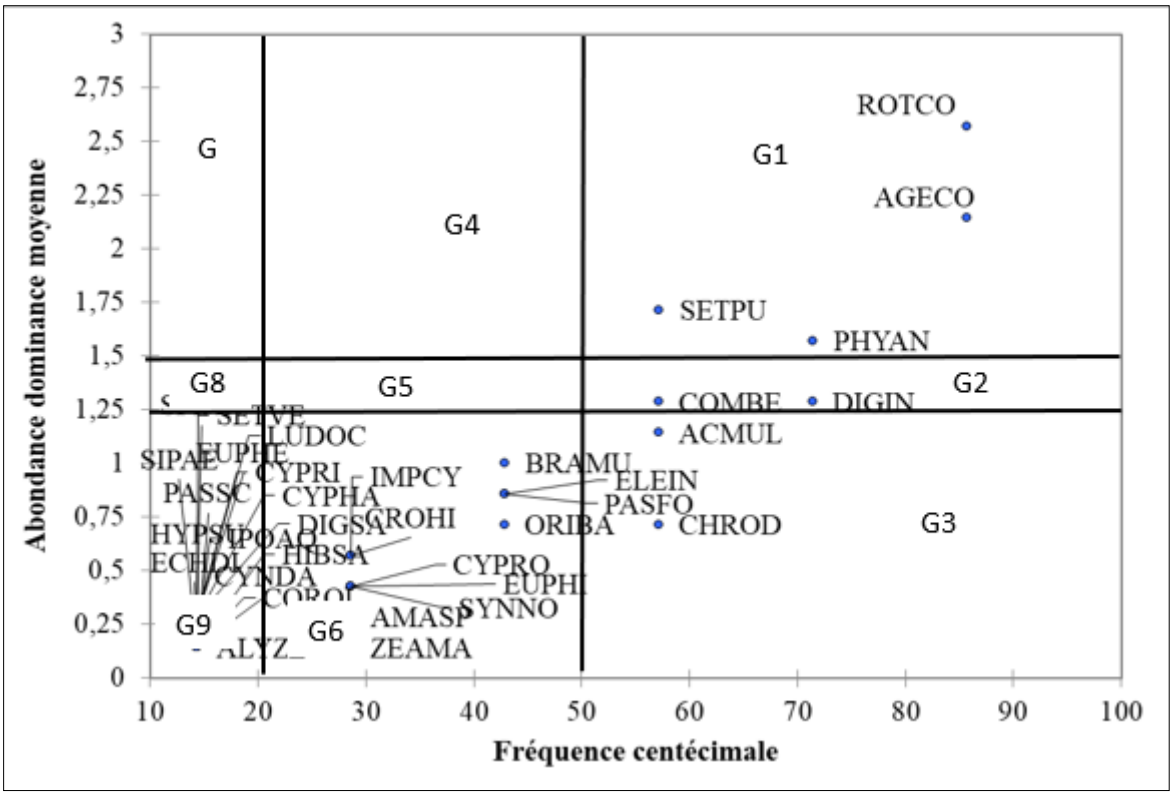

Figure 4 Diagram showing weed infestation after chemical weed control on plots

3.3. Chemical weed control combined with manual weed control (T2)

Regarding the floristic surveys carried out in the case of chemical weed control combined with manual weed control, 50 weeds were recorded before weed control (manual). This flora is divided into 36 genera and 16 botanical families, 7 biological types, and 3 morphological types. Poaceae (12 species) and Fabaceae (9 species) are the most common. The dominant biological types are therophytes (40%) and nanophanerophytes (30%). Herbaceous plants (60%) are the most widespread morphological type. Regarding the agronomic importance of the species, Figure 5 illustrates the potential harmfulness of the weeds identified before manual weeding. Analysis of Figure 5 reveals four major groups of weeds : groups G1, G3, G6, and G9.

Groups G1 and G3 contain six species each for group G1 *Ageratum conyzoides* (AGECO), *Commelina benghalensis* (COMBE), *Rottboellia cochinchinensis* (ROTCO), *Digitaria sanguinalis* (DIGSA), *Eleusine indica* (ELEIN), and *Passiflora foetida* (PASFO)), and seven species for group G3 (*Amaranthus spinosus* (AMASP), *Crotalaria retusa* (CRORE), *Chromolaena odorata* (CHROD), *Phyllanthus amarus* (PHYAM), *Brachiaria mutica* (BRAMU), *Setaria pumila* (SETPU) and *Crotalaria retusa* (CRORE)).

The weed flora obtained after manual weeding comprises 27 weeds divided into 26 genera and 11 botanical families, 5 biological types dominated by therophytes (51.85%) and nanophanerophytes (33.33%), and 3 morphological types containing 70.37% of herbaceous plants. Floristic analysis of the two floras reveals a sharp decline in flora after weeding. However, two new species are noted : *Celosia trigyna* (Amanranthaceae) and *Corchurus olitorius* (Malvaceae). Poaceae are predominant with 10 species. The average abundance-dominance of almost all species recorded before weeding is higher than that of species present after weeding.

The weed infestation diagram after manual weeding (Figure 6) shows five weed groups (G1, G2, G3, G6, and G9). However, analysis of the infestation diagram shows a significant reduction in the number of species in the different weed groups after weeding. In group G1, only one species remains (*Ageratum conyzoides*). The weed *Eleusine indica* (ELEIN), which belonged to group G1 before weeding, is the only one in group G2. Four weeds are found in group G3 (*Setaria pumila, Commelina benghalensis, Phyllanthus amarus*, and *Passiflora foetida*).

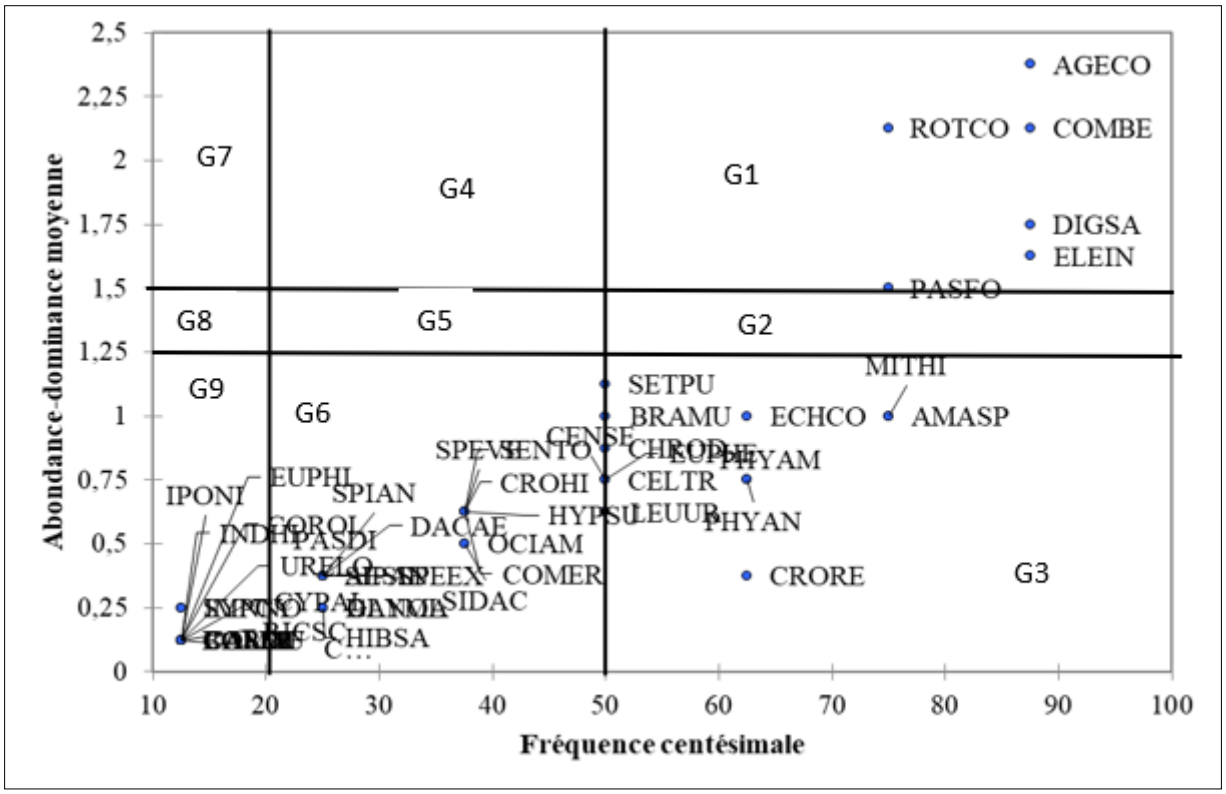

Figure 5 Diagram showing weed infestation before manual weeding of plots

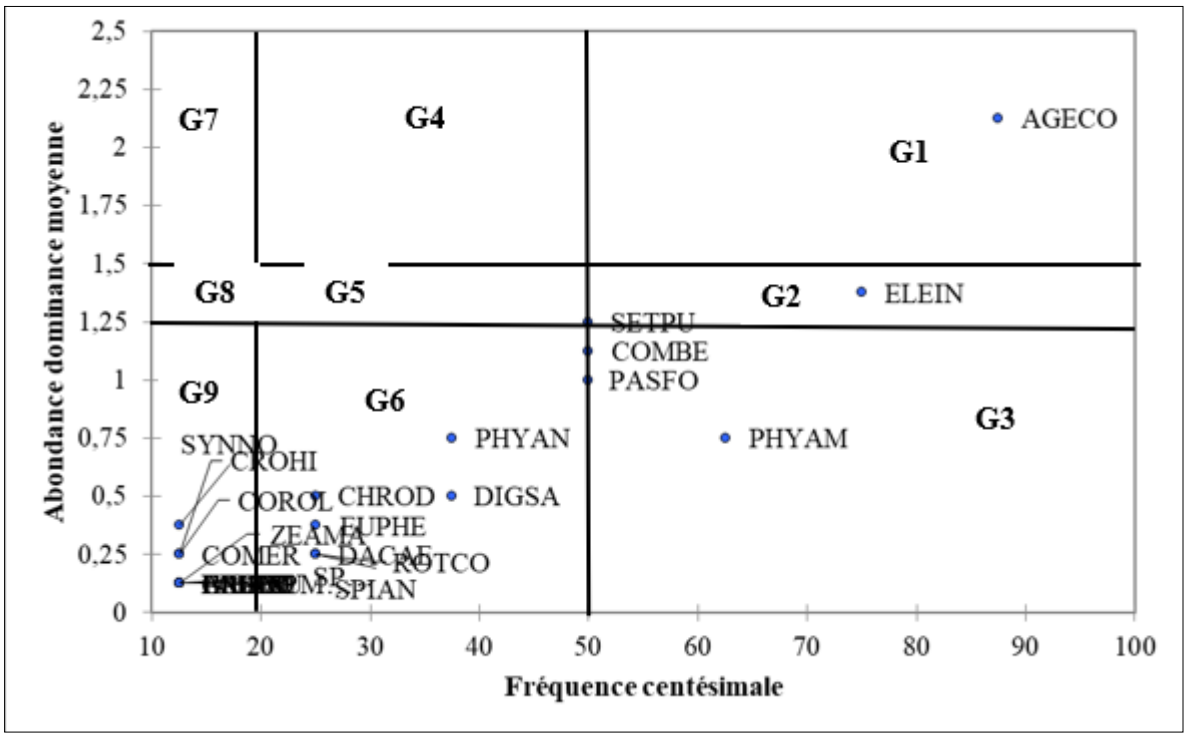

Figure 6 Diagram showing weed infestation after manual weeding of plots

4. Discussion

The survey conducted among rice producers identified 22 species of problematic weeds belonging to eight families, with a strong dominance of Poaceae. The strong dominance of Poaceae in the flora of problematic weeds could be explained not only by their strong ability to colonize disturbed environments, their ability to produce large quantities of seeds, and the presence of underground organs (tubers, rhizomes, etc.) capable of enhancing resistance to bush fires and shallow plowing, thereby ensuring the species' survival (Merlier and Montégut, 1982; Akobundu and Agyakwa, 1989; Johnson, 1997) [20]; [21]; [22]. Almost all producers plow their fields. However, when plowing is done poorly, it can cause these weeds to proliferate. Our findings on the high proportion of Poaceae in rice cultivation were reported by Johnson (1997) [22]. Therophytes (63.64%) and herbaceous plants (81.82%) are the two predominant biomorphological types. The high proportion of therophytes has been noted in several studies in Côte d'Ivoire. Examples include those carried out by Ipou (2005) [16] in the cotton-growing area in northern Côte d'Ivoire and those by Kouamé et al. (2011) [23] in rice cultivation in central Côte d'Ivoire. The remarkable proportions of therophytes and herbaceous plants are justified by the fact that they are pioneer species when an environment is anthropized, and the study was conducted in the north-central part of Côte d'Ivoire (Guillaumet and Adjanohoun, 1971) [24]. Eight restrictive weeds are the most frequently cited. Among these, *Ageratum conyzoides, Rottboellia cochinchinensis, Commelina benghalensis,* and *Imperata cylindrica* have been cited in several studies as recurring and/or problematic (Kouakou, 2016, and Yapi, 2017) [25] [26].

In terms of the effects of the two weeding methods on the dynamics and agronomic importance of weeds, the study revealed a significant reduction in the number of weed species after weeding operations. Indeed, when weeding is carried out properly, it results in a reduction in the flora. The decrease in the average abundance and dominance of major weeds would justify the effectiveness of weeding methods. However, certain species such as *Setaria pumila* and *Physalis angulata* maintain high average abundance and dominance value. This can be explained by the resistance of these species to treatment. The infestation diagrams show that species classified as major weeds (G1) decrease significantly after weeding. In the case of chemical treatment alone, the reduction from 6 to 4 species in the G1 group demonstrates relative effectiveness, while in the case of mixed weeding, only one species remains, highlighting the increased effectiveness of combined weeding. These results corroborate those of Sylla et al (2017) [27] in Daloa, who assert that combining manual and chemical techniques allows for better weed control and improves the agronomic parameters of rice. In addition, the flora of the rice fields visited is heavily dominated by the Poaceae family, which is also the family of rice.

5. Conclusion

This study conducted in the department of Niakaramandougou has provided in-depth knowledge of the flora of problematic weeds. The Poaceae family is the botanical family containing the most species. The species identified belong mainly to the group of therophytes and herbaceous plants. Species such as *Rottboellia cochinchinensis* and *Setaria pumila* are the most problematic species in all the villages surveyed. The weed flora has decreased considerably thanks to the management techniques used. Species belonging to the Poaceae family could not be effectively controlled, unlike broad-leaved dicotyledons, with the herbicides used by producers.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict-of-interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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