Phytosociological Study of Weeds in Maize Crop Area in Nampula City, Mozambique

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Abstract:
The presence of weeds in cultivated areas significantly interferes with agricultural productivity, causing considerable economic losses. This study aimed to identify the weed community associated with maize cultivation through a phytosociological survey, carried out in a maize cultivation area, in the city of Nampula. There were analyzed the number of individuals, absolute and relative frequency, absolute and relative density, abundance, and the importance value index (IVI). A total of 1,797 individuals were identified, distributed in 14 families and 28 species, with greater emphasis on Poaceae and Amaranthaceae families. The most important species were Cyperus rotundus and Eleusine indica.

Keywords: Phytosociology, Weeds, Maize cultivation.

INTRODUCTION

Cereals are the cornerstone of our global diet, playing a fundamental role in food security. Among these, maize (Zea mays L.) is one of the most significant cereal crops, with an estimated cultivated area of approximately 150 million hectares and an average productivity of 5 tons per hectare. The United States leads global maize production, followed by China, Brazil, Argentina, and India (FAOSTAT, 2019).

In Mozambique, maize is vital for the income and livelihood of rural families, particularly on small and medium-sized farms that operate under rain-fed conditions. These farms account for approximately 99% of agricultural units and occupy over 95% of the country's cultivated area (Mosca, 2017; Rosário, 2019; Sousa et al., 2016). However, maize cultivation faces significant challenges, particularly the emergence of weed populations.

Factors contributing to weed proliferation include planting density and inadequate crop arrangement, which negatively affect competitive relationships for essential resources such as water and nutrients (LeQuia et al., 2020; Rai et al., 2020). In this context, phytosociological studies serve as valuable tools for ecological assessment. According to consensus et al. (2013), these studies encompass methods that provide a comprehensive view of the composition and distribution of species within a plant community. Guglieri-Caporal et al. (2010) highlight the importance of these methods in describing plant species present in an area, underscoring their critical role in weed science.

Despite their relevance, progress in phytosociological studies in Mozambique remains limited, with a notable scarcity of publications from various research institutions. A primary factor contributing to this gap is the low number of researchers specializing in this field. Cruz et al. (2009) emphasize the importance of identifying weed species, as each species can establish itself in a given area, with varying levels of aggressiveness that impact crops differently. The authors also point out that phytosociological indices are essential for analyzing the effects of management systems and agricultural practices on the growth dynamics of weed communities.

Phytosociological studies enable the assessment of cover crop species composition, yielding data on metrics such as frequency, relative frequency, density, relative density, abundance, relative abundance, and the importance value index. These metrics are vital for inferring information about the community in question (Gomes et al., 2010). From an agronomic perspective, understanding species diversity is crucial for comprehending the dynamics of weeds in relation to crops across different growing seasons. However, such information is often lacking in producing regions (Albuquerque et al., 2012).

Identifying weed species is critical, as the damage caused by competition depends on the specific species involved, their population density, and their developmental stage. Furthermore, weed communities can exhibit varying floristic compositions depending on the type and intensity of crop treatments. Therefore, it is essential to identify the species present and invest in methods that enhance our understanding of these communities (Nordi & Landgraf, 2009).

The hypothesis of this research is that the composition of weed species varies according to the agricultural practices adopted and the growing season. Thus, the objective of this study is to assess the dynamics of weeds in maize crops throughout the growing season.

MATERIAL AND METHODS

This research was conducted in August 2024 in a maize production field located in Muhala village, Nampula city (15°14'865.6"S and 39°31'695.3"E). The climate is classified as tropical Aw, with a rainy season from November to April and a dry season from May to October, according to the Köppen classification. The average annual temperature ranges between 23°C and 27°C, while annual precipitation varies from 800 to 1,200 mm. The area studied was 5,000 m² (0.5 ha) with sandy loam soil, exhibiting the following chemical characteristics: pH (H_2O) = 5.25, P = 55 mg dm^{-3}, K^+ = 70 mg dm^{-3}, Ca^{2+} = 1.5 cmolc dm^{-3}, Mg = 1.2 cmolc dm^{-3}, H + Al = 4.3 cmolc dm^{-3}, V(%) = 39.1, and organic matter (OM) = 13.2 g dm^{-3}. This area has been utilized for various agricultural crops for over five years, during which a high diversity of weeds has been observed. To manage these weeds, the producer predominantly employed hand weeding with a hoe, creating an environment conducive to maize growth.

The weed community survey was conducted using the 1.0 m² inventory square method, with samples randomly placed in a zigzag pattern, resulting in a total of 30 samples. After placement, the material was pressed into the soil to facilitate collection and subsequently sent to the Biology Laboratory of Rovuma University – Napipine Campus, located 5 km from the sampling site. Botanical identification was carried out at the family, genus, and species levels, based on the APG II classification system (2003), supplemented by the works of Souza and Lorenzi (2005) and Lorenzi (2014).

Once identification was complete, the samples were dried in an oven with air circulation at 65 °C for 72 hours for subsequent determination of dry matter using a precision electronic scale (0.0001 g). Based on the species count and dry matter determination, the average species data were calculated for the phytosociological evaluations of the emerging flora. The absolute and relative frequency, absolute and relative density, relative abundance, and the importance value index were estimated. The classification adopted was based on the Angiosperm Phylogeny Group III system (2009), with assistance in family delimitations according to Lorenzi (2008) and Lorenzi (2014).

RESULTS AND DISCUSSION

In the present phytosociological study, a total of 1,797 individuals were identified, distributed among 14 botanical families and 28 weed species. The families Poaceae and Amaranthaceae were particularly notable, comprising seven (7) species (25%) and four (4) species (14.3%), respectively, which together accounted for 39.3% of the observed diversity (**Table 1**). The Solanaceae family presented three (3) species (10.71%), while Asteraceae, Commelinaceae, and Euphorbiaceae were each represented by two (2) species (7% each). The remaining families contributed one (1) species (3.6%) each to the total identified species.

The observed results can be attributed to several ecological and agronomic factors. The predominance of the Poaceae family suggests that these species are highly adaptable to the conditions of maize cultivation, further supported by agricultural practices that create an environment conducive to their proliferation. Additionally, the significant presence of Amaranthaceae indicates the resilience of these weeds to control methods, complicating crop management. This species diversity reflects the complexity of the agricultural ecosystem, where the interaction between weeds and crops leads to intense competition for resources such as light, water, and nutrients.

These findings corroborate research by Aviles et al. (2024), who evaluated weed communities in maize crops in Mocache, Balzar, and Ventanas, noting that the Poaceae family was the most abundant across all three locations, with Mocache exhibiting the highest number of individuals. Similarly, Pusparani et al. (2022) highlighted field infestations involving six distinct families of 15 different weed species, with Asteraceae and Poaceae emerging as the most dominant.

Furthermore, research by Takim et al. (2023), which examined the diversity and composition of weed species in a maize field treated with pre-emergent herbicides, also observed the predominance of the Poaceae family, followed by Fabaceae and Cyperaceae. Ndam et al. (2014) noted that the Asteraceae family represented 15% of the weed flora in maize cultivation, followed by Poaceae (8%) and Amaranthaceae (6%).

These comparisons underscore that the families identified with the highest occurrence in this study are common in other agricultural regions. For instance, in cassava cultivation, Horácio et al. (2024) reported that the Asteraceae family comprised 22% of the identified species, along with Poaceae (19%), Amaranthaceae (7%), Cyperaceae (7%), and Euphorbiaceae (7%), totaling 62% of the total species identified in the cultivated area. Costa et al. (2019) found that the Poaceae family represented 27% of the total species in papaya cultivation, followed by Asteraceae at 19% and Amaranthaceae at 8%. In a grain sorghum cultivation area, Custódio et al. (2019) observed that 39% of the species belonged to the Poaceae family, while 22% were from the Asteraceae family.

The high incidence of species in these families can partially be attributed to their substantial diaspore production, which facilitates their dissemination across diverse environments, making them influential species in the study area (Caetano et al., 2018). This high dispersal capacity is believed to be related to the small size of the seeds produced by these plants, averaging 0.8 mm in length (Xavier et al., 2019). Understanding the relationship between seed morphology and dispersal capacity is crucial for comprehending the dynamics of weed communities and their management in agricultural systems.

Table 1. Botanical families and weed species found in the maize growing area.

Family	**Species**
Amaranthaceae	Amaranthus deflexus
	Amaranthus spinosus
	Amaranthus hybridus
	Amaranthus retroflexus
Asteraceae	Blainvillea dichotoma
	Bidens pilosa
Commelinaceae	Murdannia nudiflora
	Commelina benghalensis
Cyperaceae	Cyperus rotundus
Euphorbiaceae	Euphorbia heterophylla
	Ricinus communis
Fabaceae	Senna obtusifolia
Malvaceae	Sida rhombifolia
Poaceae	Rottboellia cochinchinensis
	Echinocholoa crus-galli
	Eragrostis pilosa
	Eleusine indica
	Echinochloa colonum
	Urochloa decumbens
	Cenchrus echinatus
Papaveraceae	Argemone mexicana
Portulacaceae	Portulaca oleracea
Phyllanthaceae	Phyllanthus tenellus
Polygonaceae	Polygonum persicaria
Rubiaceae	Richardia brasiliensis
Solanaceae	Physalis angulata
	Solanum americanum
	Nicandra physalodes

The species with the highest incidence in this study was Cyperus rotundus, with 389 individuals recorded, yielding a relative frequency (Fr) of 16.59%, relative density (Dr) of 21.58%, relative abundance (Ar) of 6.20%, and an importance value index (IVI) of 44.37%. Following closely, Eleusine indica was observed with 266 individuals, demonstrating a relative frequency of 8.03%, relative density of 14.75%, and an IVI of 31.55%, indicating higher values compared to other surveyed species (**Table 2**).
Other notable species included Echinochloa colona with 145 individuals and an IVI of 22.03%; Blainvillea dichotoma with 139 individuals and an IVI of 21.28%; Bidens pilosa with 122 individuals and an IVI of 18.29%; Cenchrus echinatus with 120 individuals and an IVI of 19.76%; Portulaca oleracea with 115 individuals and an IVI of 19.54%; Amaranthus spinosus with 108 individuals and an IVI of 16.86%; and Solanum americanum with 85 individuals and an IVI of 14.26% (**Table 2**). The remaining species identified had fewer than 50 individuals.

According to Jagadish and Prashant (2016), the weed flora associated with maize comprises a diverse array of plant species, ranging from grasses to broadleaf weeds and sedges, which can significantly reduce yields by 18% to 85%. Pusparani et al. (2022) observed a greater infestation of Eleusine indica, Ageratum houstonianum, Cressocephalum crepidiodes, and Bidens alba when evaluating weed diversity and phytosociology in maize. Takim et al. (2023) reported the predominance of fifteen weed species, highlighting Richardia scabra, Digitaria horizontalis, and Digitaria sanguinalis. This indicates that low representation in the number of species within a family does not necessarily reflect diminished ecological relevance.

This concept is exemplified by Cyperus rotundus and Portulaca oleracea, which, despite being the only representatives of the Cyperaceae and Portulacaceae families, respectively, ranked as the first and seventh species with the highest IVI values in the studied area. The Cyperaceae family consists of herbaceous, generally perennial plants characterized by triangular stems and linear leaves. Their small, petalless flowers are grouped in spikelets, and they reproduce by both seeds and underground structures such as rhizomes and tubers. This adaptability makes Cyperus rotundus highly invasive in agricultural settings and challenging to control.

Albuquerque et al. (2010) reported similar findings when evaluating weed occurrence after maize cultivation in the Amazonian savanna, identifying Cyperus rotundus (233 individuals) and Eleusine indica (13 individuals) as the only species present in all collections. Rocha dos Santos et al. (2019), in their study of weed communities in organic green corn cultivation intercropped with legumes and coffee husks, also identified Cyperus rotundus as the weed of greatest relative importance. Salaudeen et al. (2022) confirmed that Cyperus rotundus had the highest IVI (38.6%) in maize-growing areas in Nigeria, followed by Portulaca oleracea, reaffirming its dominant behavior in tropical crops.

According to Carvalho and Almeida (2020), the Importance Value Index (IVI) reveals the impact of a plant species on agricultural production systems, considering density, frequency, and dominance. In phytosociological surveys, the IVI serves to highlight the most significant species, enhancing our understanding of vegetation composition and dynamics. The predominance of Cyperus rotundus and Eleusine indica indicates their strong competitive ability for essential resources, which can negatively affect maize growth.

The coexistence of Cyperus rotundus and Eleusine indica in maize crops reflects a high pressure from invasive plants that compete intensely for resources such as water, nutrients, and light. This association can significantly reduce crop productivity, necessitating integrated management strategies to control both species and minimize agricultural losses.

Table 2. Number of individuals (NI), frequency (F), Relative frequency (RF), Density (D), Relative density (RD), Abundance and Relative abundance (A and RA) and Importance Value Index (IVI), of a weed population found in the maize growing land.

Species	NI	F	RF (%)	D	RD (%)	A	RA (%)	IVI (%)
Amaranthus deflexus	36	0.20	3.21	1.20	2.00	6.00	2.97	8.18
Amaranthus spinosus	108	0.40	6.42	3.60	5.99	9.00	4.45	16.86
Amaranthus retroflexus	16	0.13	2.14	0.53	0.89	4.00	1.98	5.01
Amaranthus hybridus	48	0.13	2.14	1.60	2.66	12:00	5.93	10.73
Argemone mexicana	1	0.03	0.54	0.03	0.06	1.00	0.49	1.08

Bidens pilosa	122	0.30	4.82	4.07	6.77	13.56	6.70	18.29
Blainvillea dichotoma	139	0.23	3.75	4.63	7.71	19.86	9.82	21.28
Cenchrus echinatus	120	0.20	3.21	4.00	6.66	20.00	9.89	19.76
Commelina benghalensis	3	0.03	0.54	0.10	0.17	3.00	1.48	2.19
Cyperus rotundus	389	1.03	16.59	12.97	21.58	12.55	6.20	44.37
Echinochloa colonum	145	0.23	3.75	4.83	8.04	20.71	10.24	22.03
Eragrostis pilosa	41	0.30	4.82	1.37	2.27	4.56	2.25	9.34
Eleusine indica	266	0.50	8.03	8.87	14.75	17.73	8.77	31.55
Euphorbia heterophylla	2	0.03	0.54	0.07	0.11	2.00	0.99	1.64
Echinocholoa crus-galli	1	0.03	0.54	0.03	0.06	1.00	0.49	1.09
Murdannia nudiflora	2	0.03	0.54	0.07	0.11	2.00	0.99	1.64
Nicandra physalodes	24	0.17	2.68	0.80	1.33	4.80	2.37	6.38
Portulaca oleracea	115	0.63	10.17	3.83	6.38	6.05	2.99	19.54
Physalis angulata	17	0.17	2.68	0.57	0.94	3.40	1.68	5.30
Phyllanthus tenellus	31	0.13	2.14	1.03	1.72	7.75	3.83	7.69
Polygonum persicaria	2	0.03	0.54	0.07	0.11	2.00	0.99	1.64
Rottboellia cochinchinensis	37	0.33	5.35	1.23	2.05	3.70	1.83	9.23
Richardia brasiliensis	9	0.17	2.68	0.30	0.50	1.80	0.89	4.07
Ricinus communis	4	0.10	1.61	0.13	0.22	1.33	0.66	2.49
Solanum americanum	85	0.33	5.35	2.83	4.71	8.50	4.20	14.26
Senna obtusifolia	4	0.13	2.14	0.13	0.22	1.00	0.49	2.85
Sida rhombifolia	4	0.10	1.61	0.13	0.22	1.33	0.66	2.49
Urochloa decumbens	32	0.10	1.61	1.07	1.77	10.67	5.27	8.65
TOTAL	1797	6.23	100.00	60.10	100.00	202.30	100.00	300.00

CONCLUSIONS

The phytosociological survey identified 28 weed species across 14 botanical families in the corn-growing area, with Amarantaceae and Poaceae being the most prevalent. Cyperus rotundus and Eleusine indica showed the highest importance value indices (IVI), indicating strong aggressiveness and adaptability. This diverse weed flora poses a significant competitive threat to corn yields, especially without effective management practices. Additionally, species like Portulaca oleracea and Bidens pilosa, while less abundant, demonstrated considerable ecological importance.

REFERENCES

1. Albuquerque JAA, Melo VF, Siqueira RHS, Martins SA, Finoto EL, Sediyama T, Silva AA, Ocorrência de plantas daninhas após cultivo de milho na savana amazônica, Planta Daninha, dez 2012, 30(4), 775–782, https://doi.org/10.1590/S0100-83582012000400017.
2. Angiosperm Phylogeny Group, An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III, Botanical Journal of the Linnean Society, abr 2009, 161(2), 105–121, https://doi.org/10.1111/j.1095-8339.2009.00996.x.

3. Aviles DFV, Toledo CRB, Sanchez SVB, Herrera-Feijoo RJ, Chicaiza-Ortiz CD, Guamán-Rivera SA, Phytosociological study of weed communities in Zea mays cultivation: Contributions to sustainable development goals (SDGs) in the Ecuadorian tropics, Journal of Life Style & SDGs Review, 2024, 4, e02044, 01–21.
4. Caetano APO, Nunes RTC, Rampazzo MC, Silva GL, Soares MRS, São José AR, Moreira ES, Levantamento fitossociológico na cultura da soja em Luís Eduardo Magalhães/BA, Scientia Agraria Paranaensis, set 2018, 17(3), 359–367.
5. Canuto RSO, Canuto DMF, Oliveira LS, Jacobi NMNS, Ribeiro Neto JC, Levantamento fitossociológico de plantas daninhas em área de produção de café catuaí amarelo, Revista Inova Ciência & Tecnologia, 2020, 6(1), 18–23.
6. Carvalho FT, Almeida RG, Índice de valor de importância na avaliação de comunidades vegetais: Aplicações e limitações, Revista Brasileira de Botânica Aplicada, 2020, 4(2), 101–110.
7. Concenço G, Tomazi M, Correia IVT, Santos SA, Galon L, Phytosociological surveys: Tools for weed science?, Planta Daninha, 2013, 31(2), 469–482, https://doi.org/10.1590/S0100-83582013000200027.
8. Costa RN, Ribeiro Silva DM, Rocha AO, Silva Lima AN, Camilo dos Santos JCC, Santos Silva LK, Acchile S, Levantamento fitossociológico de plantas daninhas em área de produção de mamão, Revista Científica Rural, 2019, 21(3), 183–193.
9. Cruz DLS, Rodrigues GS, Dias FO, Alves JMA, Albuquerque JAA, Levantamento de plantas daninhas em área rotacionada com as culturas da soja, milho e arroz irrigado no cerrado de Roraima, Revista Agro@mbiente, 2009, 3(1), 58–63, https://doi.org/10.18227/1982-8470ragro.v3i1.227.
10. Custódio IG, Karam D, Borges ID, Levantamento fitossociológico de plantas daninhas na cultura do sorgo granífero em função do manejo químico, Revista Brasileira de Milho e Sorgo, 2019, 18(1), 148–157.
11. Erasmo EAL, Silva DV, Ferreira EA, Santos JB, Cecon PR, Levantamento fitossociológico de plantas daninhas na cultura do milho em sistema de plantio direto, Planta Daninha, 2004, 22(4), 627–634, https://doi.org/10.1590/S0100-83582004000400010.
12. FAOSTAT, Agricultural Statistics at a Glance 2019, 2019, p. 141.
13. Gomes GLGCC, Ibrahim FN, Macedo GL, Nobrega LP, Alves E, Cadastramento fitossociológico de plantas daninhas na bananicultura, Planta Daninha, 2010, 28(1), 61–68, https://doi.org/10.1590/S0100-83582010000100007.
14. Guglieri-Caporal A, Caporal FJM, Pott A, Phytosociology of sown pasture weeds under two levels of degradation in Brazilian savanna areas, Mato Grosso do Sul State, Brazil, Pesquisa Agropecuária Tropical, 2010, 40(3), 312–321.
15. Horácio EH, Cabo IBJA, Sousa EC, Gusmão ADRC, Timossi PC, Phytosociological survey of weeds in cassava growth area, African Journal of Agricultural Research, 2024, 20(10), 910–914, https://doi.org/10.5897/AJAR2022.16212.
16. Jagadish S, Prashant CS, A review on weed management on maize (Zea mays L.), Advances in Life Sciences, 2016, 5(9), 3448–3455.
17. Jakelaitis A, Silva AA, Santos JB, Vivian R, Biologia e manejo de Cyperus rotundus L., Planta Daninha, 2003, 21(2), 313–323, https://doi.org/10.1590/S0100-83582003000200017.
18. Kissmann KG, Groth D, Plantas infestantes e nocivas, 2ª ed., Vol. 2, BASF Brasileira.
19. Kuva MA, Pitelli RA, Alves PLC, Marques RP, Levantamento fitossociológico de plantas daninhas em área de produção de cana-de-açúcar no município de Ribeirão Preto-SP, Planta Daninha, 2007,

25(2), 287–294, https://doi.org/10.1590/S0100-83582007000200009.
20. LeQuia KD, Morishita DW, Walsh OS, Adjesiwor AT, Pinto bean response to seeding rate and herbicides, Weed Technology, 2020, 35(4), 628–631, https://doi.org/10.1017/wet.2020.137.
21. Lorenzi H, Plantas daninhas do Brasil: Terrestres, aquáticas, parasitas e tóxicas, 4ª ed., Instituto Plantarum.
22. Lorenzi H, Manual de identificação e controle de plantas daninhas: Plantio direto e convencional, 7ª ed., Instituto Plantarum.
23. Mosca J, Agricultura familiar em Moçambique: ideologias e políticas, Revista Nera, 2017, 20(38), 68–105.
24. Ndam TW, Bang CC, Kamga A, Survey of weed flora in maize (Zea mays L.) farms in the humid forest zone of Cameroon, International Journal of Biological and Chemical Sciences, 2014, 8(6), 2582–2592, https://doi.org/10.4314/ijbcs.v8i6.10.
25. Nordi JC, Landgraf PRC, Composição florística e fitossociologia da comunidade infestante em gramado de Paspalum notatum Flügge, Revista Biociências, 2009, 15(2), 106–114.
26. Pitelli RA, Interferência de plantas daninhas em culturas agrícolas, Informe Agropecuário, 1985, 11(129), 16–27.
27. Pusparani N, Ram V, Panda S, John C, Studies on weed diversity and phytosociology in maize crop, Indian Journal of Hill Farming, 2022, 35(2), 6–12.
28. Rai A, Sharma V, Heitholt J, Dry bean (Phaseolus vulgaris L.) growth and yield response to variable irrigation in the arid to semi-arid climate, Sustainability, 2020, 12(9), 3851, https://doi.org/10.3390/su12093851.
29. Rocha dos Santos T, Galvão JCC, Giehl J, Coelho SP, Campos SA, Mendonça BF, Weed communities in organic cultivation of green corn intercropped with legumes and coffee husk, Revista Facultad Nacional de Agronomía Medellín, 2029, 72(2).
30. Rosário NM, Agronegócio em Moçambique: uma breve análise da situação de estrangerização do agronegócio, Sociedade e Território, 2019, 31(1), 183–200, https://doi.org/10.21680/2177-8396.2019v31n1ID12862.
31. Salaudeen MT, Sulaiman AH, Olaniyan MA, Adebayo BC, Weed flora and dynamics in maize cropping systems in Nigeria, Journal of Agricultural Sciences, 2022, 67(1), 77–88, https://doi.org/10.2298/JAS2201077S.
32. Sousa W, Ducrot R, Munguambe P, Bjornlund H, Machava A, Cheveia E, Faduco J, Irrigation and crop diversification in the 25 de September irrigation scheme, Mozambique, International Journal of Water Resources Development, 2016, https://doi.org/10.1080/07900627.2016.1262246.
33. Takim FO, Lawal AA, Olatunji D, Weed flora composition in maize (Zea mays L.) field under different pre-emergence herbicides in Nigeria, African Journal of Plant Science, 2023, 17(1), 18–27.
34. Xavier TMT, Silva DV, Ferreira EA, Características das sementes de plantas daninhas e sua influência na dispersão, Planta Daninha, 2019, 37, e019191256.