Abuja Journal of Agriculture and Environment (AJAE ISSN (2736-1160) | Vol. 6 No 1, 2026 Website: https//www.ajae.ng Hussein, (2026)

IMPACT OF DIFFERENTIAL MANAGEMENT STRATEGIES ON WEED COMPOSITION, DYNAMICS AND DOMINANCE IN LOWLAND RICE (ORYZA SATIVA L.)

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ABSTRACT
Weed infestation remains a major constraint to productivity and sustainability in lowland rice ecosystems. This study evaluated the effects of rice variety, weed management strategy, and fertilizer regime on weed community composition during the 2023 and 2024 cropping seasons at the University of Abuja, Nigeria. The experiment was arranged in a split–split plot design with three rice varieties (FARO 44, FARO 57, FARO 60), four weed management strategies (standard herbicide rate, reduced herbicide rate, manual weeding, and no weeding), and three fertilizer regimes (organic, inorganic, and no fertilizer). Weed sampling was conducted at 4, 8, and 12 weeks after sowing using a 0.5 m × 0.5 m quadrat. Weed species were identified and classified by family and growth form. 35 weed species from 15 families were recorded in 2023, while 38 species from 16 families were identified in 2024, indicating increased diversity. Cyperaceae and Poaceae were dominant across years. Standard herbicide application resulted in the lowest weed density, while reduced herbicide rates and manual weeding altered species composition but allowed persistence of perennial weeds. Unweeded plots recorded the highest weed diversity. The findings underscore the importance of integrated weed management for sustainable lowland rice production.

Keywords: *Biodiversity conservation, herbicide rate, integrated management, organic fertilizer, weed flora*

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereal crops globally, providing a staple food for more than half of the world's population and serving as a major source of income for millions of smallholder farmers (Birla *et al*., 2017; Alabi *et al*., 2023; Asma *et al*., 2023). In lowland rice ecosystems, weed infestation remains one of the most persistent biotic constraints to productivity (Fahad *et al*., 2019). Weeds compete directly with rice for nutrients, water, light, and space, leading to substantial yield losses that may range from 15% to 90%, depending on the intensity of infestation and the management practices adopted (Dass *et al*., 2017; Kaur *et al*., 2018). Beyond yield reduction, weeds also hinder harvesting operations and act as alternate hosts for pests and diseases, further affecting rice quality and economic returns (Kumar *et al*., 2017).

Weed flora composition and dynamics in rice fields are influenced by a complex interaction of environmental factors and management practices (Hussein *et al*., 2025). The major among these are weed control methods, fertilizer type, cropping intensity, and hydrological conditions (Jiang *et al*., 2024). Continuous dependence on a single management approach particularly repeated herbicide application has been shown to alter weed community structure, encouraging shifts toward tolerant or resistant species (Beckie *et* *al*., 2019; Ofosu *et al*., 2023). Such shifts not only reduce herbicide effectiveness but also threaten the sustainability of rice production systems (Nath *et al*., 2024). Integrating different weed management methods, such as herbicide use combined with manual weeding or cultural practices, can mitigate these effects by targeting weeds with diverse life cycles and ecological niches (Scavo & Mauromicale, 2020; Monteiro & Santos, 2022).

Fertilizer management also plays a significant role in shaping weed communities in lowland rice systems (Jiang *et al*., 2024). The application of mineral fertilizers such as NPK often enhances the growth of nutrient-demanding weed species alongside the crop, thereby intensifying competition (Dass *et al*., 2017). In contrast, organic manure applications improve soil physical and biological properties, leading to slower nutrient release and sometimes modifying weed emergence patterns (Kaur *et al*., 2018; Yan *et al*., 2025). The interaction between fertilizer type and weed management strategy can therefore influence the relative dominance, diversity, and succession of weed species in rice ecosystems (Hussein *et al.,* 2024). Understanding these interactions is critical for designing integrated management systems that optimize crop performance while maintaining ecological balance (Kaur *et al*., 2018).

In lowland rice fields, fluctuating water regimes also contribute to weed population dynamics (Vu & Phan, 2025). Flooding conditions typically suppress the growth of many upland weed species, while promoting the proliferation of aquatic and semi-aquatic weeds such as *Echinochloa crus-galli*, *Cyperus difformis*, and *Fimbristylis miliacea* ((Liu *et al*., 2016; Roy*, et al*., 2022). The interaction between water level, fertilizer source, and weed control method creates a dynamic environment that influences weed seed germination, establishment, and persistence over time (Kaur *et al*., 2018; Travlos *et al*. 2020).

Therefore, understanding how combinations of weed control methods and fertilizer types affect weed flora composition and dynamics is essential for developing ecologically sound and sustainable weed management programs. Such knowledge provides insights into species adaptation, community succession, and long-term ecosystem resilience under different management regimes.

This study was thus undertaken to assess the composition, abundance, and dynamics of weed flora in lowland rice (*Oryza sativa* L.) ecosystems under variable management strategies, combining weed control methods (herbicide, manual weeding, integrated, and control) with fertilizer types (NPK, organic manure, and no fertilizer). The findings will contribute to a better understanding of weed ecology in managed rice systems and support the formulation of integrated weed management strategies that enhance productivity while promoting environmental sustainability.

Materials and Methods

Study Site

This study was conducted at the Teaching and Research Farm of the Faculty of Agriculture, University of Abuja, Nigeria. The experimental site lies between latitudes 8°58′0″N and 8°59′30″N and longitudes 7°9′30″E and 7°11′0″E, based on the World Geodetic System (WGS) 1984 (Kumar, 1988). The area falls within the tropical savanna climatic zone, characterized by two distinct seasons: a wet season from April to October and a dry season from November to March. The site elevation varies between 300 and 500 meters above sea level. The region receives an average annual rainfall of approximately 1,200–1,500 mm, while mean wet-season temperatures range from 22°C to 30°C (Adenaiye *et al*., 2021; NiMet, 2021).

Experimental Design

A field experiment was conducted during the 2023 and 2024 cropping seasons. Split–split plot factorial design was employed to investigate the combined effects of rice variety, weed control strategy, and fertilizer type on weed flora dynamics. The experimental layout consisted of a 3 × 4 × 3 factorial arrangement.

Three upland rice varieties (FARO 44, FARO 57, and FARO 60) were allocated to the main plots. Four weed management approaches were applied to the subplots: M_1 – standard herbicide rate (500 mL ha^{-1} of Agriforce), M_2 – reduced herbicide rate (300 mL ha^{-1}), M_3 – manual weeding with hand and hoe, and M_4 – no weeding (control). Each subplot was further divided into three sub-subplots based on fertilizer treatments: organic fertilizer (F_1) (HELIN-1 FARM), inorganic NPK (15:15:15) (F_2), and no fertilizer (F_3) (control). All treatment combinations were replicated three times, giving a total of 108 experimental units per cropping season. Individual plots measured 1 m × 1 m, separated by 0.5 m alleys between subplots and 1 m spacing between replications to prevent treatment interference.

Weed Management Implementation

Herbicide treatments were applied at 4, 8 and 12 weeks after sowing using a hand sprayer calibrated to deliver a uniform spray volume. Manual weeding was carried out at 4, 8 and 12 weeks after sowing, using hand and hoe to remove all emerged weeds within the plots. No-weeding plots (control) were left undisturbed throughout the growing season to allow natural weed growth. These management practices were maintained consistently across both cropping seasons.

Data Collection

Weed sampling was carried out at 4, 8, and 12 weeks after sowing (WAS) using a 0.5 m × 0.5 m quadrat. All weeds enclosed within the quadrat were carefully uprooted, counted, and identified following standard botanical identification keys (Akobundu et al. 2016; FHI, 2024). Identified species were grouped according to their taxonomic families and growth habits (annual, perennial, or mixed). Recorded data included weed density, relative abundance, and species richness. Data were analyzed using PAST v5.1.0. ANOVA determined differences among treatments, and means were separated at $p \leq 0.05$ using standard error (SE).

Results and Discussion

Weed Species Composition and Diversity

A total of 35 weed species belonging to 15 families were recorded in 2023 (Table 1), while 38 species from 16 families were identified in 2024 (Table 2). This increase in both species' richness and family representation in the second year indicates greater weed diversity and ecological succession within the rice ecosystem. This progressive increase in weed species richness and diversity between 2023 and 2024 reflects the dynamic nature of weed communities in lowland rice ecosystems. According to Chauhan and Johnson (2010), fluctuations in weed flora composition are influenced by changes in management intensity, cropping practices, and hydrological regimes. In 2024, several new species emerged, including *Alternanthera philoxeroides*, *Ludwigia abyssinica*, *L. hyssopifolia*, *Melastomastrum capitatum*, *Nymphaea lotus*, *Panicum laxum*, *Paspalum vaginatum*, and *Pistia stratiotes*. The appearance of these species suggests ecological shifts likely driven by differences in rainfall pattern, soil moisture, or management strategies between seasons. The presence of aquatic and semi-aquatic weeds such as *Pistia stratiotes*, *Eichhornia natans*, and *Nymphaea lotus* further indicates that water stagnation or reduced drainage favored hydrophyte proliferation.

Table 1: Weed floral encountered in lowland field during the experiment in 2023

Species	Family	Growth form
Aeschynomene indica L.	Fabaceae	
Alternanthera sessilis (L.)	Amaranthaceae	Perennial
Azolla pinnata R. Br.	Azollaceae	Annual/perennial
Calopogonium mucunoides Desv.	Fabaceae	Perennial
Clappertonia ficifolia (Willd.) Decne.	Malvaceae	Perennial
Cyperus difformis L.	Cyperaceae	Annual
Cyperus haspan L.	Cyperaceae	Perennial
Cyperus iria L.	Cyperaceae	Annual
Cyperus rotundus L.	Cyperaceae	Perennial
Echinochloa pyramidalis (Lam.)	Poaceae	Perennial
Eclipta alba (L.)	Asteraceae	Annual
Eichhornia natans (P. Beauv.)	Pontederiaceae	Perennial
Eleutheranthera ruduralis (Sw.)	Asteraceae	Annual
Fimbristylis littoralis Gaudich.	Cyperaceae	Annual/perennial
Fuirena umbellata Rottb.	Cyperaceae	Perennial
Heteranthera callifolia Rchb.	Pontederiaceae	Annual
Heterotis rotundifolia (Sm.).	Melastomataceae	Perennial
Hydrolea palustris (Nutt.).	Hydroleaceae	Perennial
*Ipomoea aquatica (*Forssk.)	Convolvulaceae	Perennial
Ischaemum rugosum Salisb.	Poaceae	Annual/perennial
Kyllinga erecta Schumach.	Cyperaceae	Perennial
Leptochloa caerulescens Steud.	Poaceae	Annual
Ludwigia abyssinica A. Rich.	Onagraceae	Perennial
Ludwigia hyssopifolia (G.Don)	Onagraceae	Perennial
Melastomastrum capitatum (Naudin)	Melastomataceae	Perennial
Oryza barthii A. Chev.	Poaceae	Annual
Oryza sativa L.	Poaceae	Annual
Panicum brevifolium Sw.	Poaceae	Annual
Panicum laxum Sw.	Poaceae	Annual/perennial
Paspalum vaginatum Sw.	Poaceae	Perennial
Pentodon pentandrus (Schumach. & Thonn.)	Rubiaceae	Annual
Pistia stratiotes L.	Araceae	Perennial
*Polygonum salicifolium (*Brouss.)	Polygonaceae	Perennial
*Scleria naumanniana (*Boeckeler)	Cyperaceae	Perennial
Spilanthes costata (Hutch. & Dalziel)	Asteraceae	Annual

Table 2: Weed floral encountered in lowland field during the experiment in 2024

Species	Family	Growth form
Aeschynomene indica (L.)	Fabaceae	Annual/perennial
Alternanthera sessilis (L.).	Amaranthaceae	Perennial
Alternanthera philoxeroides (Mart.)	Amaranthaceae	Perennial
Azolla pinnata R. Br.	Azollaceae	Annual/perennial
Calopogonium mucunoides Desv.	Fabaceae	Perennial
Clappertonia ficifolia (Willd.)	Malvaceae	Perennial
Chloris pilosa Schumach.	Poaceae	Annual
Cyperus difformis (L)	Cyperaceae	Annual
Cyperus haspan L.	Cyperaceae	Perennial
Cyperus iria (L.)	Cyperaceae	Annual
Cyperus rotundus (L.)	Cyperaceae	Perennial
Digitaria horizontalis Willd.	Poaceae	Annual/perennial
Echinochloa pyramidalis (Lam.)	Poaceae	Perennial
Eclipta alba (L.)	Asteraceae	Annual
Eichhornia natans (P. Beauv.)	Pontederiaceae	Perennial
Eleutheranthera ruderalis (Sw.)	Asteraceae	Annual
Fimbristylis littoralis Gaudich.	Cyperaceae	Annual/perennial
Fuirena umbellata Rottb.	Cyperaceae	Perennial
Heteranthera callifolia Rchb.	Pontederiaceae	Annual
Heterotis rotundifolia (Sm.)	Melastomataceae	Perennial
Hydrolea palustris (Nutt.)	Hydroleaceae	Perennial
Ipomoea aquatica Forssk.	Convolvulaceae	Perennial
Ischaemum rugosum Salisb.	Poaceae	Annual/perennial
Kyllinga erecta Schumach.	Cyperaceae	Perennial
Leptochloa caerulescens Steud.	Poaceae	Annual
Ludwigia abyssinica A. Rich.	Onagraceae	Perennial
Ludwigia hyssopifolia (G.Don)	Onagraceae	Perennial
Melastomastrum capitatum (Naudin)	Melastomataceae	Perennial
Nymphaea lotus (L.)	Nymphaeaceae	Perennial
Panicum brevifolium Sw.	Poaceae	Annual
Panicum laxum Sw.	Poaceae	Annual/perennial
Paspalum vaginatum Sw.	Poaceae	Perennial
Pentodon pentandrus (Schumach. & Thonn.)	Rubiaceae	Annual
Pistia stratiotes (L.)	Araceae	Perennial
Polygonum salicifolium (Brouss.)	Polygonaceae	Perennial
Sacciolepsis africana C.E. Hubb.	Poaceae	Annual
Scleria naumanniana (Boeckeler)	Cyperaceae	Perennial
Spilanthes costata (Hutch. & Dalziel)	Asteraceae	Annual

Effect of Weed Management Strategies on Weed Flora Composition

Weed density and weed richness increased with crop age across both cropping seasons, with the no-weeding treatment (M4) showing a pronounced rise at 8 and 12 weeks after sowing (Figure 1a, b). This pattern reflects cumulative weed emergence and unrestricted establishment of successive cohorts when control measures are absent, a trend commonly reported in lowland rice systems (Mahajan *et al., 2014*). In contrast, herbicide-based treatments (M1 and M2) maintained consistently low weed density and reduced species richness throughout the growing period, indicating effective early suppression and disruption of weed community development. Similar reductions in weed abundance and diversity following timely herbicide application have been documented in rice-based cropping systems (Chauhan, 2020; McAlpine *et al*., 2018). Manual weeding (M3) resulted in intermediate weed pressure and species richness, likely due to incomplete removal and rapid re-establishment of later-emerging weeds, particularly sedges and grasses (Naruhn *et al*., 2021). Seasonal trends were largely consistent between years, although slightly higher weed density and richness observed in 2024 at later growth stages may be attributed to interannual variation in climatic conditions influencing weed germination and growth (Alagbo *et al*., 2022).

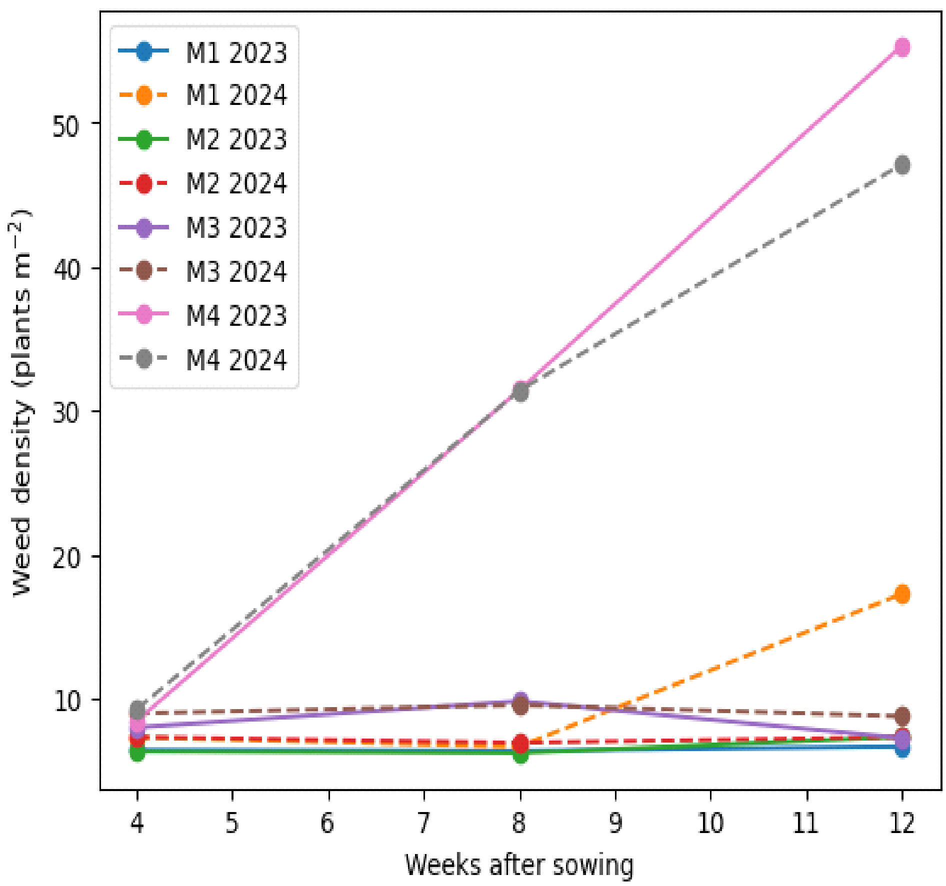

Figure 1a: Weed density under different weed management strategies at 4, 8 and 12 weeks after sowing during the 2023 and 2024 cropping seasons. Solid lines represent 2023, while dashed lines represent 2024.

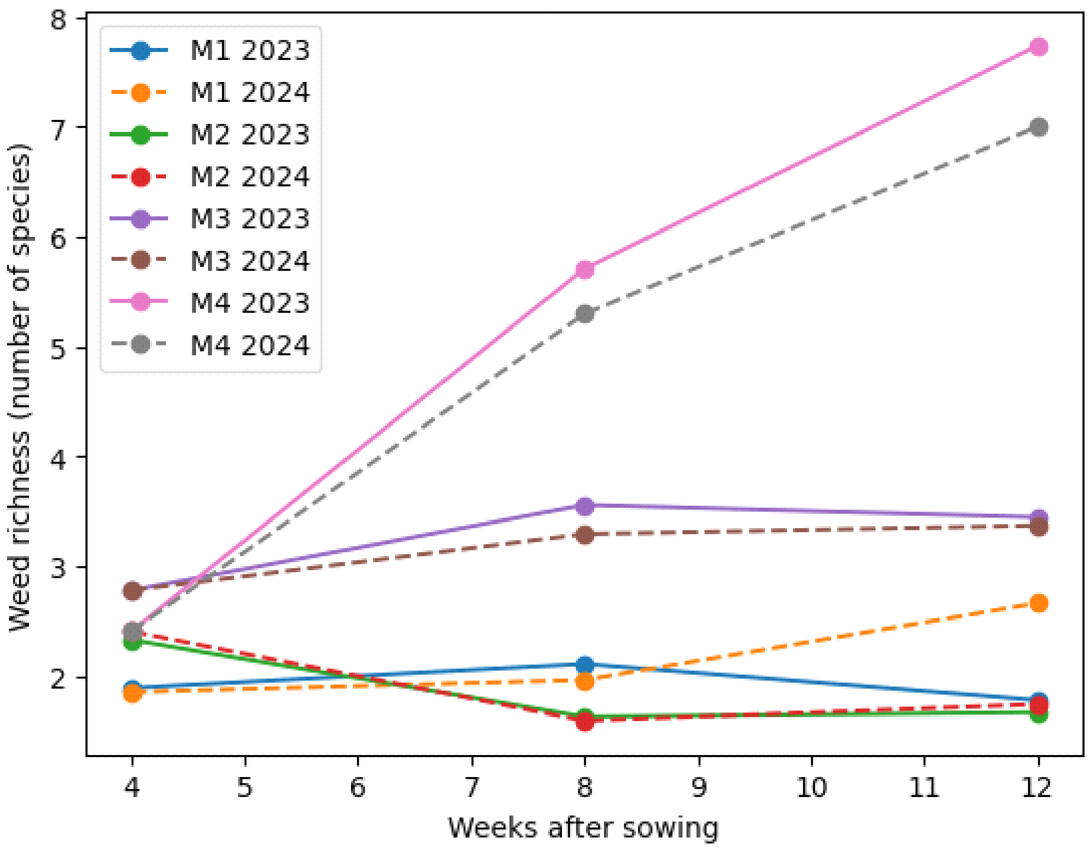

Figure 1b: Weed richness under different weed management strategies at 4, 8 and 12 weeks after sowing during the 2023 and 2024 cropping seasons. Solid lines represent 2023, while dashed lines represent 2024.

Dominant Weed Species

In 2023, the Cyperaceae family was the most represented (Figure 1), with species such as *Cyperus difformis*, *C. haspan*, *C. iria*, *C. rotundus*, *Fimbristylis littoralis*, *Fuirena umbellata*, and *Kyllinga erecta*. This dominance reflects their strong adaptability to wetland environments and their ability to regenerate from underground propagules. The Poaceae family followed closely, featuring perennial grasses such as *Echinochloa pyramidalis*, *Ischaemum rugosum*, and *Leptochloa caerulescens*, which thrive under intermittent flooding and nutrient-rich soils. The dominance of Cyperaceae and Poaceae aligns with previous findings in flooded rice systems across West Africa, where sedges (*Cyperus spp.*, *Fimbristylis spp.*) and grasses (*Echinochloa spp.*, *Ischaemum spp.*) form the core of the weed community (Rodenburg *et al.,* 2011; Hussein *et al.*, 2024). The occurrence of nitrogen-loving species such as *Aeschynomene indica*, *Calopogonium mucunoides*, and *Eclipta alba* suggests nutrient enrichment due to fertilizer application, corroborating the findings of Blackshaw *et al.* (2003); Jabran & Doğan (2020) who reported that increased nitrogen levels promote the proliferation of certain broadleaf weeds. Conversely, species like *Cyperus rotundus* and *Ischaemum rugosum* indicate areas of poor drainage or uneven water distribution, conditions common in lowland rice fields (Tachie-Menson, 2016).

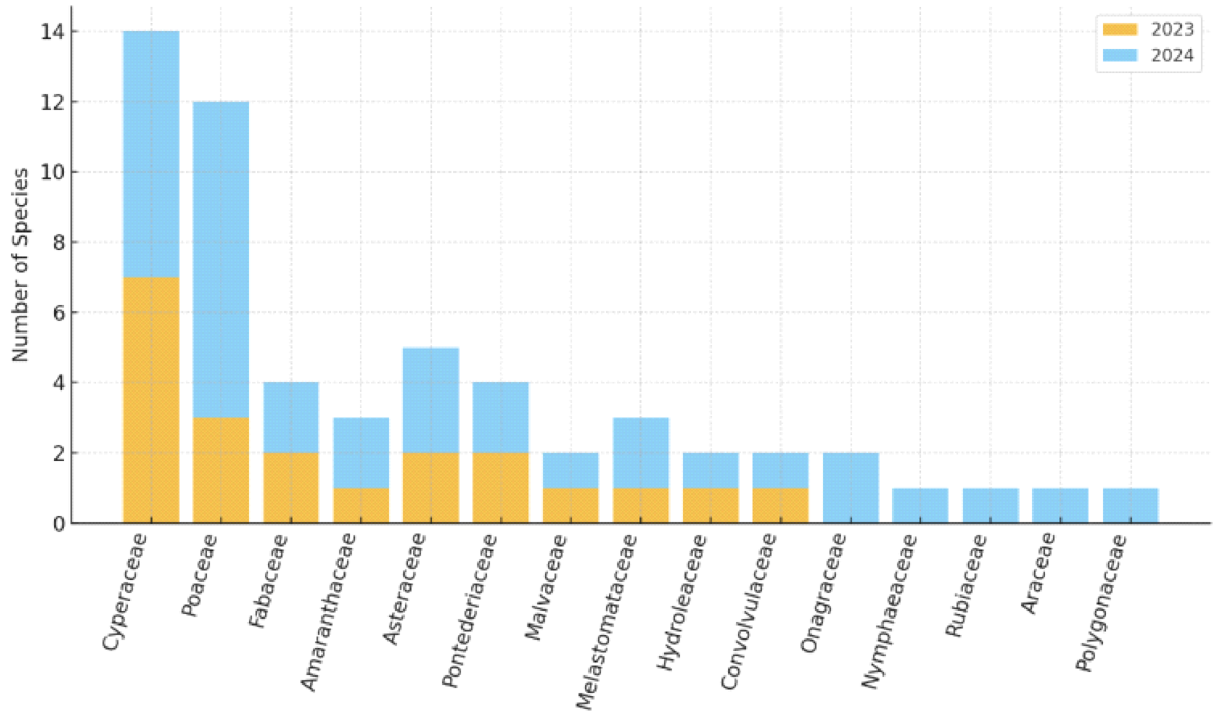

Figure 2: Dominant species across the years

Weed Growth Forms

Growth form analysis revealed that perennial species constituted a larger proportion of the weed flora in both cropping seasons, accounting for 65.7 % of the recorded species in 2023 and increasing slightly to 65.8 % in 2024 (Figure 2). The higher proportion of perennial and aquatic weeds observed in 2024, including *Pistia stratiotes*, *Nymphaea lotus* and *Alternanthera philoxeroides*, may be associated with prolonged soil saturation and reduced mechanical disturbance, conditions that favour species with vegetative propagules capable of surviving adverse periods and rapidly recolonizing fields (*Duary et al., 2016; Zimdahl, 2018; Feledyn-Szewczyk et al., 2020*).

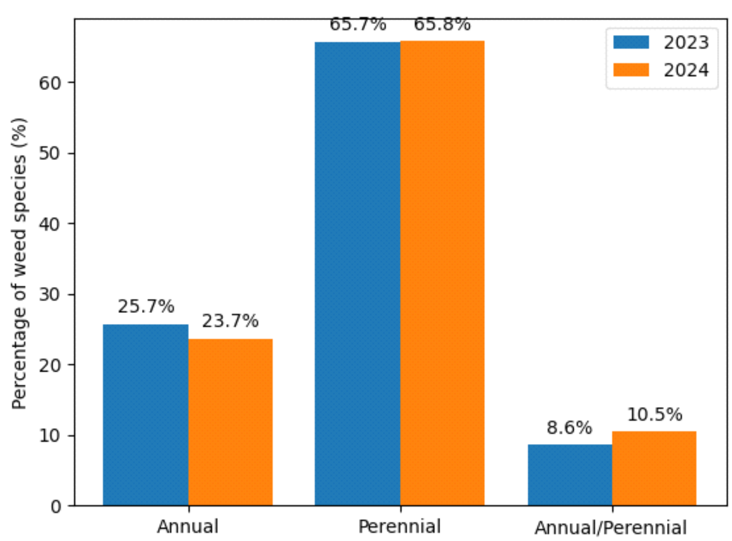

Figure 3: Growth form of weed floral encountered

Conclusion

The study demonstrated that weed flora composition and dynamics in lowland rice ecosystems are strongly influenced by weed management strategy and seasonal conditions. Cyperaceae and Poaceae dominated across both years, reflecting their ecological fitness in flooded environments. Standard herbicide application provided the most effective weed suppression, while reduced herbicide rates achieved weed control nearly comparable to the standard rate and performed better than manual weeding, although both reduced rate and manual weeding approaches altered weed community composition and allowed some perennial weeds to persist. Unweeded plots recorded the highest weed density and diversity, emphasizing the necessity of active weed control.

Integrated weed management approaches that combine optimized herbicide use with complementary control measures are essential for sustainable weed suppression and long-term productivity of lowland rice systems.

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