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Effectiveness of Weed Management Strategies and Fertilizer Types on Weed Dynamics in Upland Rice Field

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Abstract

Rice yield is constrained by weed competition, while fertilizer and weed management practices strongly influence weed dynamics in upland rice fields. The effects of rice variety, weed management, and fertilizer types on weed dynamics were evaluated using a split-split plot design. The experiment was conducted during the 2023 and 2024 cropping seasons with three rice varieties (FARO 55, FARO 56, FARO 59), four weed management (standard herbicide rate, reduced herbicide rate, manual weeding, and control), and three fertilizer types (organic, inorganic, and no fertilizer) across 108 plots. Weed density, height, species richness, cover, dry biomass, and competitive index were assessed at 4, 8, and 12 weeks after sowing. Data collected were analyzed using Statistical Package for the Social Sciences (SPSS) version 27. FARO 59 consistently showed greater weed suppression than FARO 55 and FARO 56, with lower weed density (6.67 plants/m^2), cover (2.77 %), and biomass (0.28 g), attributed to rapid canopy closure and higher crop biomass. Herbicide treatments, especially standard and reduced rates, effectively controlled weeds, while untreated control plots recorded the highest density (80.56 plants/m^2) and biomass (2.72 g). Fertilizer application, particularly organic and inorganic, enhanced crop vigor and improved weed suppression compared to no fertilizer. Integrating FARO 59 with optimized herbicide use and fertilizer application proved most effective for sustainable weed management. The findings demonstrate that rice variety and weed management significantly influenced weed dynamics in upland rice. FARO 59 demonstrated superior weed suppression, while reduced herbicide rates combined with organic or inorganic fertilizers achieved comparable control to standard rates, offering sustainable management options.

Keywords: Fertilizer types, resource efficiency, crop vigour, upland rice, weed dynamics.

Introduction

Rice (*Oryza sativa* L.) serves as a staple food for over half of the world's population, playing a crucial role in food security and economic stability, especially in developing countries (Arouna *et al*., 2017; Bin Rahman and Zhang, 2023). Upland rice is particularly important in areas with limited water resources and underdeveloped irrigation systems. However, its cultivation faces numerous challenges, with weed infestation being one of the most significant obstacles (Fahad *et al*., 2019). Weeds compete with rice for essential resources such as nutrients, water, light, and space, leading to substantial yield losses (Dass *et al*., 2017; Kaur *et al*., 2018). Effective weed management is therefore essential for maintaining upland rice production and ensuring food security, particularly in smallholder farming systems (Daramola *et al*., 2020; Alagbo *et al*., 2022).

Weed management in upland rice fields is complicated by the high diversity of weed species and their varying growth habits, which make them difficult to control with a single approach (Kumar *et al*., 2023). Manual weeding, the most common method among smallholder farmers, is labor-intensive, time-consuming, and often economically unfeasible (Sims *et al*., 2018; Kakarla *et al*., 2024). Chemical control methods, particularly herbicides, are increasingly used due to their effectiveness in reducing weed populations (Davis and Frisvold, 2017). However, the excessive and indiscriminate use of herbicides raises concerns about herbicide-resistant weed species, environmental pollution, and health risks to farmers and consumers (Basu and Rao, 2020; Parven *et al*., 2024). Therefore, integrated weed management strategies that enhance efficiency and sustainability are needed (Hussain *et al*., 2021).

In addition to weed control, nutrient management is critical in upland rice cultivation (Dhyana, 2020). Fertilizers not only improve rice growth and yield but also influence weed dynamics by affecting the competitive balance between crops and weeds (Kaur *et al*., 2018). Inorganic fertilizers are favored for their immediate nutrient availability, helping to boost productivity. However, their long-term use can lead to soil degradation, reduced microbial diversity, and environmental pollution (Pahalvi *et al.,* 2021; Verma *et al*., 2023). Organic fertilizers, in contrast, improve soil structure, enhance nutrient cycling, and promote biodiversity, but they may not provide nutrients as rapidly as inorganic options (Singh and Ryan, 2015). The type and application rate of fertilizers can significantly influence weed species composition, density, and competitiveness, requiring a deeper understanding of how fertilizer management interacts with weed control (Kaur *et al*., 2018; Kumar *et al.,* 2024)

The combination of weed management and nutrient application presents an opportunity to optimize upland rice production while addressing the challenges of environmental sustainability and resource efficiency (Ghosh *et al*., 2020; Kumar *et al*., 2023; Pervaiz *et al*., 2024). Several studies have explored the potential of combining weed control methods, Scavo and Mauromicale, (2020) reported that herbicide application and manual weeding, with different fertilizer types improve crop performance and weed suppression. However, these studies often focus on individual aspects of weed management or nutrient application without considering their interactive effects on weed dynamics and rice growth.

Therefore, this study aims to evaluate the combined effects of weed management strategies and fertilizers on weed growth and competition with rice crops. The findings from this research are expected to contribute to the development of integrated weed management strategies tailored to the specific needs of upland rice ecosystems by identifying the most effective combinations of weed control and fertilizer application.

Materials and Methods

Description of Experimental Site and Conditions

The research was conducted at the Teaching and Research Farm, Faculty of Agriculture, University of Abuja, situated in Abuja, which has a tropical savanna climate characterized by distinct wet and dry seasons. The experimental site was located at an elevation between 360 and 490 meters above sea level. The area receives an average annual rainfall of 1,200 mm to 1,500 mm, with rainfall predominantly occurring from April to October. During the wet season, temperatures typically range from 22°C to 30°C (NiMet, 2021). The soil at the experimental site is sandy loam, consisting of 71% sand, 14% silt, and 15% clay, with a pH of 6.5 and a carbon content of 9.8 g/kg (University of Uyo Lab.). Prior to the experiment, the site was left fallow for one year to ensure uniform soil conditions and minimize any residual effects from previous crops.

Experimental Treatments and Design

A split-split plot design was used, with rice variety as the main factor, herbicide treatments as the sub-factor, and fertilizer types as the sub-sub factor. The experiment involved three rice varieties (FARO 55, FARO 56, and FARO 59), grown in upland rice fields during the 2023 and 2024 cropping seasons. The herbicide treatments included M1 (herbicide at the standard rate), M2 (reduced herbicide rate), M3 (manual weeding), and M4 (control, no weed management). Three fertilizer types were applied: F1 (organic- HELIN 1 liquid fertilizer), F2 (inorganic- NPK 15:15:15), and F3 (no fertilizer). AGRI FORCE (Bispyribac-Sodium at 100 g/l active ingredient) herbicide was applied at the rate of 0.05 ml per plot (standard rate) and 0.03 ml per plot (reduced rate) at 4, 8 and 12 weeks after sowing. A total of 12 treatments were applied for each rice variety, with each treatment replicated three times, resulting in 108 plots. Each plot covered an area of 1 square meter, with a 0.5-meter gap between plots of the same variety and a 1-meter gap between different varieties and replicates.

Data Collection

Weed density, weed height (cm), weed species richness, weed cover, weed dry biomass, and weed competitive index were assessed at 4, 8, and 12 weeks after sowing (WAS) in accordance with the established weed assessment protocol. (McGilchrist, 1965; Taylor *et al*., 1993; Bàrberi and Lo Cascio, 2001; Magurran, 2003; Andreasen and Streibig 2011; Travlos *et al*., 2018). The data collected were analyzed using analysis of variance (ANOVA) in the Statistical

Package for the Social Sciences (SPSS) version 27 to evaluate the significance of the treatments. Mean comparisons were performed using Duncan's Multiple Range Test (DMRT) at the 5% significance level. Significant differences among treatments were identified, and the interaction effects were analyzed to understand the combined influence of rice varieties, weed management strategies, and fertilizer types.

Results

There was no significant difference among the three rice varieties in weed density at 4 weeks after sowing (WAS) in 2023. In 2024, FARO 55 had the highest weed density (7.64 plants/m^2) at 4WAS, although it was not significantly different from FARO 56. At 8WAS in both years, there was no significant difference in weed density between FARO 55 (22.44 plants/m^2) and FARO 56 (22.00 plants/m^2), but both varieties differed significantly from FARO 59 (17.97 plants/m^2). At 12WAS, FARO 55 had higher weed density (29.94 plant/m^2) compared to both FARO 56 and FARO 59, with no significant difference between FARO 56 and FARO 59 across the years.

At 4 WAS in 2023, there was no significant difference among the treatments in weed density, but in 2024, treatments M1F1 (herbicide at the standard rate treated with organic fertilizer) and M2F2 (reduced herbicide rate treated with NPK) had the highest weed densities (8.00 plants/m^2), though not significantly different from several other treatments. Treatment M2F3 (reduced herbicide rate with no fertilizer) resulted in lower weed density of 5.97 plants/m^2, but it was not significantly different from some of the treatments. At 8WAS and 12WAS, treatments M4F1 (control treated with organic fertilizer), M4F2 (control treated with NPK), and M4F3 (No weed management, no fertilizer) exhibited significantly higher weed densities (67.89 plants/m^2, 79.89 plants/m^2, 80.56 plants/m^2 respectively) across both years.

Regarding weed height, FARO 59 had higher weed heights at 4WAS in both years (7.44 cm, 7.49 cm respectively), but it was not significantly different from FARO 55 in 2023 and FARO 56 in 2024. At 8WAS in 2023, there was no significant difference in weed height between FARO 55 and FARO 56, while in 2024, FARO 55 had the highest weed height (20.56 cm), but it was not significantly different from FARO 56. At 12WAS, there was no significant difference in weed height among the three varieties across both years. Treatment M2F1 produced taller weeds (7.62 cm) at 4WAS in 2023, although it was not significantly different from several other treatments. Treatment M2F3 resulted in shorter weeds in both years (6.16 cm; 5.57 cm respectively) and was not statistically different from several other treatments. At 8WAS across both years, M4F3 had significantly taller weeds of 47.20 cm; 46.74 cm respectively compared to other treatments. Treatments with M4 resulted in taller weeds (62.87 cm) at 12WAS in both years, with no significant difference observed among the other treatments (Table 1).

At 4 WAS across both years, there weas no significant difference in weed richness among the three rice varieties. However, FARO 55 showed significantly higher weed richness (5.25 in 2023, 5.03 in 2024) compared to FARO 56 and FARO 59 at 8 and

12 WAS in both years. FARO 59, on the other hand, FARO 55 exhibited the lowest weed richness (3.69, 3.42) at 12 WAS across both years. At 4 WAS in 2023, there was no significant differences among the treatments, but in 2024, treatment M3F2 had the highest weed richness (3.89), although it was not statistically different from other treatments, except for M1F3. Treatment M4F3 exhibited the highest weed richness at 8 WAS in both years (7.56, 6.78), but it was not significantly different from M4F1 and M4F2. Treatment M1F3 showed the lowest weed richness (2.00 in 2023, 2.11 in 2024) and was not significantly different from M1F2 and M2F3 in 2023 and from M1F1, M2F1, M3F1, M1F2, M2F2 and M2F3 in 2024. At 12 WAS, M4F1, M4F2, and M4F3 showed significantly higher weed richness (7.22, 7.00, 8.00 respectively) across both years, while treatments with standard (M1) and reduced (M2) herbicide rates resulted in lower weed richness.

Regarding weed cover, FARO 56 had the highest weed cover (3.97%) at 4 WAS in 2023, though it was not significantly different from FARO 55 (3.36 %). FARO 59 had the least weed cover (2.77 %), but it was not significantly different from FARO 55. In 2024, there was no significant difference among the three varieties. At 8 WAS in 2023, FARO 55 exhibited higher weed cover (29.56 %), while FARO 56 had the lowest weed cover (26.03 %); however, neither was significantly different from FARO 59. There was no significant difference in weed cover among the varieties at 8 WAS in 2024 and 12 WAS across both years. Treatments M2F3 and M4F3 showed higher weed cover (4.22 %, 4.33 % respectively), while Treatment M3F1 exhibited lower weed cover (2.33 %) at 4 WAS across both years, though none of these differences were significant compared to several other treatments. At 8 and 12 WAS across both years, treatments with M4 (control) showed significantly higher weed cover compared to other treatments, while treatments with M1 (standard herbicide) and M2 (reduced herbicides) resulted in lower weed cover (Table 2).

Throughout the growth stages and across both years, FARO 55 exhibited higher weed dry weight (WDW) (0.53 g, 0.59 g respectively), while FARO 59 showed lower WDW (0.28 g, 0.29 g respectively). Generally, treatments M4F1, M4F2, and M4F3 resulted in higher WDW (2.49 g, 2.48 g, 2.72 g respectively) compared to other treatments, particularly M1F2 and M2F3.

In 2023, FARO 56 showed a higher weed competitive index (WCI) value at both 4 and 12 WAS (0.03, 0.32 respectively), although it was not significantly different from FARO 59 at 12 WAS. In 2024, FARO 59 had a higher WCI than the other varieties at both 4 and 12 WAS (0.03, 0.38 respectively), though it was not statistically different from FARO 56 at 12 WAS. No significant differences in WCI were observed among the three varieties at 8 WAS across the years. Treatments M4F1, M4F2, and M4F3 resulted in higher WCI values (20.99, 30.05, 26.61 respectively) compared to other treatments across both years and growth stages (Table 3).

Discussion

The absence of significant differences in weed density among the three rice varieties at 4 weeks after sowing (WAS) in 2023 suggested that all varieties provided a similar environment for early weed establishment. However, FARO 55 exhibited the highest weed density at 4 WAS in 2024, although it was not significantly different from FARO 56. This could indicate variability in early competitiveness, potentially influenced by environmental factors or seedling vigor. Early weed competition can have lasting effects on crop productivity if left unmanaged (Chauhan and Johnson, 2011). The consistently lower weed density in FARO 59 highlights its competitive advantage, likely due to its inherent morphological traits, such as rapid canopy closure, higher tillering capacity, and greater biomass production, all of which were known to suppress weed growth (Ruzmi *et al*., 2021). The lack of significant differences in weed density across treatments suggested that herbicides or fertilizers alone may not effectively influence early-stage weed emergence, as reported by Mishra *et al*. (2016). However, by 8 and 12 WAS, untreated plots (M4F1, M4F2, M4F3) consistently exhibited significantly higher weed densities compared to herbicide-treated plots (M1, M2), emphasizing the critical role of chemical weed control in managing late-emerging weeds (Duke, 2015). The reduced herbicide rate (M1) combined with organic (F1) or inorganic (F2) fertilizers achieved comparable weed suppression to the standard herbicide rate (M2), demonstrating that reduced herbicide doses can still be effective in integrated systems. This was in line with Scavo and Mauromicale (2020), who highlighted that optimized herbicide applications could balance efficacy with environmental safety.

The higher weed height in FARO 59 at 4 WAS in both years suggested that the growth pattern of this variety allowed weeds to take advantage of early growth opportunities, a phenomenon observed in less competitive varieties during early crop stages (Chauhan, 2013). The inconsistency in weed height at 8 WAS could be due to environmental factors such as rainfall, temperature, and soil moisture, which influence weed growth dynamics (Upasani and Barla, 2018). The lack of significant differences in weed height among the three varieties at 12 WAS may reflect the convergence of weed growth as the rice canopy closed, suppressing further elongation, supporting the idea that late-season weed height is more influenced by canopy closure than by inherent varietal competitiveness (Chauhan and Johnson, 2011). Consistently shorter weeds across growth stages in herbicide-treated plots (M1, M2) compared to untreated plots (M4) underscores the role of chemical control in limiting weed growth, as untreated plots allowed weeds to grow taller, increasing competition for light and negatively impacting crop yields (Damalas and Koutroubas, 2022). The treatments involving organic or inorganic fertilizers (F1, F2) resulted in shorter weeds compared to those without fertilizers (F3), suggesting that nutrient availability enhances crop vigor, which suppresses weed growth (Mohler and Johnson, 2009; Lowry and Smith, 2018).

At 4 WAS across both years, the lack of significant differences in weed richness among the three rice varieties suggested that early weed emergence was not strongly influenced by varietal traits. This finding aligns with Dass *et al*. (2017), who noted that early weed suppression is typically driven by external management practices rather than varietal competitiveness during the seedling stage. FARO 55 consistently exhibited higher weed richness at 8 and 12 WAS compared to FARO 56 and FARO 59, which could be due to FARO 55's canopy structure or slower canopy closure, allowing greater light penetration and resource availability for diverse weed species (Lowry and Smith, 2018). On the other hand, FARO 59 displayed the lowest weed richness at 12 WAS across both years, indicating superior weed suppression, potentially due to its competitive traits, such as greater biomass accumulation and an aggressive growth habit, which reduce weed diversity by monopolizing resources (Schreiber *et al*., 2018). The lower weed cover in FARO 59 aligned with its known competitive traits, such as rapid canopy closure and greater biomass production, which suppress early weed establishment (Schreiber *et al*., 2018). The lack of significant differences among varieties at 4 WAS in 2024 suggested that environmental conditions, such as rainfall or temperature, may have minimized the influence of varietal traits on early weed cover, as reported by Chauhan and Johnson (2011). FARO 55 exhibited higher weed cover at 8 WAS compared to FARO 56, but the differences was not statistically significant. The similarity in weed cover between varieties at this stage may indicate that canopy closure, a critical factor in weed suppression, was similarly effective across varieties (Osipitan *et al*., 2018). The lack of significant differences in weed cover at 12 WAS further highlighted the diminishing influence of varietal traits as the crop canopy fully developed and shades out weeds (Nathalie *et al*., 2020).

Higher weed cover observed in treatments M2F3 and M4F3 at 4 WAS suggested that the absence of herbicide application or fertilizer input allowed weeds to exploit available resources and establish rapidly, consistent with findings of Kaur *et al.* (2018). In contrast, treatment M3F1 showed lower weed cover at 4 WAS, although not significantly different from other treatments, highlighting the potential of manual weeding combined with organic fertilizer to suppress early weed growth by promoting vigorous crop establishment (Ghosh *et al.,* 2022). Significantly higher weed cover at 8 and 12 WAS in treatments observed in M4 (control) indicated that the lack of weed control in these treatments allowed unchecked weed growth, leading to greater weed cover. These findings reinforce the importance of timely and effective weed control measures in reducing weed proliferation (Osipitan, 2017). Lower weed cover observed in herbicide-treated treatments (M1 and M2) across both growth stages underscores the efficacy of chemical weed control in limiting weed growth. Notably, the reduced herbicide rate (M2) performed comparably to the standard rate (M1), highlighting the potential for reducing herbicide doses without compromising weed control efficacy (Shehata *et al*., 2019; Monteiro and Santos, 2022).

The consistently higher weed dry weight (WDW) in FARO 55 across growth stages and years suggested that this variety is less competitive against weeds compared to FARO 59, which exhibited lower WDW. This could be attributed to FARO 55 morphological or physiological traits, such as a less vigorous canopy or slower growth rate, which may allow for greater weed establishment. Conversely, FARO 59 lower WDW indicated superior weed-suppressive ability, likely due to attributes such as rapid canopy closure, taller plant height, or better resource utilization (Dass *et al*., 2017; Lowry and Smith, 2018; Mwendwa *et al*., 2020). The higher WDW observed in treatments M4F1, M4F2, and M4F3 compared to others may be related to suboptimal combinations of weed management and fertilizer application, as fertilizing without effective weed management can exacerbate weed growth (Kaur *et al*., 2018). Conversely, the better performance of M1F2 and M2F3 in suppressing weeds suggested that the proper timing and integration of weed control measures with nutrient management could lead to more effective weed suppression. The weed competitive index (WCI) values revealed the competitive interactions between rice varieties and weeds. In 2023, the higher WCI of FARO 56 at 4 and 12 WAS, similar to FARO 59 at 12 WAS, suggested that FARO 56 was more competitive against weeds during these stages. However, in 2024, FARO 59 exhibited a higher WCI at both 4 and 12 WAS, indicating variability in competitive performance across years, potentially influenced by environmental factors or changes in weed species composition (Ramesh *et al*., 2017). The lack of significant differences in WCI among varieties at 8 WAS across years suggested that this stage may represent peak resource competition, where varietal differences are less pronounced (Nath *et al*., 2024). The consistently higher WCI in treatments M4F1, M4F2, and M4F3 suggested that these weed management and fertilizer combinations created conditions favorable for weeds over rice, as reported by Nazir *et al*. (2022).

Conclusion

The results from the findings showed that rice variety and weed management practices significantly affected weed dynamics in upland rice production. Among the varieties evaluated, FARO 59 consistently exhibited superior weed-suppressive ability, resulting in lower weed density, cover, and dry weight compared to FARO 55 and FARO 56. Clear differences were observed among weed management practices, with untreated control plots (M4F1, M4F2, M4F3) recording the highest weed density, height, cover, and dry weight highlighting the necessity of effective weed control. Treatments involving standard herbicide rates combined with either organic (M1F1) or inorganic (M1F2) fertilizers achieved strong weed suppression. Reduced herbicide rates combined with organic (M2F1) or inorganic (M2F2) fertilizers provided comparable control to standard rates, suggesting their potential as sustainable management alternatives. Furthermore, the combination of reduced herbicide rates without fertilizer (M2F3) effectively lowered weed density and height, indicating its suitability for resource-limited or low-input production systems.

Recommendations

Farmers are advised to grow FARO 59 in areas with high weed pressure because it consistently suppressed weeds throughout the growing season. To achieve the best weed control, use the standard herbicide rate (M1) combined with organic (F1) or inorganic (F2) fertilizers. For a cost-effective and eco-friendly option, reduced herbicide rates with organic (M2F1) or inorganic (M2F2) fertilizers should be considered as it also provided effective weed suppression like standard rate. In low-input systems, using a reduced herbicide rate without fertilizer (M2F3) is a good choice, as it effectively reduces weed density and height, especially at 8 and 12 WAS. Avoid untreated plots, as they resulted in the highest weed density, height, cover, and dry weight, which can reduce rice yields. Weed management required attention at 8 and 12 WAS when weed pressure is highest and can most affect crop growth. Further research is needed to understand the long-term impact of these practices on crop yields, weed seed banks, and sustainability.

Table 1: Mean of weed density and weed height as influenced by weed management and fertilizer combination at 4, 8 and 12 weeks after sowing (WAS) in year 2023 and 2024.

VARIABLE	WEED DENSITY						WEED HEIGHT					
	4WAS		8WAS		12WAS		4WAS		8WAS		12WAS	
	2023	2024	2023	2024	2023	2024	2023	2024	2023	2024	2023	2024
Variety												
FARO 55	6.97	7.64^{a}	22.81^{a}	22.44^{a}	29.58^{a}	29.94^{a}	6.98^{ab}	6.73^{b}	21.11^{a}	20.56^{a}	23.60	23.55
FARO 56	6.75	7.08^{ab}	21,86^{a}	22.00^{a}	24.06^{b}	24.67^{b}	6.74^{b}	6.95^{ab}	18.78^{a}	18.52^{ab}	23.95	24.08
FARO 59	6.86	6.67^{b}	18,08^{b}	17.97^{b}	21.25^{b}	22.25^{b}	7.44^{a}	7.49$_{a}$	16.99^{b}	16.90^{b}	21.31	21.53
SEM±	0.29	0.29	0.71	0.74	1.2	1.22	0.21	0.22	1.04	1.00	1.65	1.63
Treatment												
M1F1	7.67	8.00^{a}	6.79^{c}	7.11^{d}	6.33^{c}	7.11^{c}	6.37^{ab}	7.13^{a}	5.43^{e}	5.76^{e}	8.47^{b}	8.58^{b}
M2F1	7.33	8.00^{a}	7.56^{c}	7.44^{d}	6.22^{c}	6.89^{c}	7.62^{a}	7.42^{a}	6.78^{e}	6.50^{e}	9.16^{b}	9.19^{b}
M3F1	6.78	7.89^{ab}	15.11^{b}	15.11^{c}	10.22^{c}	11.00^{c}	7.07^{ab}	7.34^{a}	10.94^{de}	10.62^{de}	11.23^{b}	11.38^{b}
M4F1	6.67	6.22^{abc}	53.11^{a}	51.89^{b}	67.78^{b}	67.89^{b}	7.40^{ab}	7.09^{a}	40.99^{b}	40.11^{b}	61.19^{a}	61.28^{a}
M1F2	6.58	7.56^{abc}	8.33^{c}	8.33^{d}	7.44^{c}	7.89^{c}	6.64^{ab}	6.54^{ab}	8.22^{e}	8.08^{e}	9.44^{b}	9.53^{b}
M2F2	6.44	7.33^{abc}	7.67^{c}	8.22^{d}	7.22^{c}	8.00^{c}	7.00^{ab}	7.20^{a}	11.53^{de}	11.18^{de}	12.09^{b}	12.08^{b}
M3F2	7.64	7.22^{abc}	13.58^{b}	13.67^{c}	11.89^{c}	12.22^{c}	7.14^{ab}	7.42^{a}	19..96^{c}	19.73^{c}	11.92^{b}	12.02b
M4F2	7.56	7.33^{abc}	53.67^{a}	53.22^{ab}	79.33^{a}	79.89^{a}	7.29^{ab}	7.39^{a}	45.28^{ab}	44.74^{ab}	62.57^{a}	59.77a
M1F3	6.22	6.00^{bc}	8.22^{c}	8.00^{d}	5.33^{c}	6.11^{c}	6.57^{ab}	6.52^{ab}	7.01^{e}	6.97^{e}	9.07^{b}	9.32^{b}
M2F3	5.89	5.89^{c}	6.89^{c}	6.69^{d}	7.00^{c}	7.89^{c}	6.16^{b}	5.57^{b}	9.06^{de}	8.84^{de}	9.06^{b}	9.19^{b}
M3F3	6.11	6.56^{abc}	13.67^{b}	13.44^{c}	11.00^{c}	12.00^{c}	7.69^{a}	7.37^{a}	15.04^{cd}	14.61^{cd}	11.29^{b}	11.43^{b}
M4F3	7.44	7.56^{abc}	56.44^{a}	56.33^{a}	79.78^{a}	80.56^{a}	7.74^{a}	7.67^{a}	47.20^{a}	46.74^{a}	59.94^{a}	62.87^{a}
SEM±	0.58	0.58	1.43	1.47	2.40	2.43	0.43	0.44	2.07	2.01	3.30	3.26
V x T	Ns	Ns	<0.001	<0.001	<0.001	<0.001	Ns	Ns	Ns	Ns	Ns	Ns

Mean value of figures with the same superscript in a column are not significantly different ($p<0.05\%$). Weed density=WD, weed height=WH.

M1F1= Standard rate of herbicide with organic fertilizer, M2F1= Reduced rate of herbicide with organic fertilizer, M3F1= Manual weeding with organic herbicide, M4F1=Control with organic fertilizer, M1F2= Standard rate of herbicide with inorganic fertilizer, M2F2= Reduced rate of herbicide with inorganic fertilizer, M3F2= Manual weeding with inorganic herbicide, M4F2=Control with inorganic fertilizer, M!F3= Standard rate of herbicide with no fertilizer, M2F3= Reduced rate of herbicide with no fertilizer, M3F3= Manual weeding with no fertilizer, M4F3=Control with no fertilizer.

Table 2: Mean of weed richness and weed cover as influenced by weed management and fertilizer combination at 4, 8 and 12 weeks after sowing (WAS) in year 2023 and 2024

VARIABLE	WEED RICHNESS						WEED COVER					
	4WAS		8WAS		12WAS		4WAS		8WAS		12WAS	
	2023	2024	2023	2024	2023	2024	2023	2024	2023	2024	2023	2024
Variety												
FARO 55	3.44	3.53	5.25^{a}	4.69^{a}	5.03^{a}	4.17^{a}	3.36^{ab}	3.11	29.56^{a}	33.33	27.26	27.69
FARO 56	3.44	3.31	$4{,}08^{b}$	3.28^{b}	4.36^{b}	3.25^{b}	3.97a	3.83	26.03^{b}	29.81	25.39	26.94
FARO 59	3.31	3.31	3.86^{b}	3.64^{b}	3.69^{c}	3.42^{c}	2.77^{b}	2.81	27.36^{ab}	30.83	26.47	28.22
SEM±	0.12	0.12	0.14	0.23	0.15	0.19	0.23	0.22	1.01	1.20	1.12	1.18
Treatment												
M1F1	3.67	3.44^{ab}	2.89^{d}	2.67^{de}	1.89^{c}	3.11^{b}	3.00^{ab}	2.78^{bc}	4.89^{d}	4.67^{d}	1.89^{c}	5.56^{c}
M2F1	3.44	3.56^{ab}	3.11^{d}	2.33^{de}	2.22^{c}	2.78^{bc}	2.56^{bc}	2.67^{bc}	7.67^{d}	5.44^{d}	2.22^{c}	4.33^{c}
M3F1	3.67	3.33^{ab}	4.78^{c}	3.33^{de}	4.22^{b}	3.00^{bc}	2.33^{c}	2.44^{c}	22.79^{c}	32.78^{c}	4.22^{b}	16.67^{b}
M4F1	3.67	3.44^{ab}	6.56^{b}	5.67^{ab}	8.89^{a}	7.22^{a}	2.56^{bc}	2.67^{bc}	71.11^{a}	72.78^{a}	8.89^{a}	77.78^{a}
M1F2	3.00	3.56^{ab}	2.07^{de}	1.89^{e}	2.11^{c}	2.00^{bc}	3.56^{ab}	3.67^{abc}	4.78^{d}	9.11^{d}	2.11^{c}	5.78^{c}
M2F2	3,56	3.33^{ab}	3.33^{d}	3.22^{de}	2.44^{c}	2.11^{bc}	3.44^{ab}	2.78^{bc}	7.78^{d}	8.78^{d}	2.44^{c}	9.22^{c}
M3F2	3,56	3.89^{a}	5.11^{c}	3.67^{cd}	4.56^{b}	2.11^{bc}	3.11^{ab}	3.44^{abc}	33.33^{b}	43.89^{b}	4.56^{b}	21.67^{b}
M4F2	3.22	3.22^{ab}	7.22^{ab}	6.67^{a}	9.00^{a}	7.00^{a}	3.67^{ab}	3.33^{abc}	73.33^{a}	75.00^{a}	9.00^{a}	78.33^{a}
M1F3	3.00	2.89^{b}	2.00^{e}	2.11^{e}	1.56^{c}	1.78^{c}	3.89^{b}	4.00^{ab}	5.22^{d}	4.22^{d}	1.56^{c}	5.44^{c}
M2F3	3.11	3.44^{ab}	2.56^{de}	3.33^{de}	1.78^{c}	1.89^{bc}	4.22^{a}	3.56^{abc}	7.00^{d}	8.00^{d}	1.78^{c}	7.78^{c}
M3F3	3.33	3.33^{ab}	5.00^{c}	4.78^{bc}	4.00^{b}	2.33^{bc}	3.67^{ab}	3.44^{abc}	19.44^{c}	32.22^{c}	4.00^{b}	18.89^{b}
M4F3	3.56	3.44^{ab}	7.56^{a}	6.78^{a}	9.67^{a}	8.00^{a}	4.33^{a}	4.22^{a}	74.44^{a}	78.89^{a}	9.67^{a}	80.00^{a}

SEM±	0.23	0.24	0.27	0.46	0.30	0.38	0.45	0.43	2.02	2.41	2.20	2.36
V x T	Ns	Ns	<0.001	<0.01	0.004	0.006	Ns	Ns	Ns	<0.001	Ns	Ns

Mean value of figures with the same superscript in a column are not significantly different ($p<0.05\%$). Weed richness=WR, weed cover=WC.

M1F1= Standard rate of herbicide with organic fertilizer, M2F1= Reduced rate of herbicide with organic fertilizer, M3F1= Manual weeding with organic herbicide, M4F1=Control with organic fertilizer, M1F2= Standard rate of herbicide with inorganic fertilizer, M2F2= Reduced rate of herbicide with inorganic fertilizer, M3F2= Manual weeding with inorganic herbicide, M4F2=Control with inorganic fertilizer, M!F3= Standard rate of herbicide with no fertilizer, M2F3= Reduced rate of herbicide with no fertilizer, M3F3= Manual weeding with no fertilizer, M4F3=Control with no fertilizer.

Table 3: Mean of weed dry weight and weed competitive index as influenced by weed management and fertilizer combination at 4, 8 and 12 weeks after sowing (WAS) in year 2023 and 2024.

VARIABLE	WEED DRY WEIGHT						WEED COMPETITIVE INDEX					
	4WAS		8WAS		12WAS		4WAS		8WAS		12WAS	
	2023	2024	2023	2024	2023	2024	2023	2024	2023	2024	2023	2024
Variety												
FARO 55	0.53^{a}	0.59^{a}	1.52^{a}	1.49^{a}	1.15^{a}	1.21^{a}	0.01^{b}	0.01^{c}	5.97	5.76	0.25^{b}	0.25^{b}
FARO 56	0.45^{a}	0.59^{b}	1.13^{b}	1.14^{b}	1.02^{a}	1.07^{ab}	0.03^{a}	0.02^{b}	8.21	8.12	0.32^{a}	0.32^{ab}
FARO 59	0.28^{b}	0.29^{c}	1.17^{b}	1.19^{b}	0.79^{b}	0.87^{b}	0.02^{b}	0.03^{a}	7.59	7.57	0.37^{a}	0.38^{a}
SEM±	0.03	0.03	0.07	0.06	0.12	0.07	0.002	0.00	0.98	0.96	0.37	0.04
Treatment												
M1F1	0.44^{ab}	0.48^{abcd}	0.68^{ef}	0.69^{ef}	0.44^{c}	0.46^{c}	0.01^{c}	0.01^{c}	0.27^{c}	0.27^{c}	0.01^{c}	0.01^{c}
M2F1	0.50^{b}	0.49^{abcd}	0.56^{ef}	0.60^{f}	0.34^{c}	0.37^{c}	0.02^{c}	0.02^{bc}	0.33^{c}	0.26^{c}	0.01^{c}	0.01^{c}
M3F1	0.50^{b}	0.51^{abc}	0,97^{de}	1.00^{de}	0.62^{c}	0.68^{c}	0.02^{c}	0.02^{abc}	1.79^{c}	1.69^{c}	0.05^{c}	0.05^{c}
M4F1	0.52^{a}	0.58^{a}	2.67^{a}	2.64^{a}	2.40^{a}	2.49^{a}	0.02^{c}	0.02^{bc}	20.99^{b}	20.02^{b}	1.05^{b}	1.06^{b}
M1F2	0.29^{c}	0.33^{cd}	0.53^{f}	0.51^{f}	0.36^{c}	0.42^{c}	0.02^{c}	0.03^{abc}	0.33^{c}	0.31^{c}	0.01^{c}	0.01^{c}
M2F2	0.32^{bc}	0.34^{bc}	0.78^{ef}	0.78^{ef}	0.43^{c}	0.49^{c}	0.02^{c}	0.02^{abc}	0.61^{c}	0.61^{c}	0.00^{c}	0.03^{c}
M3F2	0.50^{b}	0.50^{abc}	1.56^{c}	1.46^{c}	1.04^{b}	1.13^{b}	0.02^{c}	0.02^{abc}	3.71^{c}	3.67^{c}	0.04^{c}	0.03^{c}
M4F2	0.52^{a}	0.46^{abcd}	2.23^{b}	2.23^{b}	2.34^{a}	2.48^{a}	0.04^{a}	0.03^{abc}	30.05^{a}	29.83^{a}	1.28^{a}	1.25^{ab}
M1F3	0.31^{bc}	0.41^{abcd}	0.64^{ef}	0.69e^{f}	0.31^{c}	0.38^{c}	0.03^{b}	0.03^{abc}	0.30^{c}	0.31^{c}	0.01^{c}	0.01^{c}
M2F3	0.34^{bc}	0.31^{d}	0.77^{ef}	0.76^{ef}	0.43^{c}	0.46^{c}	0.02^{c}	0.02^{abc}	0.42^{c}	0.40^{c}	0.02^{c}	0.02^{c}
M3F3	0.46^{ab}	0.53^{ab}	1.22^{cd}	1.21^{cd}	0.47^{c}	0.54^{c}	0.03^{b}	0.03^{abc}	1.69^{c}	1.71^{c}	0.04^{c}	0.04^{c}
M4F3	0.37^{bc}	0.39^{bcd}	2.68^{a}	2.71^{a}	2.62^{a}	2.72^{a}	0.04^{a}	0.03^{a}	26.61^{a}	26.70^{a}	1.25ab	1.28^{a}
SEM±	0.06	0.06	0.13	0.12	0.14	0.14	0.004	0.00	1.96	1.93	0.07	0.07
V x T	Ns	Ns	0.04	0.004	Ns	Ns	Ns	Ns	**Ns**	Ns	Ns	Ns

Mean value of figures with the same superscript in a column are not significantly different (p<0.05%). weed biomass=WB, weed competitive index=WCI.

M1F1= Standard rate of herbicide with organic fertilizer, M2F1= Reduced rate of herbicide with organic fertilizer, M3F1= Manual weeding with organic herbicide, M4F1=Control with organic fertilizer, M1F2= Standard rate of herbicide with inorganic fertilizer, M2F2= Reduced rate of herbicide with inorganic fertilizer, M3F2= Manual weeding with inorganic herbicide, M4F2=Control with inorganic fertilizer, M!F3= Standard rate of herbicide with no fertilizer, M2F3= Reduced rate of herbicide with no fertilizer, M3F3= Manual weeding with no fertilizer, M4F3=Control with no fertilizer.

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