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Integrated Mechanical and Chemical Control of Wild Rice (*Oryza Longistaminata*) and its Impact on Rice Yield in Upper East Region, Ghana.

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ABSTRACT
Wild rice (*Oryza longistaminata*) is a pervasive weed in rice fields in the Upper East Region, significantly reducing rice yields and threatening food security. The study aimed to evaluate the efficacy of integrated mechanical and chemical control methods in Garu and Tempane Districts. The experiment was laid out in a split-plot design with three replications. The districts were assigned to the main plots and the weed control methods to the subplots. Land preparation was done manually, and Glyphosate was applied one week after, at a rate of 100 ml per 15 litres of water. One week later, Jasmine rice was planted. Data were collected on the wild rice population and rice yield parameters. The data were analyzed using GenStat 12 Edition; a two-way ANOVA was used to determine treatment differences. Means were separated using Lsd at a 5% level of significance. Results showed that glyphosate-based treatments effectively suppressed weeds. Plough + Glyphosate achieved the highest grain yields of 3.87 t/ha in Garu and 3.53 t/ha in Tempane. The weed control method was significant ($p < 0.001$) and reduced wild rice population by 2.7-fold. Uncontrolled wild rice infestation reduced rice yields by approximately 56%. Combined Plough + Glyphosate application is recommended for managing *O. longistaminata*, with Glyphosate application only where resources are limited. Awareness of the weed's rhizomatous regeneration capacity is essential for farmers to understand the control methods. Further research should examine the cost-benefit analysis of the control methods and socio-economic factors that could influence adoption.

Keywords:
Wild rice,
Glyphosate,
Ploughing,
Jasmine rice,
Garu and
Tempane districts.

INTRODUCTION

Rice (*Oryza sativa* L.) production is a vital agricultural activity that provides a staple food source for more than half of the world's population (Dauran et al., 2026), with Asia and Sub-Saharan Africa leading production and consumption (Geja and Maphosa, 2023). In Ghana, rice consumption grows at 6% annually, driven by population growth and changing dietary preferences (Abdullahi et al., 2019). However, yields lag due to constraints of weed competition, particularly from wild rice (*Oryza longistaminata*).

Wild rice is a perennial weed with an advanced underground rhizome, which causes 48-100% yield losses in Ghana (Adeyemi et al., 2017; Adigun et al., 2017). Morphologically, it is closely related to cultivated rice and has a competitive superiority over cultivated rice (Rodenburg et al., 2010). Botanically, it has a fibrous root system, elongated culms, narrow leaves, and a panicle-based reproductive structure. It has a well-developed rhizomatous root system, which allows it to reproduce vegetatively and spread laterally beneath the soil surface (Asaduzzaman, 2010). The rhizome network enables the weed to regenerate even after mechanical disturbance, making it difficult to control, particularly through conventional weed control methods (Onyeka & Tabo, 2007). It exhibits allelopathic effects on cultivated rice (Kolo et al., 2020; Rodenburg and Johnson, 2009).

The Upper East Region of Ghana, a key rice-producing area, has experienced declining rice yields, partly due to wild rice infestation, which has become a major constraint to rice production in the region (Paaga, 2020). The reduction in rice yields and quality due to wild rice infestation has a significant socio-economic impact on rice farmers. Loss of income results in increased poverty, particularly among smallholder farmers who rely heavily on rice production for their livelihoods (Addison et al., 2022).

Not all, the decline in rice production leads to increased imports (Boakye, 2025), which can strain the country's foreign exchange reserves and exacerbate the trade deficit. Weeds may be responsible for at least 2.2 million tons, or 1.45 billion US dollars, in annual rice yield losses in Sub-Saharan Africa. With better weed control, rice yield is predicted to increase by 15–23% (Rodenburg and Johnson, 2009).

Glyphosate is the world's most important herbicide, with unique properties such as its excellent uptake and translocation (Singh et al., 2020). It is a nonselective systemic herbicide which acts as an inhibitor of enolpyruvylshikimate-3-phosphate synthase (EPSPS) of the shikimic acid pathway which is important for plant growth and adaptation to the ecosystem (Kanatas, 2021).

Mechanical weed control method involves physical removal of weeds, it is labour-intensive and often ineffective against wild rice due to its rhizomatous growth habit (Ghosh, 2025; Jatav et al., 2021).

The farmers in the districts rely solely on the mechanical control method, resulting in perennial rice yield losses in their fields. Green (2018) pointed out that Glyphosate application should be integrated with mechanical weed control methods. However, the effectiveness of the herbicide can be influenced by soil type, moisture, and temperature, making it essential to evaluate its efficacy in specific locations.

This study aimed to evaluate the effect of integrated mechanical and herbicide weed control methods on wild rice to provide evidence-based recommendations for wild rice management to the farmers in the districts and for policy decisions.

MATERIALS AND METHODS

Study Area

The districts are located in the southeastern part of the Upper East Region of Ghana. They cover an area approximately on latitude 10º 38 N and 110 N and longitude 0º 06l E and 00 23l E. The Garu district covers an area of 676 km^2 and the Tempane district, on the other hand, covers an area of 1,230 km^2.

Agriculture plays a significant role in the local economy of the two districts. Many residents are engaged in subsistence farming and petty trading. Crops and livestock production are the main activities in both districts. Major crop production includes rice, maize, sorghum, cowpea and millet. Some of the livestock kept are cattle, sheep, goats and poultry such as fowls and guinea fowls. The districts were selected for the study because they participated in the Rice Sector Support Project (RSSP) to produce rice to meet the demand in Ghana, and the problem high *Oryza longistaminata* infestation in the rice fields.

Experimental Design and treatments

The experimental design was a 2 x 4 factorial in a split-plot; The main plot treatments were the two districts, Garu and Tempane.

The Subplot treatments are:

Plough Only

The land designated for ploughing was prepared manually using hoes to till the land. Debris and weeds were removed from the plots to create a clean slate for planting. This involved removing any existing vegetation, rocks, and other obstacles that could interfere with the planting. Plots were measured and demarcated and marked with wooden stakes and labels to define the boundaries.

Glyphosate Only

Glyphosate was applied one week after ploughing, when new wild rice weeds emerged. The application rate was 100 ml per 15l of water, as the recommended rate, to plots requiring herbicide treatment. The application was done early in the morning to minimize evaporation. The herbicide was applied using a calibrated knapsack sprayer with flat fan nozzles to ensure uniform coverage.

Ploughing + Glyphosate

The plots were ploughed using a hoe and left for one week after the emergence of wild rice weeds; glyphosate was applied at the recommended rate.

No treatment

Plots under this treatment were left undisturbed; no ploughing was done and no herbicide was applied.

The experiment was replicated three times, with each replication consisting of four plots, resulting in a total of 24 plots. Each plot measured 3m x 3m and there was 1m space between each plot.

Planting

Jasmine rice seeds were obtained from a certified seed company. Seeds were sown directly at a spacing of 20 cm x 20 cm one week after herbicide application. The plots were thinned to two plants per stand after emergence.

Data Collection

Wild rice population monitoring

A 1m x 1m quadrat was randomly placed within each plot, which was used to assess the wild rice population. The number of wild rice weeds within the quadrat was counted to determine the population density. Additionally, ten wild rice weeds were tagged in each plot, and their heights were measured using a meter rule and recorded every two weeks.

Rice population monitoring

The number of rice plants within a 1m^2 area within the plot was counted to determine the population density.

Rice yield parameters measured

Grain yield and 1000-grain weight

The harvested rice grains were dried to 14% moisture content, threshed and weighed on a weighing scale to determine the grain yield per $1m^2$. One thousand of the individual rice grains were counted and weighed to obtain 1000 grain weight.

Biomass weight

The above ground biomass was harvested per $1m^2$ and oven dried at a temperature of 60^0C to a constant weight. The weight of the paddy rice dried to 14% moisture content was added and to obtain the total biomass weighed on a scale.

Harvest index.

Harvest index was calculated as the ratio of grain yield after threshing to the total biomass obtained per $1m^2$. This is expressed as: HI = Economic Yield/Total Biomass x 100

Data analysis

Data collected were subjected to analysis of variance (ANOVA) using GENSTAT Discovery Package12th Edition. Means were separated using Least Significant Difference (Lsd) at 5% level of significance. Where ANOVA indicated significant differences among treatments, post-hoc mean separation was performed using Tukey's Honestly Significant Difference (HSD) test.

RESULTS AND DISCUSSION

Climatic data during the growing period at the study area

The climatic data for 2025 at the study area indicate a typical tropical savanna climate with distinct wet and dry seasons.

As shown in Table 1, the dry season spans from November to March, while the wet season occurs from April to October, with the peak rainfall months being June to September. There was no rainfall in January, February and December; these months recorded 0.0 mm of monthly rainfall**.** The highest rainfall of 260.2 mm was recorded in August, with an average temperature of 25 ^oC, which was a good temperature requirement for rice seed germination and growth. The sunshine ranging from 91 to 100 days was optimum for rice growth and yields.

Table 1: Climatic data for the 2025 cropping season in the study area

Month	Rainfall (mm)	Average Temp (°C)	Humidity (%)	Wind speed (kt)		Sunshine (°F)	
				min	max	Day	night
January	0.0	27	12	9	24	94	78
February	0.0	30	11	9	26	97	83
March	0.4	33	29	9	21	100	90
April	35.9	34	31	11	37	100	90
May	58.5	31	42	10	33	95	86
June	167.4	29	50	9	32	91	82
July	138.0	27	63	9	24	85	78
August	260.2	25	71	8	22	83	77
September	150.2	26	68	7	26	86	77
October	41.7	28	51	8	31	91	79
November	3.2	29	29	7	26	97	79
December	0.0	28	18	7	21	96	79

Effect of weed control methods on Wild Rice weed population.

Wild rice infestation differed significantly between the two districts. The Tempane district recorded a mean weed population of ($102.0/m^2$), which was significantly ($P<0.001$) higher than (37.2 weeds $/m^2$) in the Garu district. The no treatment recorded significantly ($P<0.001$) the highest weed population of 129.8 weeds/m², followed by Plough only 99.5 weeds/m². There was no significant ($P>0.05$) difference between the glyphosate only and the plough + Glyphosate. Both treatments reduced wild rice populations from 99.5 and 129.8 to 22.5 and 26.7 weeds/m², respectively. The interaction between the districts and the control methods showed that the effectiveness of the control methods was dependent on location. There was highly significant ($P<0.001$) wild rice weed infestation at Tempane without Glyphosate application (Figure 1). Plough Only failed to provide acceptable weed control in Tempane, whereas herbicide action was consistent across the district.

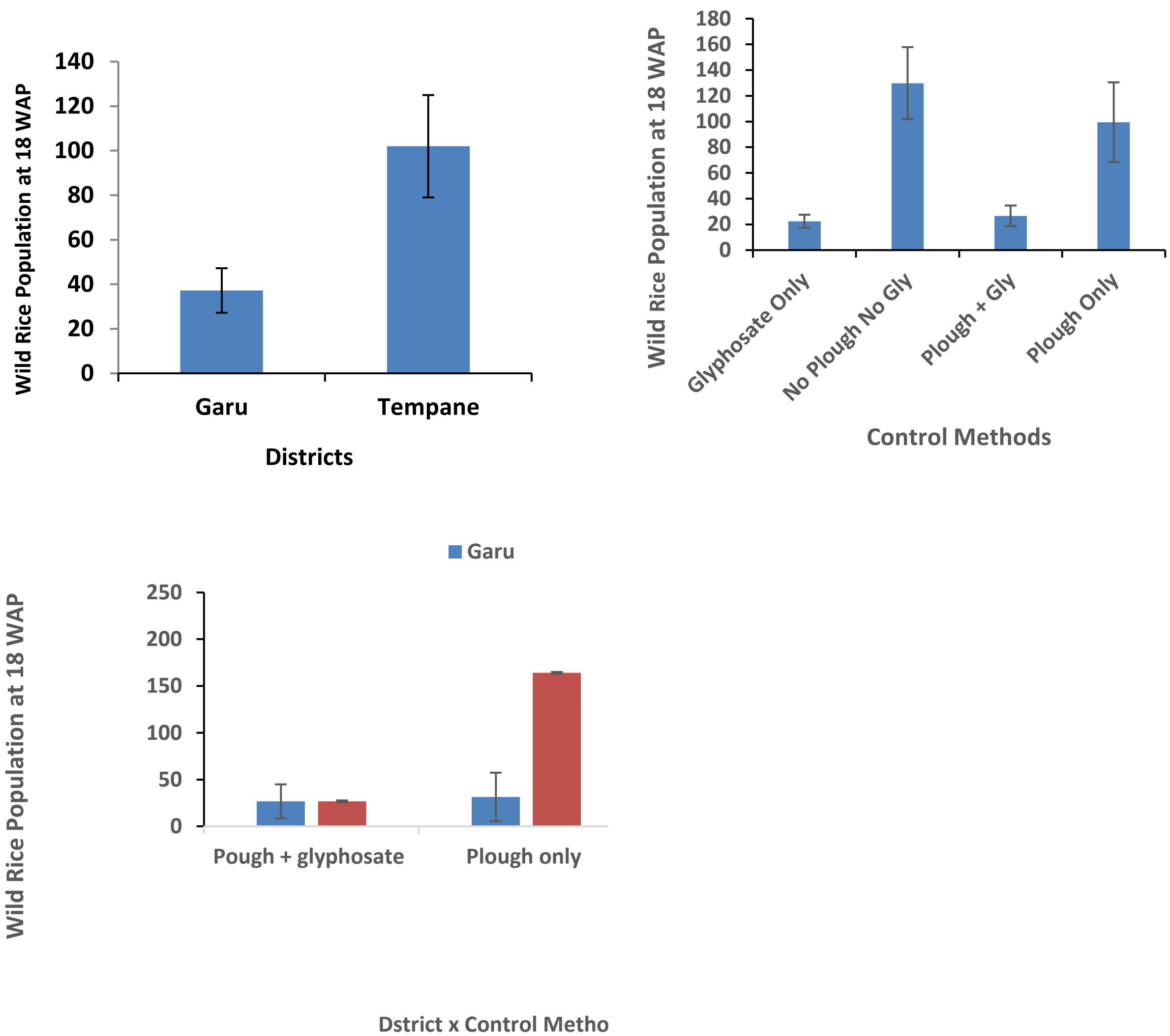

Figure 1: Effects of mechanical and chemical weed control methods on wild rice population.

Effect of Weed Control Methods on rice plant population density

The details of the effect of the control methods on rice population density are presented in Figure 2. The control method had a highly significant ($p < 0.001$) effect on the rice plant population density while the districts did not differ significantly ($p>0.05$) and the district × control method interaction was also not significant ($p > 0.05$).

Averaged across the districts, Glyphosate Only and Plough + Glyphosate maintained significantly the highest plant numbers with means of 424.8 and 423.3 plants/m^2, respectively. These were followed by Plough Only at 374.3 plants. No Treatment resulted in the lowest number of rice plants at 295.2. The differences between both glyphosate-based treatments and No Treatment indicated significant reduction in crop establishment under uncontrolled wild rice competition.

The interaction between districts and the control methods was not significant ($p>0.05$). This indicates that the effect of the integrated control method on rice plant population density was consistent across both locations.

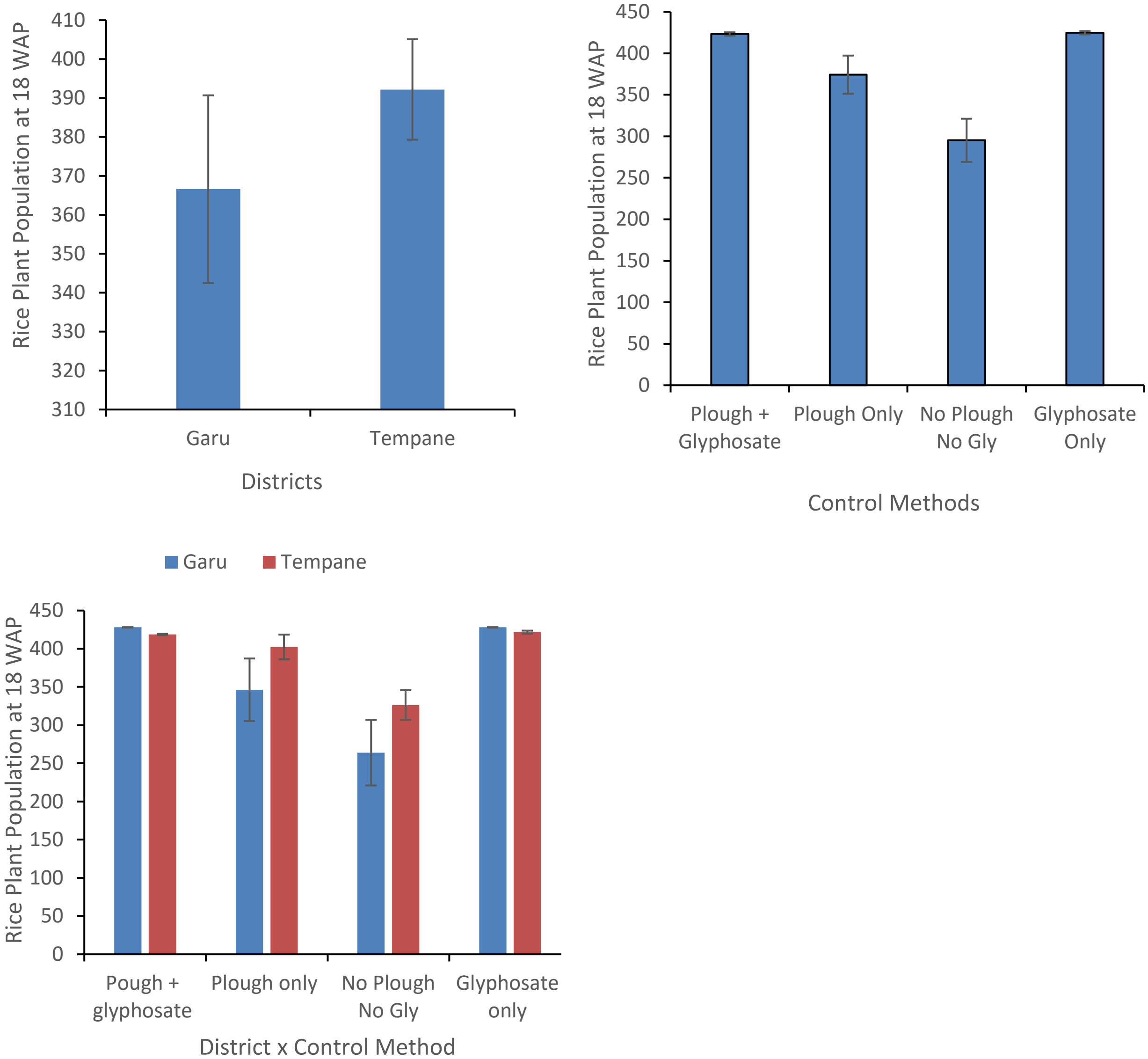

Figure 2: Effects of integrated mechanical and chemical weed control methods on rice population density.

Effect of weed control methods and district on grain yield (t/ha)

The grain yield obtained in the two districts differs significantly ($p < 0.05$), and the control method was highly significant ($p < 0.001$), but the interaction was not significant ($p > 0.05$). Garu district recorded a significantly higher mean grain yield of 3.12 t/ha, compared with 2.79 t/ha in Tempane district. Averaged across the districts, Plough + Glyphosate-treated fields produced significantly the highest mean rice grain yield ($p < 0.001$) of 3.70 t/ha, followed by Glyphosate Only (3.47 t/ha), Plough Only (2.93 t/ha) and No Treatment (1.72 t/ha).

Table 2: Effect of weed control methods and district on rice grain yield (t/ha)

District	Pough+ Gly	Plough only	No treatment	Gly only	Mean
Garu	3.87^{a}	3.23^{ab}	1.70^{c}	3.67^{a}	3.12^{a}

Tempane	3.53^{a}	2.63^{b}	1.73^{c}	3.27^{ab}	2.79^{b}
Mean	3.70^{a}	2.93^{b}	1.72^{c}	3.47^{a}	

Means with the same superscript are not significantly different at (P < 0.05).

Effect of weed control methods and district on biomass weight (kg/plot)

The rice biomass weight produced differed significantly among the districts (p<0.01), control methods (p < 0.001) and the interaction (p = 0.05). In Garu, the biomass weight produced was 13.49 kg/m^2 which was significantly higher than the biomass obtained in Tempane (12.83 kg/m^2), Among the control methods, Plough + Glyphosate produced significantly the highest biomass of 14.93 kg/m^2 in Garu and 13.17 kg in Tempane, with a mean of (14.05 kg/m^2). No Treatment application produced the lowest biomass weight of (12.27 kg/m^2) in Garu and (11.80 kg/m^2) in Tempane, with a mean of (12.03 kg/m^2).

Table 3: Effect of weed control methods and district on biomass (kg/m^2)

District	**Pough + Gly**	**Plough only**	**No treatment**	**Gly only**	**Mean**
Garu	14.93^{a}	12.97^{bcd}	12.27^{cd}	13.80^{d}	13.49^{a}
Tempane	13.17^{bcd}	12.43^{bcd}	11.80^{abc}	13.93^{ab}	12.83^{b}
Mean	14.05^{a}	12.70^{b}	12.03^{b}	13.87^{a}	

Means with the same superscript are not significantly different at (P < 0.05).

Effect of weed control methods and district on 1000-grain weight

The 1000-grain weight was not significantly affected by district (p>0.05), control method (p>0.05), or the interaction (p>0.05). From Table 4, values ranged from 22.97 g for No Treatment in Garu to 23.27 g for Plough + Glyphosate in Tempane.

Table 4: Effect of weed control methods and district on 1000-grain weight (g)

District	Pough+ Gly	Plough only	No treatment	Gly only	Mean
Garu	23.00^{ns}	23.23^{ns}	22.97^{ns}	23.17^{ns}	23.09^{ns}
Tempane	23.27^{ns}	23.17^{ns}	23.17^{ns}	23.2^{ns}	23.20^{ns}
Mean	23.13^{ns}	23.20^{ns}	23.08^{ns}	23.18^{ns}	

The superscript 'ns' = not significant at (P < 0.05).

Effect of weed control methods and district on harvest index (HI) of Rice

Harvest index was significantly affected by control method (p < 0.001) but not by district (p>0.05) or the interaction (p>0.05) (Table 5). At Garu, a harvest index of 20.54 % was recorded, and (19.53%) at Tempane. Among the control methods, Plough + Glyphosate recorded a mean HI of (23.77%), followed by Glyphosate application only (22.47%), followed by Plough only (21.02%). These were all significantly (P<0.05) higher than the No Treatment (12.57%).

Table 5: Effect of weed control methods and district on harvest index (%) of Rice

District	Pough + Gly	Plough only	No Treatment	Gly only	Mean
Garu	23.23^{a}	22.70^{a}	12.57^{a}	23.67^{a}	20.54^{a}
Tempane	24.3^{a}	19.33^{a}	13.2^{a}	21.27^{a}	19.53^{a}
Mean	23.77^{a}	21.02^{ab}	12.88^{c}	22.47^{a}	

Means with the same superscript are not significantly different at ($P < 0.05$).

Climatic conditions during the growing period in the study area

From January to May, the farmers in the study areas grew crops such as maize and millet. During this period, seeds and rhizomes are dormant in the rice fields. As the wet season begins in June, wild rice germination and growth increase, peaking in July when lowland rice production starts, leading to serious infestation. The dry season is ideal for implementing cultural control methods such as hand-weeding and roguing (Ahmed et al., 2010). During the wet season (July to September), high rainfall and humidity favour wild rice growth, making control difficult. Gianessis (2013) stated that wet conditions often cause weeds to re-root and re-establish. This period is suitable for herbicide application or biological control methods, as weeds are actively growing. The climatic requirements for rice growth and yield were optimal for panicle initiation, flowering, and grain filling. It was obvious that weed infestation and lack of proper control measures greatly affect rice yields in the district.

Effective management of wild rice populations is crucial at the onset of the rainy season, from June to July, when the rice plants are most vulnerable, and the moisture levels are moderate.

Effect of Weed Control Methods on Wild Rice (*Oryza longistaminata*) Population

The results of the study showed that glyphosate-based treatments, whether applied alone or in combination with mechanical ploughing, were substantially more effective in suppressing *Oryza longistaminata* populations than mechanical ploughing alone or the untreated fields in both districts. This may be attributed to the systemic action of Glyphosate that eventually destroys the entire biological structure of the weed by moving from the foliage to the root system. The systemic mode of action of glyphosate is particularly suited to managing perennial rhizomatous weed species (Kanatas et al., 2021).

The 2.7-fold higher infestation in Tempane versus Garu reflects differences in soil conditions. Weeds may be responsive to local environmental and soil conditions, such as soil nutrient status, pH and moisture content. It could also be attributed to rhizome load; *O. longistaminata* propagates through both shattered seeds and an extensive perennial rhizome system, and this dual reproductive strategy explains the rapid re-infestation observed in No Treatment plots, where populations persisted despite seasonal disturbances.

O. longistaminata re-emerges not only from seeds but also from an extensive network of underground rhizomes (Yoshida et al., 2016), which glyphosate can penetrate and destroy systemically. Pre-sowing applications of glyphosate or use of the herbicide on fallow land have been documented to provide effective control of weeds (Bentivegna et al., 2017; Lakara et al., 2019; Ņečajeva et al., 2026).

The failure of Plough Only in Tempane illustrates that mechanical tillage alone is insufficient for managing this weed species, and shallow tillage is often ineffective in controlling weeds. Grard et al. (2012) pointed out that manual weeding in addition to herbicide use reduced heavy wild rice infestation in Senegalese rice farmers' fields. Other integrated practices in African rice systems include zero tillage in combination with herbicides. This confirms the effectiveness of the use of an integrated approach to controlling weeds in rice fields (Alagbo et al., 2022).

The non-significant difference between Glyphosate Only and Plough + Glyphosate for wild rice density suggests that where spray coverage is adequate, glyphosate alone suffices for weed suppression. However, the added ploughing becomes agronomically relevant for crop establishment and yield.

Practically, farmers in high-infestation zones like Tempane cannot rely on ploughing alone. The consistent performance of glyphosate across districts indicates that herbicide access is the critical adoption constraint, not biophysical efficacy. Integrating mechanical and chemical tactics remains advisable to delay resistance and improve long-term control.

Effect of weed control methods on the yield parameters of rice

The yield results demonstrate the critical importance of weed management for rice productivity. The highest grain yield of 3.7 t/ha obtained from Plough + Glyphosate treated fields was achieved when wild rice was effectively suppressed, while the No Treatment produced only 1.72 t/ha. This represents a yield reduction of approximately 53.6% in the absence of any weed control. Similar yield losses of 51.09% and 60.98% were reported by Adeyemi et al. (2017). Sahoo et al. (2024) also documented yield losses attributed to O. longistaminata and other rice weeds.

Weeds are recognized as the most important yield-reducing factor in rice-based cropping systems in sub-Saharan Africa, with losses estimated to be at least 2.2 million tons of rice per year across the region (Rodenburg & Johnson, 2019). The yield of 3.12 t/ha obtained in Garu, compared with 2.79 t/ha in Tempane, directly confirmed weed pressure as the primary driver of spatial yield variability (Trevisan, 2021). Ploughing physically disrupts and exposes the rhizomes of *O. longistaminata* to desiccation and herbicide absorption (Mohapetra et al., 2025), while glyphosate targets surviving plants and regenerating rhizome tissues, producing a more complete and durable suppression of the weed (Duke, 2021). The synergistic benefit of integrated control strategies for rhizomatous weeds has been noted in West Africa (Benjamin et al., 2024), where farmers combine hand weeding with herbicide use, pre-irrigation, and crop rotations for integrated management of *O. longistaminata* (Rodenburg & Johnson, 2009).

The stability of 1000-grain weight, which ranges from 22.97 to 23.27 g, confirms that *O. longistaminata* does not impair grain filling This is consistent with findings in the wider literature (Long et al., 2023; Tong et al., 2023). 1000-grain weight is unaffected by various weed management techniques, with yield differences driven primarily by changes in effective tillers and grain numbers per panicle rather than individual grain weight (Koirala et al., 2020).

The reduction in harvest index under No Treatment versus under Plough + Glyphosate treatment provides compelling evidence of the damaging effect of *O. longistaminata* on rice productivity. Weed competition reduces average rice yield from 32 to 48% in competitive settings (Rodenburg et al., 2019). This indicates that while rice plants in no-weeded plots accumulated substantial biomass, they were unable to convert it efficiently into grain yield.

CONCLUSION

The study showed that the weed control methods significantly reduced wild rice infestation and increased rice yield in both districts. Biomass and harvest index were also highest in treated plots, demonstrating that severe wild rice competition significantly reduces the ability of rice plants to allocate resources to rice grain production. The Plough + Glyphosate treated fields recorded the highest grain yield of 3.7 t/ha when wild rice was effectively suppressed, while the No Treatment plots produced significantly lower rice yield of 1.72 t/ha. In Garu, no significant yield differences were recorded with Glyphosate application only (3.67 t/ha) compared to the Plough Only (3.23 t/ha). However, in Tempane, there was a significant difference in rice yields. Glyphosate application only recorded a rice yield of 3.27 t/ha, compared to Plough Only, which recorded 2.63 t/ha.

The study demonstrated that systemic herbicide action is essential for effective management of *Oryza longistaminata* in lowland rice systems of Garu and Tempane. Especially at Tempane were wild rice weed infestation was higher, ploughing alone could not reduce the weed populations to acceptable levels, indicating that mechanical fragmentation without chemical follow-up may not be effective in *O. longistaminata* endemic areas.

Recommendations

Rice farmers in the district should adopt ploughing plus glyphosate application for the management of wild rice (*O. Longistaminata)*. Primary tillage should be done early, especially during April-May to expose rhizomes to desiccation, followed by glyphosate application at 100 ml/15 L of water after ploughing in May–June when re-emerged shoots are at the 3–4 leaf stage. This timing aligns with peak rhizome sprouting and active translocation.

Where the cost of combining both methods may be unaffordable to the smallholder farmers, glyphosate application only should be prioritized over mechanical ploughing alone, as the results of this study indicate that Glyphosate application only treatment produced yields of 3.67 t/ha in Garu and 3.27 t/ha in Tempane, which was marginally lower than the combined treatment and substantially higher than the plough only. Extension workers in the Garu and Tempane Districts should incorporate training on the identification, biology and management of *Oryza longistaminata* into their farmer education programmes, to document its potential to cause yield losses of up to 56% as demonstrated in this study. Awareness of the weed's rhizomatous regeneration capacity is essential for farmers to understand why mechanical (tillage) control alone may not be adequate for achieving higher rice yields.

Direction for future research

Long-term multi-season field trials should be conducted to assess the cumulative effect of repeated glyphosate application and combined ploughing-herbicide treatments on *Oryza longistaminata* rhizome depletion over successive cropping seasons.

Further research should examine the cost-benefit analysis of the control methods, socio-economic factors including labour availability, access to credit, and gender dynamics that influence the adoption of effective weed management practices among rice farmers in the Upper East Region, to help make decisions about development and extension initiatives that are sensitive to the real limitations that confront smallholder farmers.

Contribution to knowledge

The study contributes to the growing body of literature on control of *O. longistaminata* in rice fields by providing empirical evaluation of the efficacy of the integrated control method to reduce the weed population and improve rice yields. By conducting the research in two districts, it offers a broader understanding of how the weed infestation could be site specific and, hence, farmers in high-infestation zones cannot rely on a single pass mechanical control method.

REFERENCE

Abdullahi, A. N., Musa, J., Usman, M., Alhassan, F. B., & Nahantsi, S. (2019). Consumer demand and preferences for local and imported rice among households in Sokoto metropolis, Nigeria. *Journal of Agriculture and Food Science,* 7(10), 295–301. https://doi.org/10.5281/zenodo.3521796

Adeyemi, O. R., Adigun, J. A., Hosu, D. O., Fanawopo, H. O., Daramola, O. S., & Osipitan, O. A. (2017). Growth and yield response of two lowland rice varieties (NERICA L-19 and WITA 4) as influenced by period of weed interference in the forest savanna agro-ecological zone of Southwest Nigeria. Nigerian Journal of Ecology, 16, 142–160.

Addison, M., Ohene-Yankyera, K., Acheampong, P. P., & Wongnaa, C. A. (2022). The impact of uptake of selected agricultural technologies on rice farmers' income distribution in Ghana. *Agriculture & Food Security*, 11(1), 2. https://doi.org/10.1186/s40066-021-00339-0

Adigun, J. A., Kolo, E., Adeyemi, O. R., Daramola, O. S., Badmus, A. A., & Osipitan, A. A. (2017). Growth and yield response of upland rice to nitrogen levels and weed control methods. *International Journal of Agronomy and Agricultural Research,* 11(6), 92–101. http://www.innspub.net

Ahmed, G. J. U., & Bhuiyan, M. K. A. (2010). Performance of weed management practices for different establishment methods of rice (Oryza sativa L.) in dry season. Pakistan Journal of Weed Science Research, 16(4). https://doi.org/10.59797/ija.v57i1.4612

Alagbo, O., Spaeth, M., Saile, M., Schumacher, M., & Gerhards, R. (2022). Weed management in ridge tillage systems—a review. *Agronomy*, 12(4), 910. https://doi.org/10.3390/agronomy12040910

Asaduzzaman, M. D., Islam, M. M., & Sultana, S. (2010). Allelopathy and allelochemicals in rice weed management. *Bangladesh research publications journal*, 4(1), 1-14. http://www.bdresearchpublications.com/admin/journal/upload/09146/09146.pdf

Benjamin, J., Idowu, O., Babalola, O. K., Oziegbe, E. V., Oyedokun, D. O., Akinyemi, A. M., & Adebayo, A. (2024). Cereal production in Africa: the threat of certain pests and weeds in a changing climate—a review. *Agriculture & Food Security*, 13(1), 18. https://doi.org/10.1186/s40066-024-00470-8

Bentivegna, D. J., Moyano, G. L., & Tucat, G. (2017). Determination of optimal doses of glyphosate for controlling weeds at several stages in southwestern Buenos Aires province (Argentina). *Journal of Plant Protection Research*. Vol. 57, No. 4: 347–354.

Boakye, S. (2025). Increasing Importation of Rice in Ghana: Can the Country Transform its Fortunes in The Rice Sector? Institute for Fiscal Studies. (June 02, 2025). www.ifsghana.org.

Daura N. S., Sagir B., Abubakar D., Faruk S. & Shehu A. (2026). Optimization of Rice Milling Processing Efficiency Using a Fractional Factorial Design: Evidence from Local Variety in Nigeria. *Journal of Basics and Applied Science Research* 4(1), 65-73. https://dx.doi.org/10.4314/jobasr.v4i1.8

Duke, S. O. (2021). Glyphosate: uses other than in glyphosate-resistant crops, mode of action, degradation in plants, and effects on non-target plants and agricultural microbes. Reviews of Environmental Contamination and Toxicology Volume 255: Glyphosate, 1-65. https://doi.org/10.1007/398_2020_53

Grard, P., T. Le Bourgeois, J. Rodenburg, P. Marnotte, A. Carrara, R. Irakiza, D. Makokha, G. kyalo, K. Aloys, K. Iswaria, N. Nguyen and G. Tzelepoglou (2012). AFROweeds V.1.0: African weeds of rice Montpellier, France & Cotonou, Bénin, Cirad-AfricaRice eds.

Geja, C. M., & Maphosa, M. (2023). Upland rice: A new high potential non-traditional cash crop for Africa. *African Journal of Food, Agriculture, Nutrition and Development*, 23(9), 24507-24522. https://ageconsearch.umn.edu/record/340758/files/Maphosa.pdf

Ghosh, P., Ghosh, P., Dolai, A. K., & Priya, A. (2025). Weed Management in Direct Seeded Rice: A Review. *Plant Archives*, 25(1), 2543-2551 https://doi.org/10.51470/Plantarchives.2025.v25.supplement-1.348.

Green, J. M. (2018). The rise and future of glyphosate and glyphosate-resistant crops. Pest management science, 74(5), 1035-1039. https://doi.org/10.1002/ps.4462

Jatav, H. S., Singh, S. K., & Singh, R. K. (2021). Mechanical weed management in rice. Indian *Journal of Weed Science*, 53(1), 1–8. www.indianjournals.com

Kanatas, P., Antonopoulos, N., Gazoulis, I., & Travlos, I. S. (2021). Screening glyphosate-alternative weed control options in important perennial crops. Weed Science, 69(6), 704-718. doi: 10.1017/wsc.2021.55 https://doi.org/10.1017/wsc.2021.55

Kolo, E., Adigun, J. A., Adeyemi, O. R., Daramola, O. S., & Bodunde, J. G. (2020). Effect of nitrogen levels and weed management methods on weed abundance and yield of upland rice. *Journal of Agricultural Sciences*, 65(2), 137–150. http://www.agrif.bg.ac.rs

Lakara, K., Verma, S., Maurya, A. C., Singh, S. B., Meena, R. S., & Shukla, U. N. (2019). Enhancing crop competitiveness through sustainable weed management practices. Sustainable agriculture, 109. https://doi.org/10.1111/wre.70026

Long, W., Li, N., Jin, J., Wang, J., Dan, D., Fan, F., ... & Li, S. (2023). Resequencing-based QTL mapping for yield and resistance traits reveals great potential of Oryza longistaminata in rice breeding. *The Crop Journal*, 11(5), 1541-1549. https://doi.org/10.1016/j.cj.2023.03.017

Mohapatra, P. K., Sarkar, R. K., Panda, D., & Kariali, E. (2025). Tillering behavior of rice plant. *Springer*. https://doi.org/10.1007/978-981-97-5235-5

Ņečajeva, J., Putniece, G., Sanžarevska, R., Šutka, A., Rancāns, K., & Zagorska, V. (2026). Effects of Glyphosate and Selective Herbicide Application Schemes on Weed Control and Species Diversity in Winter Wheat in the Zemgale Region of Latvia. *Agriculture*, 16(4), 464. https://doi.org/10.3390/agriculture16040464

Paaga, D. N. (2020). Market Participation and Its Effects on Output and Cost Efficiency of Rice Production in The Upper East Region, Ghana (Doctoral dissertation).

Rodenburg, J., Johnson, J. M., Dieng, I., Senthilkumar, K., Vandamme, E., Akakpo, C., & Saito, K. (2019). Status quo of chemical weed control in rice in sub-Saharan Africa. *Food Security*, 11(1), 69-92. https://doi.org/10.1007/s12571-018-0878-0

Tong, S., Ashikari, M., Nagai, K., & Pedersen, O. (2023). Can the wild perennial, rhizomatous rice species Oryza longistaminata be a candidate for de novo domestication? Rice, 16(1), 13. https://doi.org/10.1186/s12284-023-00630-7

Sahoo, S., Seleiman, M. F., Roy, D. K., Ranjan, S., Sow, S., Jat, R. K., & Gitari, H. (2024). Conservation agriculture and weed management effects on weed community and crop productivity of a rice-maize rotation. *Heliyon*, 10(10). https://doi.org/10.1016/j.heliyon.2024.e31554

Singh, S., Kumar, V., Datta, S., Wani, A. B., Dhanjal, D. S., Romero, R., & Singh, J. (2020). Glyphosate uptake, translocation, resistance emergence in crops, analytical monitoring, toxicity and degradation: a review. *Environmental chemistry letters*, 18(3), 663-702. https://doi.org/10.1007/s10311-020-00969-z

Trevisan, R. G., Bullock, D. S., & Martin, N. F. (2021). Spatial variability of crop responses to agronomic inputs in on-farm precision experimentation. Precision Agriculture, 22(2), 342-363. https://doi.org/10.1007/s11119-020-09720-8

Yoshida, A., Terada, Y., Toriba, T., Kose, K., Ashikari, M., & Kyozuka, J. (2016). Analysis of rhizome development in Oryza longistaminata, a wild rice species. *Plant and Cell Physiology*, 57(10), 2213-2220. www.pcp.oxfordjournals