Asian Journal of Food Research and Nutrition

Volume 3, Issue 2, Page 390-404, 2024; Article no.AJFRN.117659

Assessing the Impact of Combined Tillage and Herbicide Weed Management Combinations on Growth and Yield of Rice (*Oryza sativa* l.) in the Guinea Savannah Agroecological Zone of Ghana

Wandaat Y. E. [a*], Isreal K [b] and Karl Asekabta [c]

[a] CSIR-Savannah Agricultural Research Institute, P.O. Box- 52, Tamale, Ghana.
[b] Dzomeku University for Development Studies, P.O. Box -1350, Tamale, Ghana.
[c] Bolgatanga Technical University, P.O. Box -767, Bolgatanga, Ghana.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here:
https://www.sdiarticle5.com/review-history/117659

Original Research Article

Received: 22/03/2024
Accepted: 26/05/2024
Published: 29/05/2024

ABSTRACT

Rice production in resource-constrained environments with poor inherent soil nutrition also adversely affected by weeds depends on tillage and herbicide weed management systems that provide high yields and preserve soil, and biodiversity. The research was conducted in the Guinea savannah agroecology of Ghana, during the 2022 cropping seasons at two locations (Botanga and

---

**Corresponding author: E-mail: ewandaat@yahoo.com;*

Cite as: *Wandaat Y. E., Isreal K, & Asekabta , K. (2024). Assessing the Impact of Combined Tillage and Herbicide Weed Management Combinations on Growth and Yield of Rice (Oryza sativa l.) in the Guinea Savannah Agroecological Zone of Ghana. Asian Journal of Food Research and Nutrition, 3(2), 390–404. Retrieved from https://www.journalajfrn.com/index.php/AJFRN/article/view/141*

Golinga) to evaluate the impact of tillage and herbicide weed management systems on the sustainable production of lowland rice variety AGRA rice by resource-poor farmers. The experiment was a 3 x 3 factorial laid out in a split-plot design with three replications. The factors consisted of a tillage system at three levels (no-tillage, conventional tillage, and minimum tillage) laid out as main plots and herbicide weed management (pendimethalin 400 g a.i. /ha applied as pre-emergence, bispyribac sodium 25 g a.i/ha applied as post-emergence, and pendimethalin 400 g a.i /ha + bispyribac sodium 25 g a.i/ha applied as pre and post-emergence) laid on the subplot. All parameters measured had a significant two-way interaction effect on tillage and herbicide weed management systems ($P < 0.05$). The grain yield of rice was significantly influenced by minimum tillage systems with pre + post-emergence herbicides giving the highest yield of 8,642 kg/ha at Golinga whilst recorded the highest grain yield of 8,016 kg/ha with the same treatment combinations. This interaction also gave the highest benefit/cost ratio of 4.6. Weed density and biomass were recorded highest in pendimethalin entries but decreased under bispyribac sodium and further declined with pendimethalin + bispyribac sodium application.

Keywords: Tillage; weed control; factorial; replication; yield.

1. INTRODUCTION

Tillage operations are often performed by most resource-poor farmers who lack supporting finances for hiring tillage services and have insufficient knowledge of the effect of these operations on soil physical properties and crop responses. According to Alhammad*, et al.* [1] the objective of tillage is to develop a desirable soil structure or suitable tilth for a seedbed. Tillage is carried out mainly to loosen the upper layer of the soil, to mix the soil with fertilizer and organic residues, to control weeds, and to create a suitable seedbed for germination and plant growth [2-7]. Tillage is crucial for crop establishment, root growth, and ultimately, yield. Tillage is known to influence soil physical, chemical, and biological characteristics, which in turn alter plant growth and yield Though with varied geolocated beneficial impacts, tillage systems are site-specific and depend on crop, soil type, and climate [8]. The appropriate tillage system in a given location and weed management system can promote crop growth, yield, hunger reduction, and sustenance of crop production [9-11].

Cereal production is a major component of small-scale farming in Ghana. Rice (*Oryza sativa* L.) is the second most important cereal crop produced in Ghana next to maize and is fast becoming a cash crop for many farmers [12]. Rice is widely consumed as a staple food, with approximately 63 kg annual per capita consumption [13]. The crop contributes significantly to consumer diets and accounts for about 9 % of total caloric intake [14]. Rice represents the tenth agricultural commodity by value of production, accounting for about 45 % of the total area planted by cereals and is one of the most important crops for Ghana's agricultural sector and for food security [13].

Weed interference causes weeds to compete with rice plants for space, nutrients, water, and light, thereby minimizing the niche available to the rice plant. Additionally, weeds may exude certain chemicals that may affect the normal functioning and growth of the rice plant (allelopathy), thereby reducing crop yield and grain quality [15].

Weeds are the major pests that cause tremendous losses in rice production. The menace of weeds thus warrants management practices that are effective in reducing their competition with crops [16]. Good weed management coupled with a proper tillage system, which prepares a fine seedbed for growing crops, and a balanced and adequate supply of essential plant nutrients needed to stimulate and promote crop growth are relevant to successful rice production [17] (Naveed *et al*., 2008).

Inappropriate tillage practices and poor soil management contribute to soil degradation, adversely affecting the environment and soil productivity [18]. Different tillage systems may modify soil physical properties depending on factors such as cropping history, soil type, climatic conditions, and previous tillage systems [19]. The suitability of soil for sustaining plant growth and biological activity is a function of physical and chemical properties [20-23].

Weeds control in Ghana is predominantly by chemical or mechanical means (hand weeding), and to a limited extent by cultural methods. Though cultural methods are still useful, they are laborious, time-consuming, and expensive, especially when labour is unavailable [24]. Hand weeding when carried out timely two or three times is effective in suppressing weeds and reduces yield losses, the practice is equally time-consuming, laborious, and expensive especially where labour is scarce [25]. Hand weeding alone accounts for 40-54 % of the total labour cost of farming in Ghana, and other African countries like Nigeria, Burkina Faso, Sierra Leone, Malawi, Zambia, Ethiopia, and Tanzania, requiring 300-400 man-hours per hectare [26].

In this regard, chemical weed control is an important alternative. Herbicide application has proven to be an effective way to control the menace of weeds and improve the growth and yield of rice production (Naveed *et al*., 2008). Herbicide usage in Ghana, and West Africa as a whole, is limited as compared to the developed countries [27]. Among the few farmers that apply herbicides in Ghana do not apply adequate amounts of the recommended rates, citing the high cost of the product (Mahajan *et al*., 2005). To fully realize the usefulness of herbicide usage in rice production, proper attention must be paid to the selection of herbicides, time of application, and dosage [28]. The use of herbicides with rice in Ghana may be of great help to the farmer. Several pre and post-emergence selective herbicides are available in the Ghanaian market for weed control in rice production. However, [29,30] suggested proper scrutiny of these herbicides in their respective regions must be made in accordance with the cultivation system, the soil, rainfall, and existing species of weeds.

Though the integration of tillage systems and weed management are widely known to impact rice productivity, there is generally a lack of knowledge in the integration of these factors that could enhance rice growth and productivity in the Guinea Savannah Agro-Ecological Zone of Ghana. This research aimed to determine the combined advantage of tillage and weed management on the growth and yield of rice and its economic benefits.

2. MATERIALS AND METHODS

The study was conducted under irrigated conditions at two lowland rice experimental fields of Golinga and Botanga Irrigation Schemes, between January to May 2020. Golinga lies on latitude 09° 25” N and longitude 1° 00” W of the equator at an altitude of 183 m above sea level, whilst Botanga is between latitude 9.20ºN and 9.2.00ºN and longitude 0.55ºN and 0.55ºW. The study area is in the Guinea-savannah agro-ecological Zone of Ghana. The soil is sandy loam in texture in both layers of 0–15 cm and 15–30 cm. The mean annual rainfall for both locations is 1000 mm. The average minimum and maximum daily temperatures at both locations range between 19ºC and 41ºC.

2.1 Experimental Design and Treatments

The study was a 3 x 3 factorial experiment: comprising three tillage systems (Zero, conventional, and minimum tillage) and three weed management systems (Pre-emergence, post-emergence, and pre + post-emergence selective herbicides application). The 9 treatments were laid out in split-plot design, in three replications and the test rice variety was “AGRA Rice” on lowland.

2.2 Land Preparation and Experimental Layout

The experimental area of 2464 m^2 was demarcated into three replications, each measuring 800 $m^{2,}$ and three main plots, each measuring 256 m^2. The main plots were divided into three subplots (80 m^2 each), which were further divided into three sub-sub plots (25 m^2). Spacing of 0.5 m, 1 m, and 2 m was left between sub-plots and sub-sub-plots, main plots, and replications respectively.

Tillage systems were randomly assigned to the main plots. Zero tillage plots were left undisturbed after land clearing. Conventional tillage plots were ploughed and harrowed after land clearing, whilst minimum tillage plots were ploughed at a depth of 15 cm and harrowed. Weed control management (pre, post, and pre + post-emergence selective herbicides) was randomly assigned to subplots. Pendimethalin (0.4 kg a.i. /ha) was used as the pre-emergence herbicide and applied two days after sowing. This was followed by one-hand weeding at 35 days after sowing. Bispyribac sodium (0.025 kg a.i. /ha) was used as post post-emergency selective herbicide and was applied at 35 days after planting. Application of post-emergence selective herbicide was however preceded by hand weeding at 15 days before Bispyribac sodium application. For plots that were assigned pre + post-emergence selective herbicides, pendimethalin and bispyribac sodium were applied 2 and 30 days after sowing.

Five plants were tagged per plot for measurements of growth, dry matter yield, and yield components as described in Maddonni*, et al.* Plant height and number of tillers per plant were measured at weekly intervals for twelve weeks beginning from three weeks after planting. Weed density and biomass, straw weight, and 1000-seed weight were determined at harvest.

All data were analyzed using the Genstat statistical package, 12th edition. Treatment differences were compared using the Least Significant Difference (LSD) procedure at 5% level of probability.

The Benefit-cost (BC) ratio was calculated according to Adegede and Dittoh (1985).

3. RESULTS

3.1 Weed Occurrences

At Botanga, the dominant weeds observed in the experimental field were comprised of broadleaves, grasses and sedges. *Cyperus rotundus* (10.42%), *Oryza barthii* (10.42%) and *Amaranthus spinosus* L. (10.12) were the most prevalent weed species (Table 1). This was followed by *Euphorbia hirta* L. (9.51), *Tridax procumbens* (9.20) and *Cyperus eragrotis* (9.20). The least dominant weeds were observed as *Eleusine indica* (L.) *Scop* (4.91).

At Golinga, *Oryza barthii* (10.15%) was the most prevalent weed species followed by *Amaranthus spinosus* L. (8.59%) and *Solanum nigrium* (8.29%), *Cyperus eragrotis* (7.68%), *Tridax procumbens* (7.37%), C*yperus rotundus* (7.37%), *Cynodon dactylon* (L.) Pers. (7.06%) and C*yperus alternifolius* (7.06%). The least dominant weeds were *Digitaria sanguinalis* (L.) *Scop* (3.68) recorded the least weed dominant at (Table 2).

3.2 Weed Density

At Botanga, there were no three-way and two-way interactions *(P > 0.05)* between treatments for the various weeks. However, weed density was significantly influenced by the tillage system *(P < 0.05)* at 6 and 8 WAP. Minimum tillage recorded the lowest weed density of 1.56 plants/m^2, followed by no-tillage at 2.93 plants/m^{2,} and conventional tillage recorded the highest weed density of 3.19 plants/m^2 at 6 WAP (Fig. 1). Similar results were recorded for weed density at 8 WAP. Weed density was significantly influenced by weed management *(P < 0.05)* at 6 and 8 WAP. Pre+ post-emergence herbicide recorded the lowest weed density of 1.56 plants/m^2 (Fig. 2) at 6 WAP. This was followed by post-emergence herbicide application that recorded 2.48 plants/m^2 and pre-emergence herbicide 3.63 plants/m^2 at 6 WAP. Similarly, pre + post-emergence herbicide recorded the lowest weed population of 0.89 plants/m^2 at 8 WAP. This was followed by post-emergence herbicide and pre-emergence herbicide1.52 plants/m^2 with pre-emergence recording the highest weed density of 3.22 plants/m^2.

Table 1. Quantitative scoring of weed species frequency (F), density (D), and summed dominance ratio (SDR) at Botanga experimental rice field during 2022 cropping season.

	Number of quadrat							
	1	**2**	**3**	**4**	**5**	**F**	**D**	**SDR%**
Weed species	Weed density (scale 0-4)							
Ageratum conyzoide L.	3	2	4	2	1	5	12	8.29
Amaranthus spinosus L.	3	4	4	3	4	5	18	10.12
Commelina benghalensis L.	0	4	3	2	0	3	9	5.52
Cynodon dactylon (L.) Pers	0	3	3	2	4	4	12	7.36
Cyperus eragrotis L.	3	3	2	4	3	5	15	9.20
Cyperus rotundus L.	4	4	3	4	4	5	19	10.42
Digitaria sanguinalis (L.) *Scop*	3	1	0	3	2	4	9	6.45
Eleusine indica (L.) *Gaertn*	1	0	4	2	0	3	7	4.91
Euphorbia hirta L.	4	4	3	3	2	5	16	9.51
Solanum nigrium L.	2	4	2	3	2	5	13	8.59
Oryza barthii A. Chev. & Roehr	4	4	4	4	3	5	19	10.42
Tridax procumbens L.	3	3	4	1	4	5	15	9.20
Total						54	164	100.00

*Weediness = ½ (f/Σf +d/Σd)*100. Frequency of occurrence (F), density of weed species (D), and summed dominance ratio (SDR) expressed in percentages*

At Golinga, weed management significantly affected weed density. Pre + post-emergence herbicide treatment recorded the lowest weed density of 1.59 plants/m^2 at 6 WAP (Fig. 3). This was followed by post-emergence herbicide application recording 2.52 plants/m^2 while pre-emergence herbicide recorded the highest weed density of 4 plants/m^2. Similar results were recorded at 8 WAP.

Table 2. Quantitative scoring of weed species frequency (F), density (D), and summed dominance ratio (SDR) at Golinga experimental rice field during 2022 cropping season

	Number of quadrat							
	1	2	3	4	5	F	D	SDR %
Weed species	**Weed density (scale 0-4)**							
Ageratum conyzoide L.	2	2	3	0	1	4	8	6.14
Amaranthus spinosus L.	3	2	1	3	4	5	13	8.59
Centrosema pubescens (L.) Benth	1	0	2	1	2	4	6	5.53
Commelina benghalensis L.	0	2	1	2	1	4	6	5.53
Cynodon dactylon (L.) Pers	0	2	3	2	4	4	11	7.06
Cyperus alternifolius L.	2	0	2	3	4	4	11	7.06
Cyperus eragrotis L.	1	2	2	3	2	5	10	7.68
Cyperus rotundus L.	1	2	2	1	3	5	9	7.37
Digitaria sanguinalis (L.) *Scop*	1	1	1	3	0	2	6	3.68
Eleusine indica (L.) *Gaertn*	1	0	3	2	0	3	6	4.61
Euphorbia hirta L.	0	2	3	0	2	3	7	4.91
Oryza barthii A. Chev. & Roehr	3	4	3	4	3	5	17	10.15
Sida acuta L.	0	2	2	1	3	4	8	6.14
Solanum nigrium L.	2	3	2	3	2	5	12	8.29
Tridax procumbens L.	1	3	2	1	2	5	9	7.37
Total						62	139	100.0

*Weediness = ½ (f/Σf +d/Σd)*100. Frequency of occurrence (F), density of weed species (D), and summed dominance ratio (SDR) expressed in percentages.*

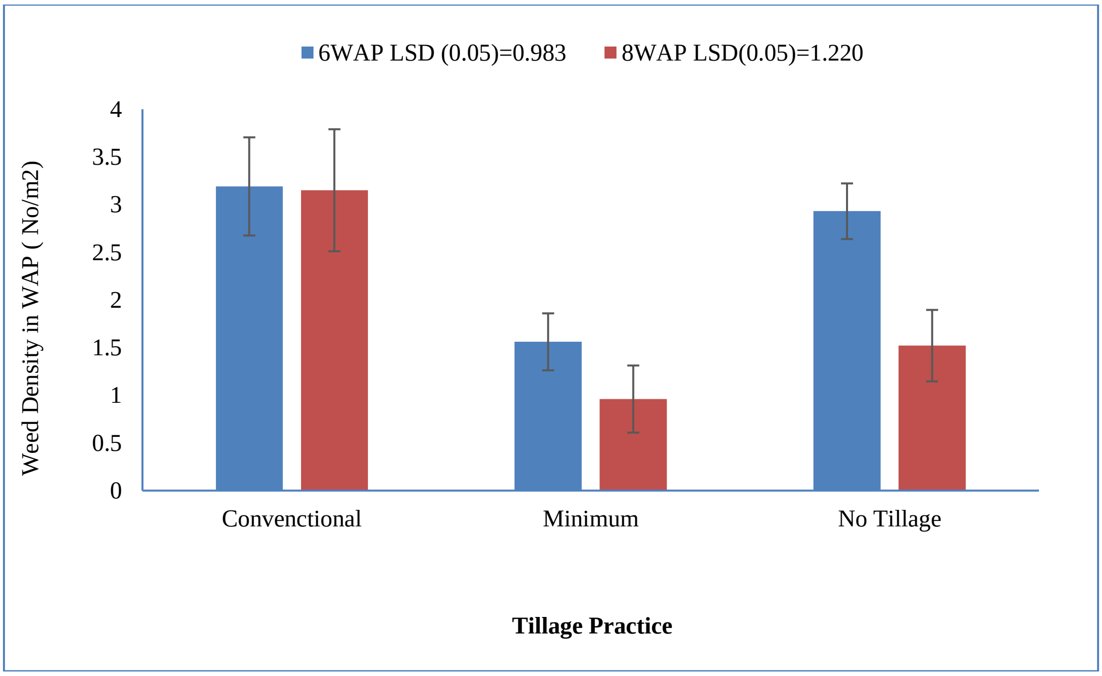

Fig. 1. Effect of tillage system on weed density of rice at 6 and 8 WAP, at Botanga, 2022 cropping season. Error bars: +/- SE

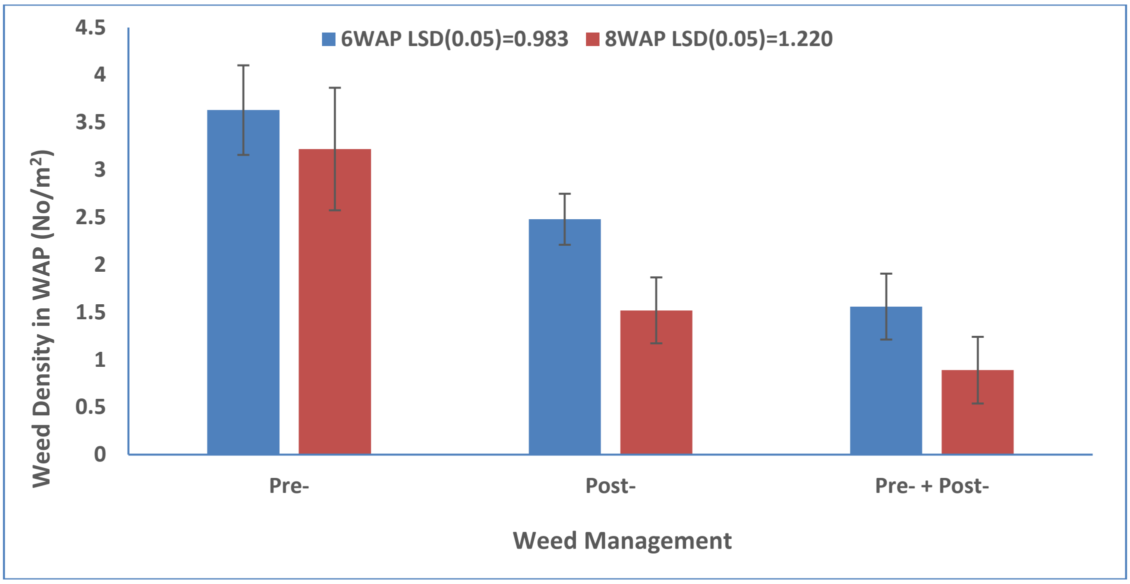

Fig. 2. Effect of weed management on weed density of rice at 6 and 8 WAP, grown at Botanga, 2022 cropping season. Error bars: +/- SE. Pre = Pre-emergence herbicide, Post = Post-emergence herbicides, Pre + Post = Pre + Post-emergence herbicide

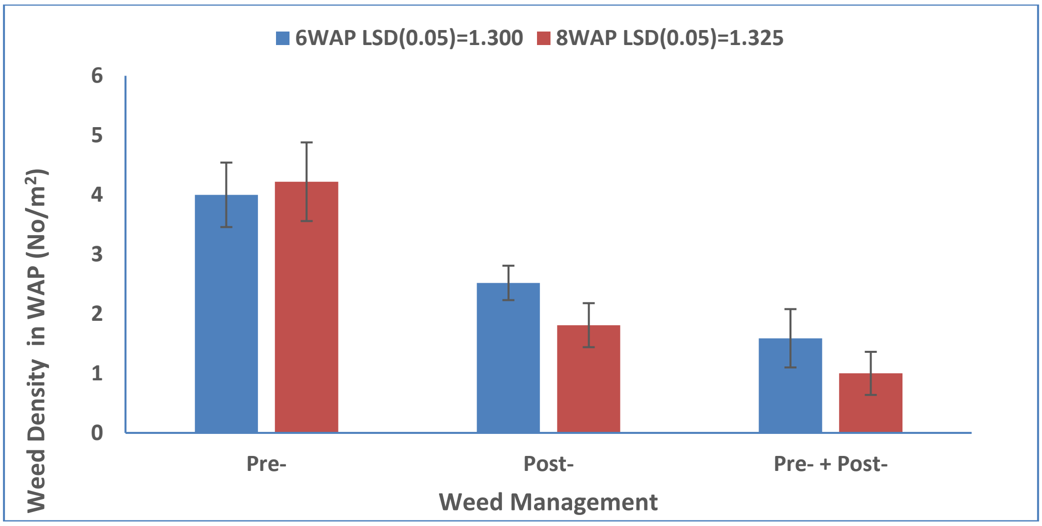

Fig. 3. Effect of weed management on weed density of irrigated rice at 6 AND 8 WAP, grown at Golinga, 2022 cropping season. Error bars: +/- SE. Pre = Pre-emergence herbicide, Post = Post-emergence herbicides, Pre + Post = Pre + Post-emergence herbicide

3.3 Weed Density and Biomass

Weed control management significantly *(P<0.05)* influenced weed density and weed biomass such that the highest weed density of 159 plants/m^2 (Fig. 4) and weed biomass of 4 kg/m^2 (Fig. 5) were recorded by pre-emergence herbicide application. Both parameters decreased with the use of post-emergence selective herbicide and further reduction with pre + post selective emergence selective herbicide applications.

3.3.1 Plant height

Botanga had a two-way interaction effect *(P < 0.05)* between the tillage system and herbicide weed management on plant height at 6 and 8 WAP. The combination of pre-emergence herbicide application with no-tillage system recorded the highest plant height of 44.67 cm and 60.53 cm for weeks 6 and 8 respectively (Fig. 6). This was followed by pre + post-emergence selective herbicide application plus conventional tillage system, which recorded a similar plant height of 60.4 cm at 8WAP. Sole post-emergence selective herbicide with conventional tillage system, sole pre-emergence herbicide application and minimum tillage and sole post-emergence selective herbicides with no tillage system produced similar plant height of 58.8 cm, 58.3 cm, and 58.0 cm respectively at 8WAP, and were the least entries.

Golinga had a two-way interaction effect *($P < 0.05$)* between the tillage system and herbicide weed management on plant height at 6 and 8 WAP. The combination of pre + post emergence herbicide application with minimum tillage system recorded the highest plant height week 6 and 8 respectively (Fig. 7). This was followed by pre + post-emergence selective herbicide application plus conventional tillage system, which recorded similar plant height at 8WAP. Sole post-emergence selective herbicide plus conventional tillage system, sole pre-emergence herbicide application plus minimum tillage and sole post-emergence selective herbicides plus no tillage system produced similar plant height at 8WAP, and were the least entries.

3.2 Effective Tillers

The main effect of tillage system and weed control management interactions had no significant *($P>0.05$)* effect on number of effective tillers.

3.3 Grain Yield

At Botanga, there was a two-way interaction effect *($P < 0.01$)* between the tillage system and herbicide weed management that significantly affected the grain yield of rice. Treatments of pre + post-emergence under minimum tillage recorded the highest grain yield of 8,016 kg/ha (Fig. 8). This was followed by pre + post-emergence application under conventional tillage that recorded a grain yield of 6,821 kg/ha but was similar to post-emergence under minimum tillage system that recorded 6,567 kg/ha. The lowest grain yield of 3,347 kg/ha was recorded by pre-emergence herbicide application under a no-tillage system.

At Golinga, there was a two-way interaction effect *($P < 0.004$)* between tillage systems x herbicide weed management significantly affected grain yield of rice. Applying pre + post-emergence under minimum tillage recorded the highest grain yield of 8,642 kg/ha (Fig. 9). This was followed by post-emergence under minimum tillage recording a grain yield of 7,604 kg/ha. Pre + post-emergence under conventional tillage and post-emergence under conventional tillage produced similar results. The lowest grain yield of 4,285 kg/ha was recorded pre-emergence herbicide application under a no-tillage system.

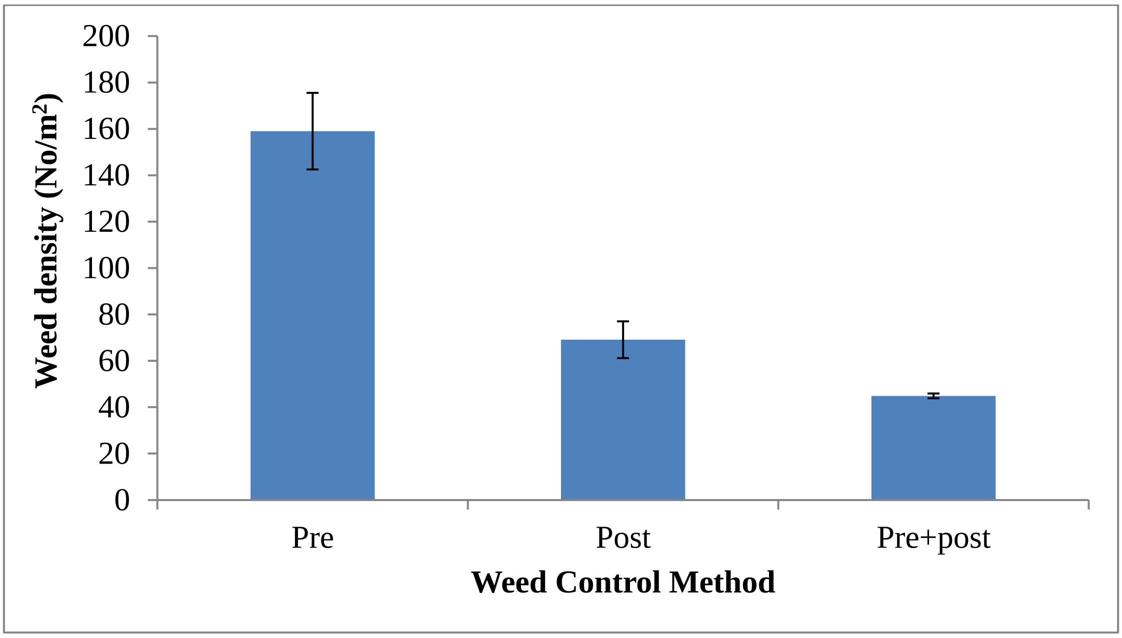

Fig. 4. Effect of weed control management on weed density. Bars represent SEM. Pre = Pre-emergence herbicide, Post = Post-emergence herbicides, Pre + Post- = Pre + Post-emergence herbicide

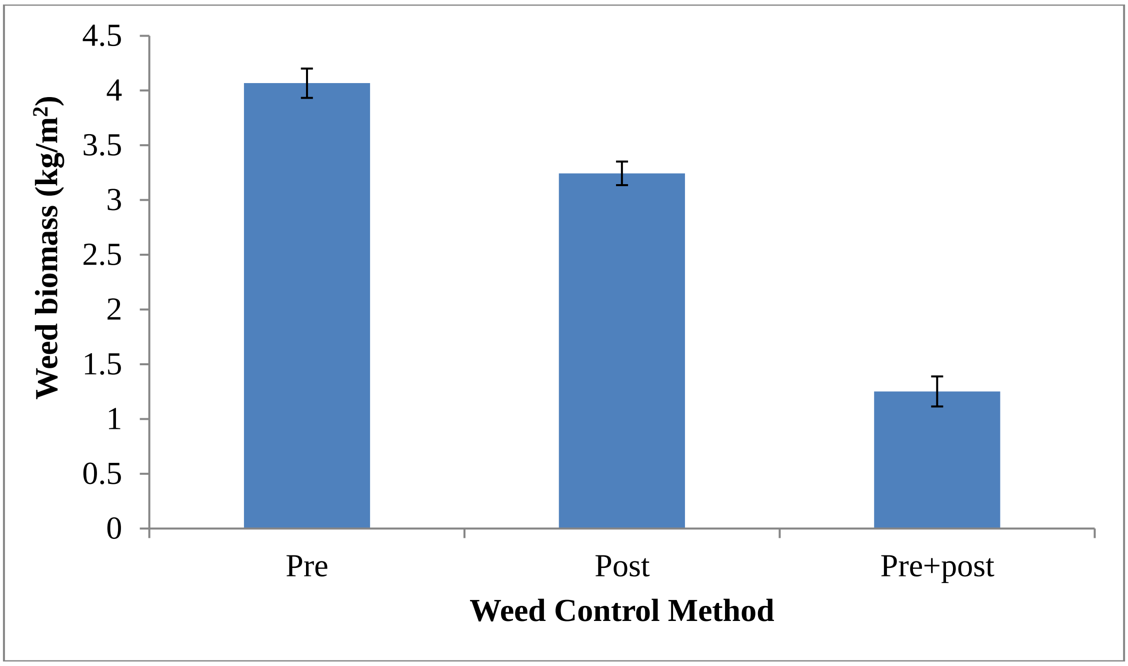

Fig. 5. Effect of weed control management on weed biomass. Bars represent SEM. Pre = Pre-emergence herbicide, Post = Post-emergence herbicides, Pre + Post = Pre + Post-emergence herbicide

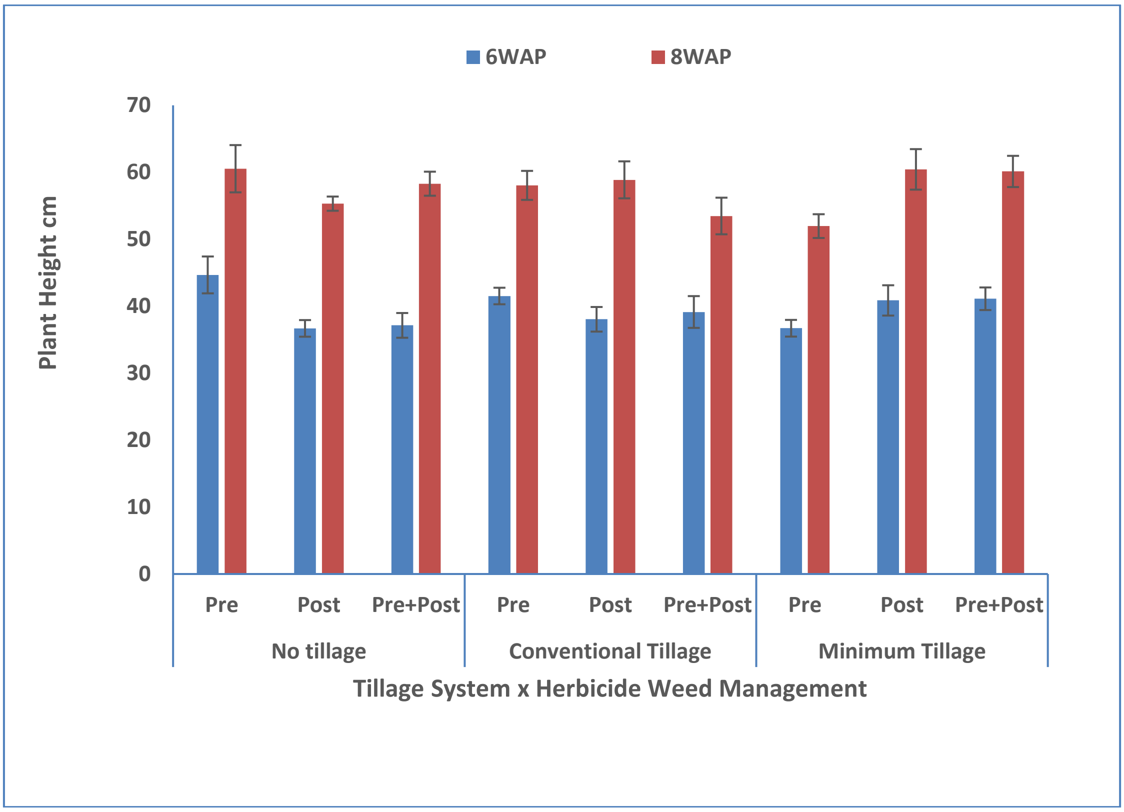

Fig. 6. Effect of tillage system and herbicide weed management application on plant height of rice, grown at Botanga, 2022 cropping season. Error bars: +/- SE. Pre = Pre-emergence herbicide, Post = Post-emergence herbicides, Pre + Post- = Pre + Post-emergence herbicide

Table 3. Effect of tillage system and weed control management on effective tillers

	Weed control method		
Tillage system	**Pre**	**Post**	**Pre + post**
Zero	4.33	4.00	5.33
	4.00	4.33	7.00
	6.67	4.67	10.33
Conventional	5.30	4.00	5.33
	5.67	4.00	6.67
	7.00	4.33	8.67
Minimum tillage	4.67	4.33	7.00
	5.33	4.33	9.00
	6.67	4.33	11.33
	LSD (0.05)		11.01

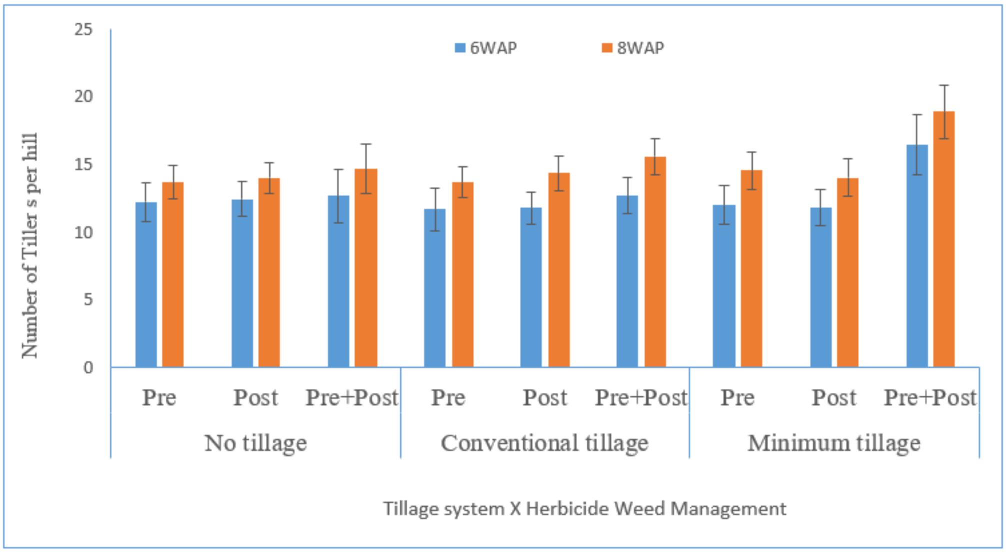

Fig. 7. Effect of tillage system and herbicide weed management application on plant height of rice, grown at Golinga, 2022 cropping season. Error bars: +/- SE. Pre = Pre-emergence herbicide, Post = Post-emergence herbicides, Pre + Post = Pre + Post-emergence herbicide

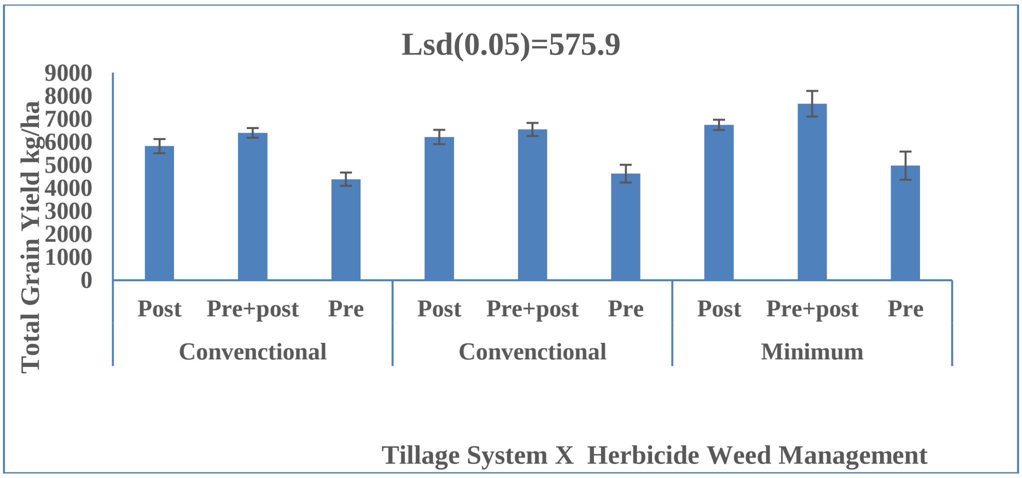

Fig. 8. Effect of tillage systems and weed control management on grain yield at Botanga during 2022 cropping season. Bars represent SEM. Pre = Pre-emergence herbicide, Post = Post-emergence herbicides, Pre + Post = Pre + Post-emergence herbicide

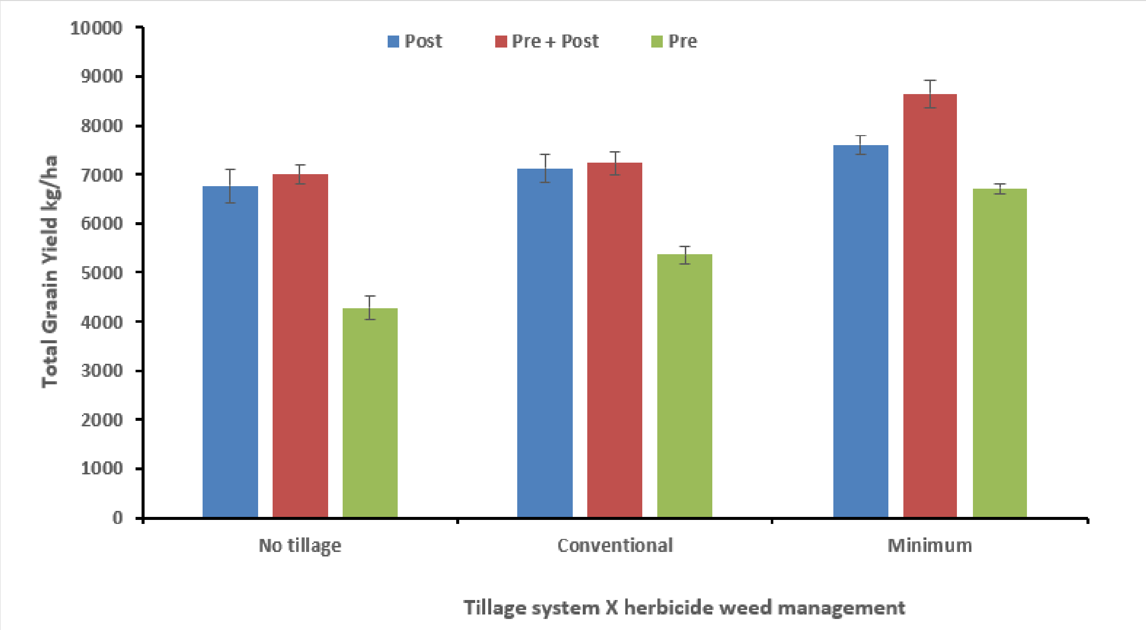

Fig. 9. Effect of tillage systems and weed control management on grain yield at Golinga. Bars represent SEM. Pre = Pre-emergence herbicide, Post = Post-emergence herbicides, Pre + Post = Pre + Post-emergence herbicide

Table 4. Benefit-cost analysis influence of tillage system x weed control management interactions on yield of rice

Tillage System	Weed Management	Service charges (GHC)	Input cost (GHC)	Labor cost (GHC)	Total cost (GHC)	Total revenue (GHC)	Benefit/cost ratio
Zero	Pre	155	80	100	335	960	2.9
Conventional	Pre	382	80	100	562	1040	1.9
Ripped & M	Pre	255	80	100	435	1080	2.5
Zero	Post	169	75	100	343	1366	4.0
Conventional	Post	394	75	100	570	1440	2.5
Ripped & M	Post	281	75	100	445	1740	3.9
Zero	Pre + Post	181	155	75	411	1740	4.2
Conventional	Pre + Post	402	155	75	638	1620	2.5
Ripped & M	Pre + Post	297	155	75	511	2340	4.6

3.4 Benefit-Cost Analysis

The result of the benefit-cost ratio is presented in Table 4. The interactions of the minimum tillage system with pre + post-emergence herbicide application recorded the highest benefit-cost ratio of 4.6, followed by the interactions of the zero-tillage system with pre + post-emergence herbicide application which recorded a benefit-cost ratio of 4.2. The least benefit-cost ratio of 1.9 was recorded by the interactions of the conventional tillage system with pre-emergence herbicide application.

4. DISCUSSION

4.1 Weed Occurrences, Density, and Biomass

sustainability if not controlled effectively through proper weed management practices in tillage systems (Dzomeku *et al*., 2007). The significant variation in weed density and biomass among the weed management options is attributed to the differences in the efficiency of weed control. A combination of both pre and post-emergence herbicides relatively smothered weeds more at a prolonged duration as compared to either sole pre or post-emergence selective herbicide application and accounted for the relatively lower weed density and biomass. In pre-emergence herbicide application plus one-hand weeding at 5 WAP, weeds resurged 8 WAP at Golinga aggressively, after herbicide application, the supplementary one-hand weeding could not have been enough to control weeds beyond the critical stage of the rice growth. The sole post-emergence herbicide application preceded by one-hand weeding smothered weeds beyond the critical rice growth period could not have been adequate to sustain weed control. This could have accounted for the difference in weed density and biomass among sole pre and post-emergence herbicides. These findings agreed with the findings of Ahmed *et al*. (2014) who reported on the efficacy of combined application of pre-emergence and post-emergence herbicides in reducing weed interference in rice production.

4.2 Plant Height

At both locations, the observed increased plant height under minimum tillage combined with pre and post-emergence herbicide application could have been due to increased soil organic matter and available phosphorus from the effects of the tillage system and appropriate weed management. Nath *et al*. [31] observed major determinants of growth and sustainability in rice are good tillage and efficient weed management. The results are also in agreement with [32] who reported that shoot development is dependent on root development and increasing tillage depth would improve the vegetative growth of rice plants. The potential of pre + post-emergence herbicide application to enhance plant height more than sole pre or sole post-emergence herbicide could be attributed to enhanced efficiency of pre + post-emergence herbicides to have a prolonged smothering effect on weeds especially at most critical periods of growth and development of rice under efficient tillage system or good fertility regime.

4.3 Tillering

At both locations, weed management efficacy, induced by pre + post-emergence herbicide application was relatively higher than in sole pre or sole post-emergence herbicide application. The high weed control efficiency might have reduced weed competition in designated plots, allowing the crop to grow uninterruptedly and resulting in a relatively higher number of tillers than sole pre and sole post-emergence selective herbicide application. This is similar to the findings of Pandey *et al*. [33] Maximum tillering with the application of minimum tillage and pre-emergence plus post-emergence herbicide showed that the combined effect of good tillage practice and weed control was required for maximum tillering (Fig. 9).

4.4 Grain Yield

At Botanga, results showed significant interactions between tillage system and herbicide weed management on grain yield of rice. A grain yield of 8,016 kg/ha was attained under minimum tillage with pre+post-emergence herbicide application. Weeds are major pests that cause tremendous losses in rice grain yield. The discoveries confirmed those of Pradhan *et al*., [34] who expressed that when soil is exposed to broad and dull tillage, it becomes inclined to critical run-off and soil disintegration rates, as well as soil decay. Therefore, soil usefulness keeps on lessening, bringing about low agrarian yields [35]. Mineral manure expansion ordinarily brings about an overall absence of reaction in a few crumbled soils. The menace of weeds thus warrants management practices that are effective in reducing competition with crops. Sahoo *et al*., [36] and Chauhan *et al*., (2012) stated that keeping rice fields devoid of weeds, especially at critical periods of crop growth is very essential for maximizing yield. Good weed management coupled with a proper tillage system, a prepared fine seedbed for growing crops, balanced and adequate supply of essential plant nutrients needed to stimulate and promote crop growth are relevant to successful rice production [37].

At Golinga, tillage system interaction with herbicide weed management promoted yield components and subsequently grain yield. Applying pre + post-emergence under minimum tillage recorded the highest grain yield of 8,642 kg/ha. This was followed by pre + post-emergence herbicide application under conventional tillage recorded a grain yield of 7,604 kg/ha. Post-emergence herbicide application under conventional tillage and post-emergence herbicide application under minimum tillage produced similar results. The least grain yield of 4,285 kg/ha was attained with pre-emergence under a no-tillage system. This agreed with the findings of (Chauhan *et al*., 2012.

4.5 Benefit-Cost Analysis

Minimum tillage system includes practices that keep the disturbance of the soil and loss of organic matter to a minimum, reducing soil and water losses, and proved to be the most economical among tillage systems. This is believed to be the economic and societal benefits derived from minimum tillage to improve quality of life (reduced labor, greater flexibility in planting); improved profitability (reduces wear and tear on equipment, saves fuel and fertilizer, improved productivity, carbon credits); and improved wildlife habitat (West *et al*., 2005). The effect of a minimum tillage system conserves soil and water and reduces risks to the environment. The many fungi, bacteria, and other microorganisms are the glues that hold individual soil particles together. They also process the roots and residue of the previous crops, cycling nutrients and carbon through the soil system (West *et al*., 2005).

Weed control has also proven to be an important constituent of the rice cropping system. Weed control especially at the critical periods of growth of rice has proven to be necessary if optimum yield is to be realized. Not only was the combined application of pre and post-emergence herbicide the most effective weed control method, but also the most economical (Table 4). This is in line with the findings of McNaughton and Wolf, [38] who mentioned weeds as economic pests of crops and recommended their control as essential to increasing productivity and income of farmers.

It is evident from the benefit-cost ratio that, though bi application of herbicide, increased the yield of rice, it was accompanied by a higher cost of production. This indicates that though herbicide application is very essential for increasing cereals production in Africa, its price is a major limitation to its utilization. This is highly evident, especially among resource-poor farmers who form the backbone of the agricultural sector in most developing countries [14].

5. CONCLUSION

From the results and the statistical analysis, the plant height of the rice plant under conventional and minimum tillage was similar and was in the range of 93.4 cm to 92.3 cm. The highest weed density of 159 plants/m^2 was recorded under sole pre-emergence herbicide application but decreased under post-emergence herbicide and further with pre + post-emergence herbicides to 44 plants/m^2. The lowest weed biomass was achieved under pre + post-emergence herbicides but increased with post-emergence herbicides and further with pre-emergence herbicides to 4 kg/m^2. Pre + post-emergence herbicide application with minimum tillage gave a grain yield of 8,016 kg/ha

At Golinga, a minimum density of 1.59 weed species/m^2 was attained under sole conventional tillage and sole pre-emergence herbicide application + one-hand weeding but increased under post-emergence herbicide and further with pre + post-emergence herbicides and sole minimum tillage to 4.4 weed species/m^2. Lowest weed biomass was achieved with pre + post-emergence herbicides and, also minimum tillage but increased with post-emergence herbicide and further with pre-emergence herbicide to 4.3 kg/m^2. Minimum tillage system with Pre + post-emergence herbicide application and, conventional tillage with Pre + post-emergence herbicide application gave grain yield of 8,642 and 7,604 kg/ha respectively, and have good potentials in northern Ghana. This implies exceeding pre + post-emergence herbicide application could be economically and environmentally useful in rice production in the Guinea savannah agroecology of Ghana.

6. RECOMMENDATIONS

At the end of the experiment, the following recommendations have been made.

- At, both locations, the use of minimum tillage in combination with 120 kg Nha^{-1} in 4 splits and pendimethalin (0.4 kg a.i./ha) as pre-emergence herbicides + triclopyr (0.025 kg a.i./ha) used as post-emergence herbicide gave the highest benefit/cost ratio of 4.6 across the two locations and therefore, is recommended for resource-poor farmer in the Guinea savannah agro-ecological zone of Ghana.
- At Botanga, the combination of pendimethalin (0.4 kg a.i./ha) as pre-emergence herbicides + triclopyr (0.025 kg a.i./ha) used as post-emergence herbicide with 120 kg Nha^{-1} in 4 splits obtained grain yield of 8,084 kg/ha and is recommended for resource-poor farmer in the Guinea savannah agro-ecological zone of Ghana.
- At Golinga, the combination of minimum tillage with 120 kg Nha^{-1} in 4 splits

obtained grain yield of 7,604 kg/ha and is recommended for resource-poor farmer in the Guinea savannah agro-ecological zone of Ghana.

- ❖ Integration of pendimethalin (0.4 kg a.i./ha) as pre-emergence herbicides + triclopyr (0.025 kg a.i./ha) used as post-emergence herbicide with 120 kg Nha^{-1} in 4 splits recorder the highest rice grain quality (unbroken rice grain) at both locations and therefore, is recommended for small scale farmers in the Guinea savannah agro-ecological zone of Ghana
- ❖ There is a need to determine long term effect of tillage and herbicide weed management application on rice growth, yield, and economic benefit in the Guinea savannah agro-ecological zone of Ghana.
- ❖ On-farm adoptive trials are required to validate these findings in order to arrive at conclusive recommendations for rice production within the Guinea savannah agro-ecological zone of Ghana.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Alhammad BA, Roy DK, Ranjan S, Padhan SR, Sow S, Nath D, Gitari H. Conservation tillage and weed management influencing weed dynamics, crop performance, soil properties, and profitability in a rice–wheat–greengram system in the Eastern Indo-Gangetic Plain. Agronomy. 2023;*13*(7):1953.
2. Jabran K, Cheema ZA, Farooq M, Basra SMA, Hussain M, Rehman H. Tank mixing of allelopathic crop water extracts with pendimethalin helps in the management of weeds in canola (*Brassica napus*) field. Int. J. Agric. Biol. 2008;10:293–296.
3. Mahajan G, Chauhan BS, Kumar V. Integrated weed management in rice. Recent Advances in Weed Management. 2014;125-153.
4. Mahajan G, Chauhan BS, Timsina J, Singh PP, Singh K. Crop performance and water and nitrogen use eSciences in dry seeded rice in response to irrigation and fertilizer amounts in Northwest India. Field Crops Res. 2012;134:59–70.
5. Sarma HH, Dutta SK, Konwar MJ, Rafique NT, Saikia M, Borah SR, Medhi AK. Impact of establishment techniques and weed management strategies on chemical properties of soil in wet direct-seeded winter rice. Journal of Advances in Biology & Biotechnology. 2024;27(6):269–274. Available:https://doi.org/10.9734/jabb/2024/v27i6885
6. Yernaidu Y, Reddy GRM, Sriram K, Babu MEK., Sravani P. Optimizing weed control: A review of integrated weed management in mustard (*Brassica juncea* L.). Journal of Experimental Agriculture International. 2024;46(5):654–671. Available:https://doi.org/10.9734/jeai/2024/v46i52420
7. Clements DR, Weise SF, Brown R, Stonehouse DP, Hume DJ, Swanton CJ. Energy analysis of tillage and herbicide inputs in alternative weed management systems. Agriculture, Ecosystems & Environment. 1995;52(2-3):119-28.
8. Arshad MA, Abbas RN, Khaliq A, Ahmed Z. Assessing herbicide efficacy and susceptibility for weed management and enhancing production of non-GMO soybean cultivation; 2024.
9. Dogbe W, Dzomeku IK, Yahaya BS, Siise A, Krofa EO, Awuakye SA. Influence of seed quality and soil fertility management on the productivity of rice (*Oryza sativa* L.) in the Guinea Savanna of Ghana. UDS International Journal of Development, 2015;2 (2).
10. Food and Agriculture Organization of the United Nations (FAO). Fertilizer use by crop in Ghana. Rome. 2005;39.
11. Jabran K, Cheema ZA, Farooq M, Hussain M. Lower doses of pendimethalin mixed with allelopathic crop water extracts for weed management in canola (*Brassica napus* L.). Int. J. Agric. Biol. 2010a; 12:335–340.
12. Osei-Asare YB. Mainstreaming trade policy and trade support measures in poverty reduction strategy papers in Ghana. Background paper 3, IEA/FAO. Trade Mainstreaming Project, Ghana; 2010.
13. Ministry of Food and Agriculture (MoFA). Food and Agriculture Sector Development Policy II; 2009.
14. Food and Agriculture Organization of the United Nations (FAO). Statistical databases. FAOSTAT: Agriculture Data; 2008. Available online: http://faostat.fao.org. Accessed 22/12/2015
15. Farooq M, Flower KC, Jabran K, Wahid A, Siddique KHM. Crop yield and weed

management in rainfed conservation agriculture. Soil Till. Res. 2011b;117:172–183.

16. Arunbabu T, Jena SN. Weeds and progressive weed management techniques in rice (*Oryza sativa*. L.): A review. Bull. Env. Pharmacol. Life Sci. 2018;*7*(2):108-117.
17. Iqbal M, Hassan AU, Ali A, Rizwanullah M. Residual effect of tillage and farm manure on some soil physical properties and growth of wheat (*Triticuma estivum* L.), International Journal of Agriculture and Biology. 2005;7:54 -57.
18. Biswas B, Timsina J, Garai S, Mondal M, Banerjee H, Adhikary S, Kanthal S. Weed control in transplanted rice with post-emergence herbicides and their effects on subsequent rapeseed in Eastern India. International Journal of Pest Management. 2023;69(1):89-101.
19. Ferreras LA, Costa JL, Garcia FO, Pecorari C. Effect of no-tillage on some soil physical properties of a structural degraded petrocalcicpaleudoll of the southern ‘Pampa’ of Argentina. Journal of Crop Protection Soil and Tillage Research. 2000;54:31–39.
20. Mulumba LN, Lal R. Mulching effects on selected soil physical properties. Journal of Soil and Tillage Research. 2008;98(1):106-111.
21. Akbar N, Ehsanullah Jabran K, Ali MA. Weed management improves yield and quality of direct seeded rice. Aust. J. Crop Sci. 2011;5:688–694.
22. Chauhan BS, Jabran K, Mahajan G. Rice production worldwide; Springer international publishing: Cham, Switzerland; 2017.
23. Chikoye D, Udensi UE, Lum AF. Evaluation of a new formulation of atrazine and metolachlor mixture for weed control in maize in Nigeria. Journal of Crop Protection. 2005;24:10-16.
24. Chauhan BS, Ahmed S, Awan TH, Jabran K, Manalil S. Integrated weed management approach to improve weed control efficiencies for sustainable rice production in dry-seeded systems. Crop Protection, 2015;71:19-24.
25. Chikoye D, Manyong VM, Carsky RJ, Ekeleme F, Gbehounou G, Ahanchede, A. Response of spear grass (*Imperata cylindrica*) to cover crops integrated with handweeding and chemical control in maize and cassava. Journal of Crop Protection Crop Protection. 2002;21:145-156.
26. Zimdahl RL. Improving chemical systems of weed control. FAO Plant Protection Bulletin. 2003;32(3).
27. Daramola OS, Adigun JA, Olorunmaiye PM. Challenges of weed management in rice for food security in Africa: A review. Agricultura Tropica et Subtropica, 2020;*53*(3):107-115.
28. El-Ghandor AMA. Chemical Control against aggressive broad leaves weed ipomea sp. in drill seeded-rice (*Oryza sativa* L.). Asian Journal of Research in Crop Science, 2024;9(1):10-21.
29. Ishfaq M, Akbar N, Anjum SA, Haq A. Growth, yield and water productivity of dry direct seeded and transplanted aromatic rice under different irrigation management regimes. J. Integr. Agric. 2020;19:2–19.
30. Ishfaq M, Farooq M, Zulfiqar U, Hussain S, Akbar N, Nawaz A, Anjum SA. Alternate wetting and drying: A water-saving and ecofriendly rice production system. Agric. Water Manag. 2020;241:106363.
31. Nath CP, Singh RG, Choudhary VK, Datta D, Nandan R, Singh SS. Challenges and alternatives of herbicide-based weed management. Agronomy. 2024; 14(1):126.
32. Ghosh D, Chethan CR, Chander S, Kumar B, Dubey RP, Bisen HS, Singh PK. Conservational tillage and weed management practices enhance farmers income and system productivity of rice–wheat cropping system in Central India. Agricultural Research. 2021;10:398-406.
33. Pandey BP, Kandel TP. Response of rice to tillage, wheat residue and weed management in a rice-wheat cropping system. Agronomy. 2020; 10(11):1734.
34. Pradhan DD, Rawal S, Asif M, Behera SR, Panda U. Effect of zero tillage and different weed management practices in direct seeded rice (oryza sativa l.) in indo gangetic plains: a review. Journal of Scientific Research and Reports. 2024;30(6):543-557.
35. Pervaiz R. Herbicide strategies for weed control in rice cultivation: Current practices and future directions. *Haya:* Saudi Journal of Life Sciences. 2024;9(4):114-129.
36. Sahoo S, Seleiman MF, Roy DK, Ranjan S, Sow S, Jat RK, Gitari H. Conservation

agriculture and weed management effects on weed community and crop productivity of a rice-maize rotation. Heliyon; 2024.

37. Shekhawat K, Rathore SS, Chauhan BS. Weed management in dry direct-seeded rice: a review on challenges and opportunities for sustainable rice production. Agronomy. 2020;10(9):1264.
38. McNaughton SJ, Wolf LL. General ecology. New York: Holt, Rinchart & Winston. 2003;1973:710.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/117659