

**EVALUATION OF DIFFERENT TILLAGE SYSTEMS AND HERBICIDE  
WEEDMANAGEMENT COMBINATIONS ON GROWTH AND YIELD OF RICE (*Oryza  
sativa* L.) IN THE GUINEA SAVANNAH AGROECOLOGICAL ZONE OF GHANA**

**ABSTRACT**

Rice production in resource-constrained environments that have poor inherent soil nutrition also adversely affected by weeds depends on tillage and herbicide weed management systems that provide high yields and preserve soil, water, and biodiversity. This research was conducted in the Guinea savannah agroecology of Ghana, during the 2022 cropping seasons at two locations (Botanga and 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, and minimum) 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 on the effect of these operations on soil physical properties and crop responses [1]. According to Srivastava, *et al.* [2], 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 [3]. Tillage is crucial for crop establishment, root growth, and ultimately, yield [4]. Tillage is known to influence soil physical, chemical, and biological characteristics, which in turn alter plant growth and yield [5-7]. Though with varied geolocated beneficial impacts, tillage systems are site-specific and depend on crop, soil type, and climate [3]. The appropriate tillage system in a given location and weed management system can promote crop growth, yield, hunger reduction, and sustenance of crop production.

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 (Osei-Asare, 2010). Rice is widely consumed as a staple food, with approximately 63 kg annual per capita consumption (MoFA, 2009). The crop contributes significantly to consumer diets and accounts for about 9 % of total caloric intake (FAO, 2008). Rice represents the tenth agricultural commodity by value of production, accounting for about 45 % of the total area planted to cereals and one of the most important crops for Ghana's agricultural sector and for food security (MoFA, 2009).

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.

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. Good weed management coupled with a proper tillage system, which prepares a fine seed bed 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 (Iqbal *et al.*, 2005; Naveed *et al.*, 2008).

Inappropriate tillage practices and poor soil management contribute to soil degradation, adversely affecting the environment and soil productivity (Jagadamma *et al.*, 2008). Different tillage systems may modify soil physical properties depending on factors such as cropping history, soil type, climatic conditions, and previous tillage systems (Ferrerias *et al.*, 2000). The suitability of soil for sustaining plant growth and biological activity is a function of physical and chemical properties (Mulumba and Lal, 2008). Crop establishment is the key to successful crop yields (Blake *et al.*, 2003). Stand establishment is often regarded as the most critical and vulnerable period of rice growth. The vigor of young seedlings of rice influences their growth, development, and yield (Iqbal *et al.*, 2005).

Weeds have been one of the main limitations to successful and profitable production, especially in developing countries (Avery, 2006). In the context of natural resource management, weeds are undisputedly the most complex and serious problem in that regard. Annually, weeds cause significant losses in agriculture, forestry, and other related disciplines (Tasko and Zvonko, 2007). Relative to other crop pests, weeds are the most prominent because the presence of weeds is constant, while outbreaks of insects and disease pathogens are sporadic (Gianessi and Sankula,

2003). In addition to the quantitative losses in yield caused by weeds due to competition for water, light, and nutrients and to the antagonism (parasitism and allelopathy), they cause tremendous qualitative losses as evident through unitary weight reduction, contamination of seeds and transmission of bad smells or tastes (Ashton and Monaco, 1991; Tasko and Zvonko, 2007). FAO (2008) attributed rice yield gaps on farmers' fields and attainable yields to biophysical factors such as climate/weather, soils, water, pest pressure, weeds, and technical/management factors which comprise tillage, variety/seed selection, water, nutrients, weeds, pests, and post-harvest management. Inadequate weed control especially during the first six weeks after sowing can result in rice yield losses ranging from 50 % to 90 % (Chikoye *et al.*, 2005).

Tillage is a mechanical and manipulation action exerted on soil to modify soil conditions for nurturing crops (Memon *et al.*, 2013). Tillage aims to provide a suitable environment for the radical and plumule development of germinating seeds. Tillage practice suppresses weeds, controls soil erosion, and maintains adequate soil moisture (Koller, 2003). Tillage creates an ideal seedbed condition for seedling emergence, development, and unimpeded root growth (Licht and Al-Kaisi, 2005). Tillage practices are critical components of soil management systems (Mosaddeghi *et al.*, 2009). Inappropriate tillage practices may reduce crop growth and yield. A good soil management program protects the soil from water and wind erosion, provides a good weed-free seedbed for planting, breaks hardpans that may limit root development, and allows maintenance and even an increase of organic matter (Wright *et al.*, 2008). Tillage practices influence soil physical, chemical, and biological characteristics, which in turn may alter plant growth and yield (Rashidi and Keshavarzpour, 2007). Hence selecting an appropriate tillage practice for rice production is very important for optimum growth and yield.

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 labor is unavailable. Hand weeding when carried out timely for two or three times is effective in suppressing weeds and reduces yield losses, the practice is equally time-consuming, laborious, and expensive especially where labor is scarce (Chikoye *et al.*, 2002). Hand weeding alone accounts for 40-54 % of the total labor 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 (Zimdahl, 2003).

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. 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 (Aflakpuiet *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 (Fayad *et al.*, 1998). 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, Guy (1987) suggested proper scrutiny of these herbicides in their respective regions must be made in accordance to 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 irrigation 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 9.20°N and 9.20°N and longitude 0.55°W and 0.55°W. 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 19°C and 41°C.

### **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<sup>2</sup> was demarcated into three replications, each measuring 800 m<sup>2</sup> and three main plots, each measuring 256 m<sup>2</sup>. The main plots were divided into three subplots

(80 m<sup>2</sup> each), which were further divided into three sub-sub plots (25 m<sup>2</sup>). 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.* [28]. 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, 12<sup>th</sup> 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**

#### 4.4 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).

**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..**

Weed species	Number of quadrats					F	D	SDR%
	1	2	3	4	5			
	Weed density (scale 0-4)							
<i>Ageratum conyzoides</i> L.	3	2	4	2	1	5	12	8.29
<i>Amaranthus spinosus</i> L.	3	4	4	3	4	5	18	10.12
<i>Commelinabenghalensis</i> L.	0	4	3	2	0	3	9	5.52
<i>Cynodondactylon</i> (L.) Pers	0	3	3	2	4	4	12	7.36
<i>Cyperus eragrotis</i> L.	3	3	2	4	3	5	15	9.20
<i>Cyperus rotundus</i> L.	4	4	3	4	4	5	19	10.42
<i>Digitariasanguinalis</i> (L.) Scop	3	1	0	3	2	4	9	6.45
<i>Eleusine indica</i> (L.) Gaertn	1	0	4	2	0	3	7	4.91
<i>Euphorbia hirta</i> L.	4	4	3	3	2	5	16	9.51
<i>Solanum nigrum</i> L.	2	4	2	3	2	5	13	8.59
<i>Oryza barthii</i> A. Chev. & Roehr	4	4	4	4	3	5	19	10.42
<i>Tridax procumbens</i> L.	3	3	4	1	4	5	15	9.20
Total				54	164		100.00	

Weediness =  $\frac{1}{2} (f/\Sigma f + d/\Sigma d) * 100$ . Frequency of occurrence (F), density of weed species (D), and summed dominance ratio (SDR) expressed in percentages.

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%), *Cyperus rotundus* (7.37%), *Cynodactylon*(L.) Pers. (7.06%) and *Cyperus alternifolius* (7.06%). The least dominant weeds were *Digitaria sanguinalis*(L.) Scop (3.68) recorded the least weed dominant at (Table 2).

**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.**

Weed species	Number of quadrats					F	D	SDR	
	1	2	3	4	5				
<i>Ageratum conyzoides</i> L.	2	2	3	0	1	4	8	6.14	
<i>Amaranthus spinosus</i> L.		3	2	1	3	4	5	13	8.59
<i>Centrosema pubescens</i> (L.) Benth		1	0	2	1	2	4	6	5.53
<i>Commelinabenghalensis</i> L.		0	2	1	2	1	4	6	5.53
<i>Cynodactylon</i> (L.) Pers		0	2	3	2	4	4	11	7.06
<i>Cyperus alternifolius</i> L.		2	0	2	3	4	4	11	7.06
<i>Cyperus eragrotis</i> L.		1	2	2	3	2	5	10	7.68
<i>Cyperus rotundus</i> L.		1	2	2	1	3	5	9	7.37
<i>Digitaria sanguinalis</i> (L.) Scop		1	1	1	3	0	2	6	3.68
<i>Eleusine indica</i> (L.) Gaertn		1	0	3	2	0	3	6	4.61
<i>Euphorbia hirta</i> L.		0	2	3	0	2	3	7	4.91
<i>Oryza barthii</i> A. Chev. & Roehr		3	4	3	4	3	5	17	10.15
<i>Sida acuta</i> L.		0	2	2	1	3	4	8	6.14
<i>Solanum nigrium</i> L.		2	3	2	3	2	5	12	8.29
<i>Tridax procumbens</i> L.		1	3	2	1	2	5	9	7.37

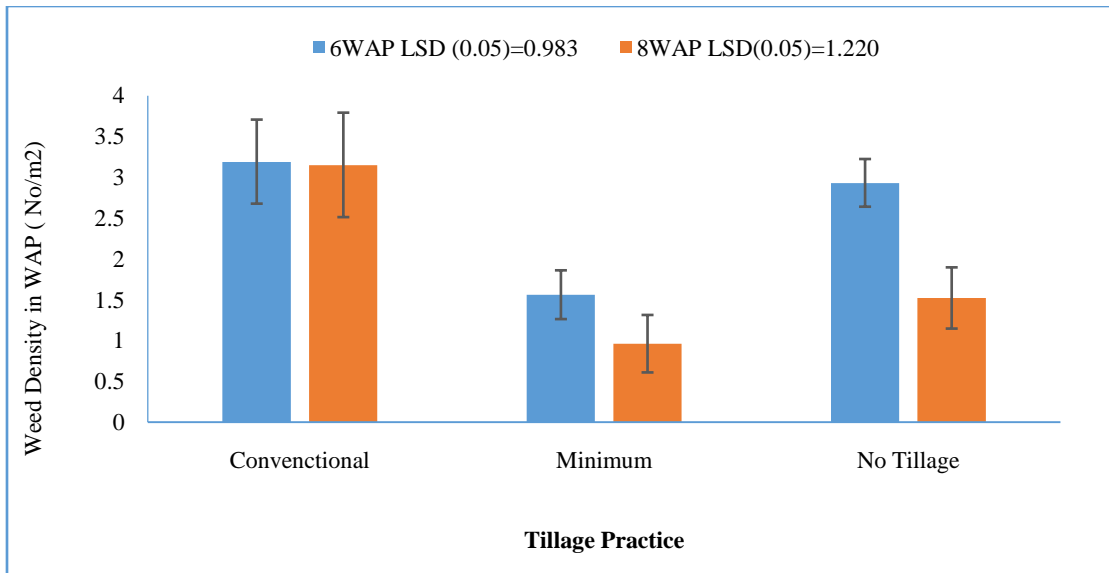
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Weediness =  $\frac{1}{2} (f/\Sigma f + d/\Sigma d) * 100$ . Frequency of occurrence (F), density of weed species (D), and summed dominance ratio (SDR) expressed in percentages.

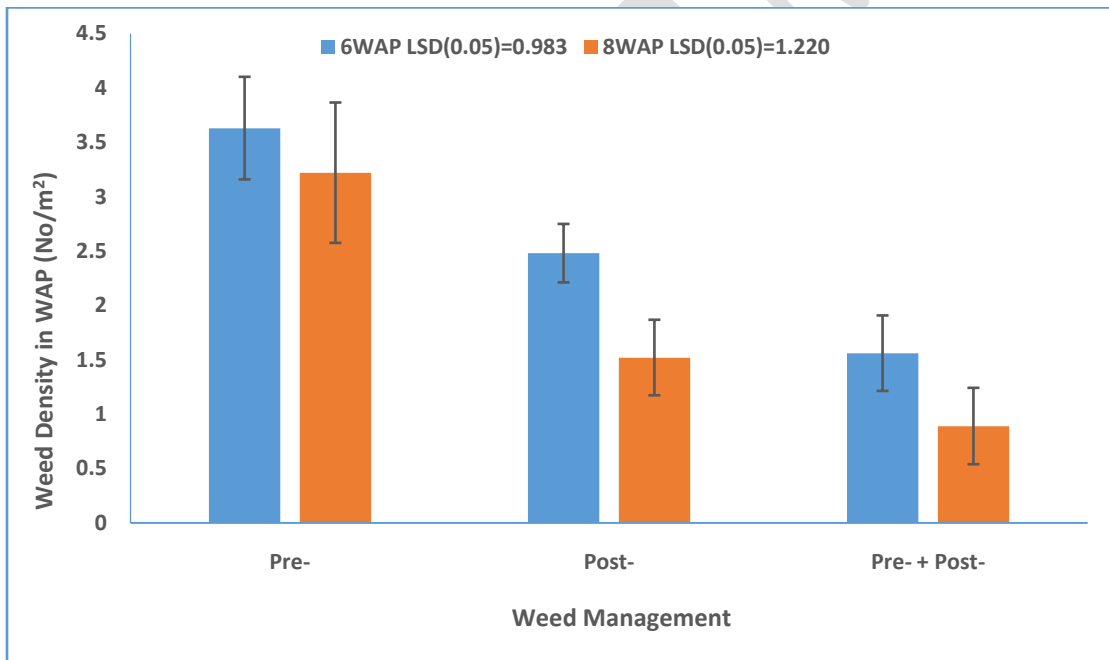
#### 4.5 Weed density

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<sup>2</sup>, followed by no-tillage at 2.93 plants/m<sup>2</sup> and conventional tillage recorded the highest weed density of 3.19 plants/m<sup>2</sup> at 6 WAP (Figure 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<sup>2</sup> (Figure 2) at 6 WAP. This was followed by post-emergence herbicide application that recorded 2.48 plants/m<sup>2</sup> and pre-emergence herbicide 3.63 plants/m<sup>2</sup> at 6 WAP. Similarly, pre- + post-emergence herbicide recorded the lowest weed population of 0.89 plants/m<sup>2</sup> at 8 WAP. This was followed by post-emergence herbicide and pre-emergence herbicide 1.52 plants/m<sup>2</sup> with pre-emergence recording the highest weed density of 3.22 plants/m<sup>2</sup>.

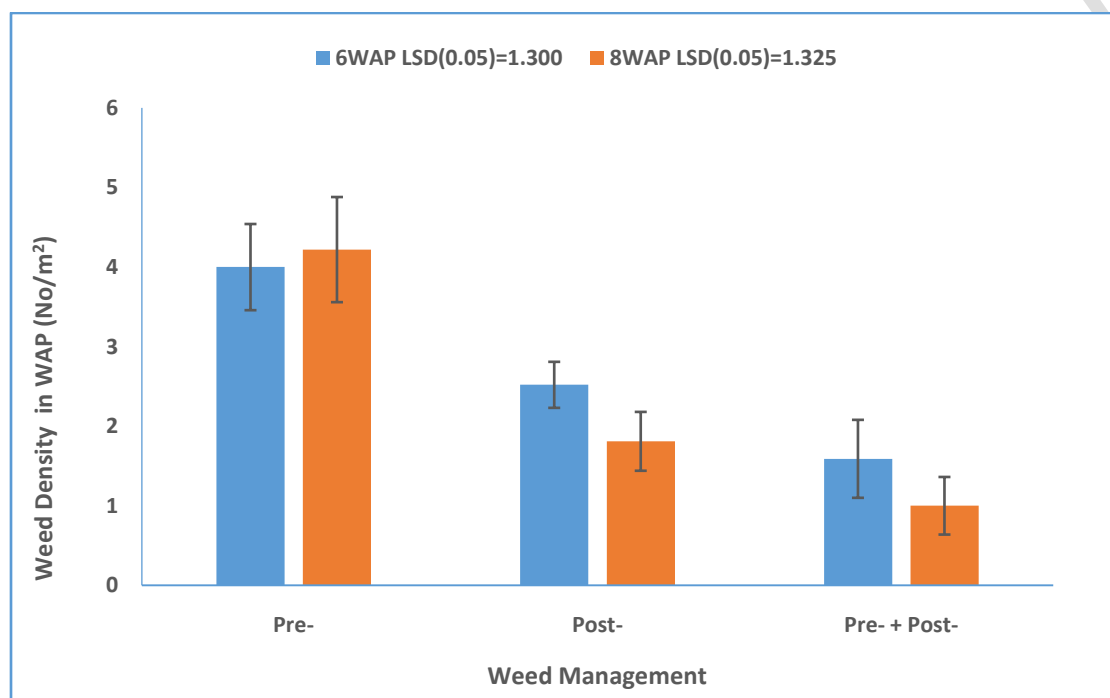


**Figure 1: Effect of tillage system on weed density of rice at 6 and 8 WAP, at Botanga, 2022 cropping season. Error bars: +/- SE.**



**Figure 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.**

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

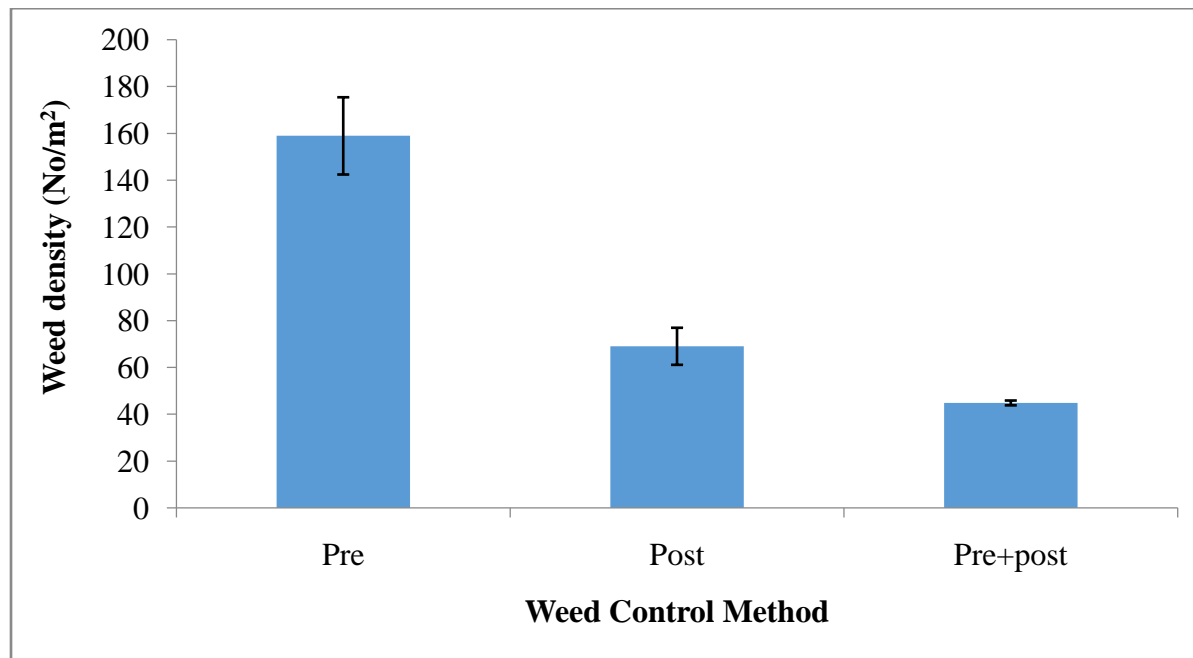


**Figure 3: Effect of weed management on weed density of irrigated rice at 6 AND 8 WAP, grown at Golinga, 2022 cropping season. Error bars: +/- SE. Pre = Pre-emergence herbicide, Post = Post-emergence herbicides, Pre- + Post- = Pre- + Post-emergence herbicide.**

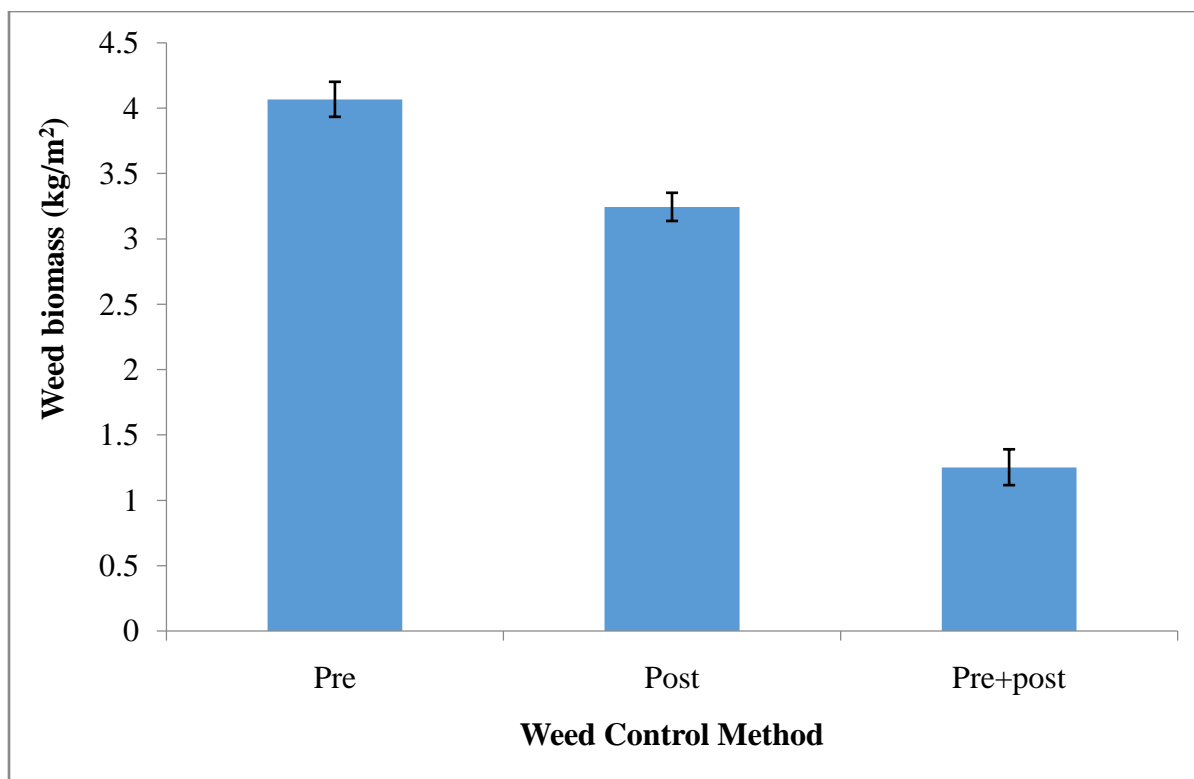
### 3.3. Weed density and biomass.

Weed control management significantly ( $P < 0.05$ ) influenced weed density and weed biomass such that the highest weed density of 159 plants/m<sup>2</sup> (Figure 4) and weed biomass of 4 kg/m<sup>2</sup> (Figure 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.



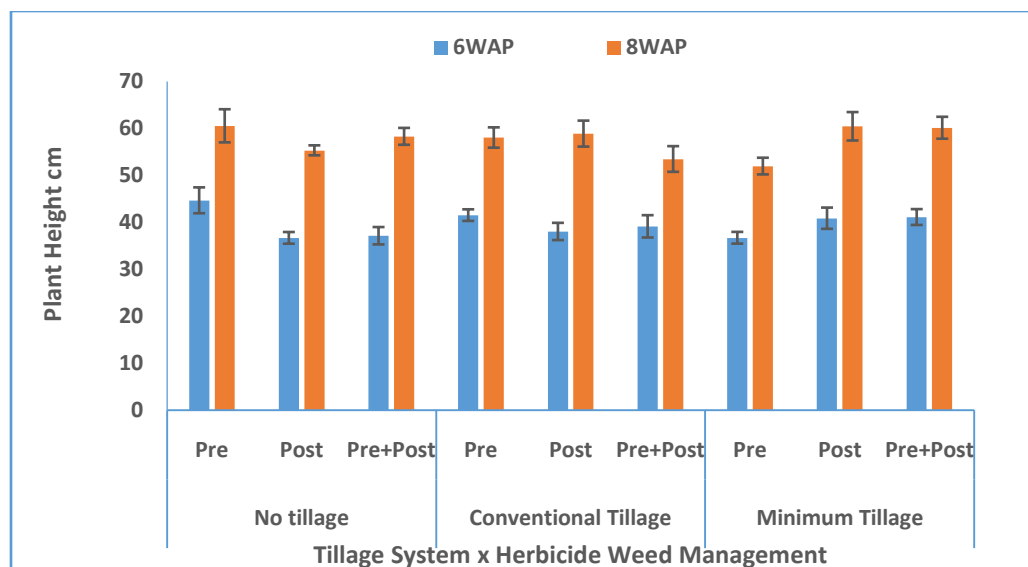
**Figure 4:Effect of weed control management on weed density. Bars represent SEM. Pre = Pre-emergence herbicide, Post = Post-emergence herbicides, Pre- + Post- = Pre- + Post-emergence herbicide.**



**Figure 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.**

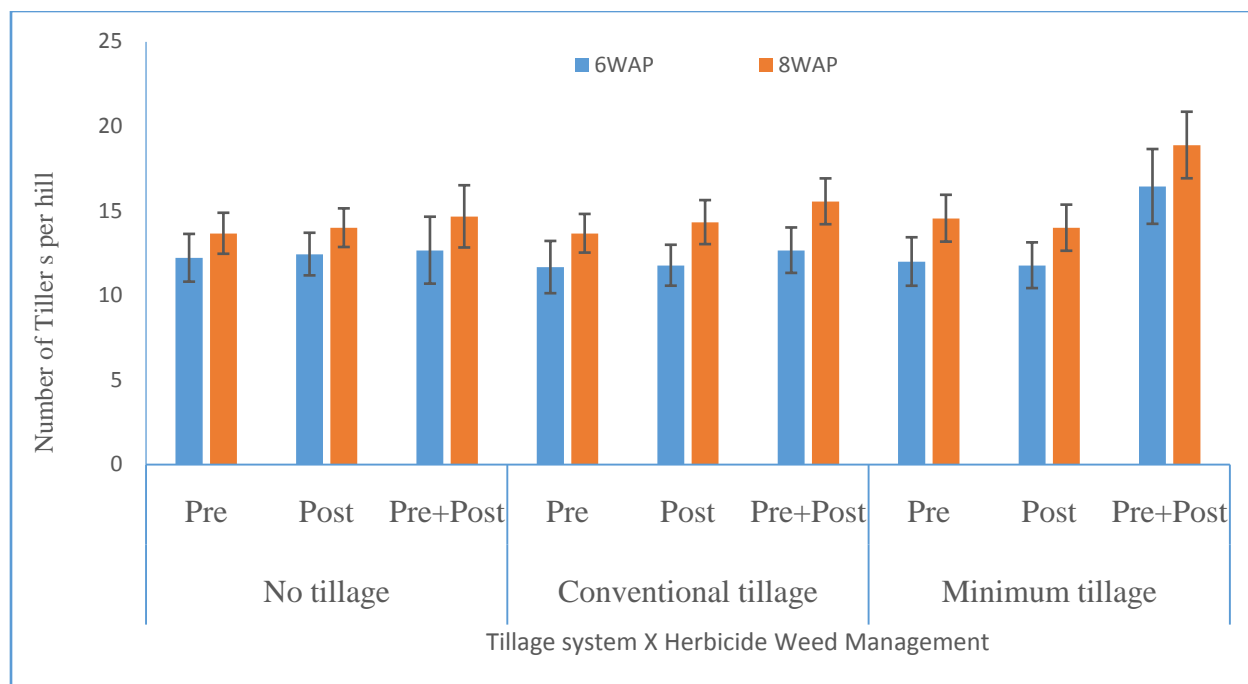
#### 4.6.1 Plant height

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 (Figure 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 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 of 58.8 cm, 58.3 cm, and 58.0 cm respectively at 8WAP, and were the least entries.



**Figure 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.**

Golonga 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 (Figure 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.



**Figure 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.**

### 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.

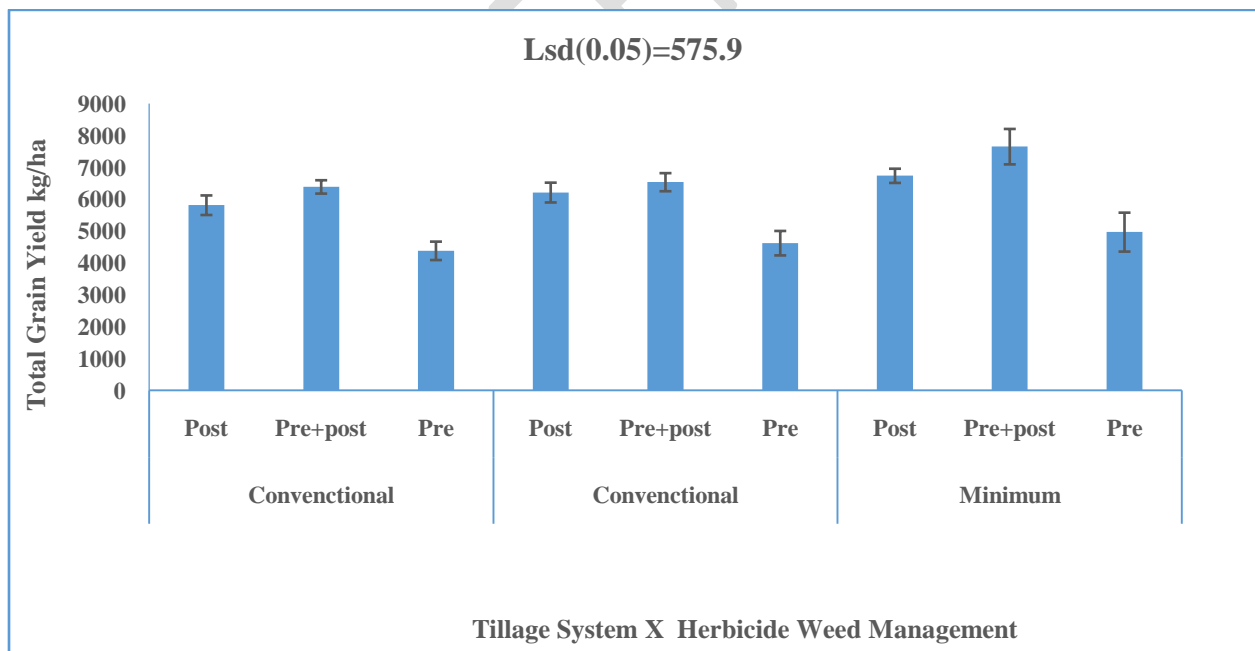
**Table 3. Effect of tillage system and weed control management on effective tillers**

Tillage system	Weed control method		
	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

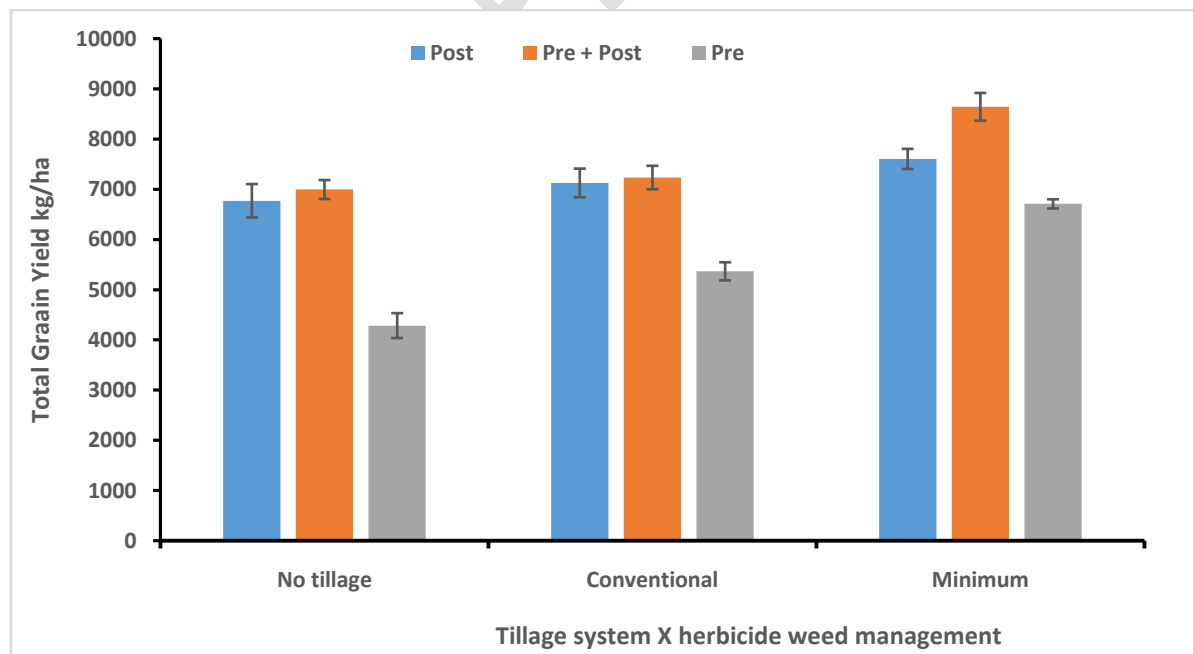
### 3.7. Grain yield

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 (Figure 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.



**Figure 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.**

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 (Figure 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.



**Figure9: 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.**

### **3.8.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.

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

<b>Tillage System</b>	<b>Weed Management</b>	<b>Service charges (GHC)</b>	<b>Input cost (GHC)</b>	<b>Labor cost (GHC)</b>	<b>Total cost (GHC)</b>	<b>Total revenue (GHC)</b>	<b>Benefit/cost ratio</b>
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

## 4. DISCUSSIONS

### 5.3 Weed occurrences, density, and biomass

Weeds are important biotic constraints if not controlled timely by adopting proper weed management practices in tillage systems, and it could pose a serious threat to crop productivity and sustainability (Dzomekue *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 and 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 period of rice growth could not have been adequate to sustain weed control. This could have accounted for 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.

### 5.4 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. Roa *et al.* (2017) observed major determinants of growth and sustainability in rice are good tillage and efficient weed management. The results are also in agreement with (Guan *et*

*al.*, 2014), 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.

### **5.5 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 Swanton *et al.* (2015). 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 (Figure 9).

### **4.5. 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 (Giller *et al.*, 2009), 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 (Giller *et al.*, 2009). 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. Ladha *et al.*, (2009) 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 (Ladha *et al.*, 2009).

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).

#### **4.6. 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 5). This is in line with the findings of McNaughton and Wolf, (2003), 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 (FAO, 2005).

## **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<sup>2</sup> 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<sup>2</sup>. 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<sup>2</sup>. 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<sup>2</sup> 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<sup>2</sup>. 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<sup>2</sup>. 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.

### **5.1. 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 N/ha<sup>-1</sup> 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 N/ha<sup>-1</sup> 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<sup>-1</sup> 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<sup>-1</sup> 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 longterm 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 inorder to arrive at conclusive recommendations for rice production within the Guinea savannah agro-ecological zone of Ghana.

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