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# Effects of Water Depth and Seedling Rate on Weed Control and Yield of Late Season Lowland Rice (*Oryza sativa* L)

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**Abstract**

Three-year late season field experiment was conducted between 2011 and 2013 on the irrigated lowland experimental field at Edozhigi (9º04N, 6º7E) in the Southern Guinea savannah ecological zone of Nigeria, to determine the effects of different water depths and seedling rates on weed control, yield and yield components of lowland rice. The trial was laid out using a split plot design with six water depths (5 cm, 10 cm, 15 cm, 20 cm, saturated soil and continuous flow of water at 3 cm depth) as the main plots while seedling rates of 2, 4, and 6) per stand constituted the sub-plots. The treatments were replicated three times. The results indicated that the growth of weed species was significantly affected as water depth increased while rice yield was significantly enhanced as water depth increased to 20 cm. The 20 cm water depth gave weed control efficiency (WCE) of 57.6, 94.1 and 93.3% at 60 days after transplanting (DAT) in 2011, 2012 and 2013 respectively which was about 87% better than that obtained from saturated plots. At water depths of 10 and 20 cm, the growth of grasses and sedges were reduced by 60 and 100% respectively, while saturated and continuous flow of water encouraged their growth. Water depths of 10, 15 and 20 cm gave grain yield of 5052, 4700 and 4066 kg $ha^{-1}$ which were 84, 85 and 85.5% higher than yields obtained from saturated plot in 2011, 2012 and 2013 respectively. Transplanting of 4 to 6 seedlings significantly suppressed weed growth and enhanced rice grain yield than 2 seedlings per stand. It is therefore concluded that maintaining water depths of 15 and 20 cm and seedling rates of 4 and 6 significantly suppressed weed growth and enhanced rice yield.

**Keywords:** water depth, seedling rate, weed control, rice yield

## 1. Introduction

The major impediment to the cultivation of rice is the heavy weed infestation which competes with the crop to such an extent that the crop gets smothered by the weeds. The weeds share not only plant nutrients but transpire a lot of valuable conserved water from the soil. The weeds also serve as alternative hosts for certain diseases and pests. Weed infestation can also interfere with operations at harvest and significantly increase harvesting and drying costs.

Weed competition is the most important yield reducing factor followed by drought, blast, soil acidity and general soil infertility (Johnson et al., 1997). Pandey (2009) reported that weeds are at present the major biotic constraint to increased rice production worldwide. Weeds constitute a big constraint to the production of rice in Nigeria. Ukwungwu and Abo (2004) reported that weeds constitute the greatest bottleneck to increased yield and quality of rice in Nigeria.

Management systems to meet the challenges of weeds are reflected in the varied rice production systems worldwide. Rice is characterized by its adaptability which allows it to grow in almost any biophysical environment in West and Central Africa. Rice is grown in a whole range of agro-ecological zones and five main rice-based systems can be distinguished with respect to water supply and topography in sub-Saharan Africa. These are rainfed upland, rainfed lowland, irrigated lowland, deep water and mangrove swamp. All these systems are increasingly threatened by weeds. Losses to weeds tend to be "chronic" in nature rather than sporadic and, as a result, are often underestimated (Johnson et al., 2010).

Management of weeds is an important component of production systems as elimination of weeds is expensive and hard to achieve. Presence of weeds is a constraint and their improper management further accentuates their effect. Among eco-friendly techniques for weed control in rice fields is effective water management which is among the oldest and cheapest cultural weed control methods.

Previous studies have shown that weed occurrence is a constant component of the ecosystem in comparison to the epidemic nature of other pests which makes farmers unaware of the significant losses they incur from their infestation (Johnson et al., 1999). The author also observed that a major impediment in the cultivation of rice is heavy weed infestation particularly in upland ecology, which competes with the crop to such extent that it could get smothered. Thus, farmers spend over US \$400 $ha^{-1}$, or 20% of their production costs to control weeds in rice fields (Islam et al., 2005). Improving weed control in farmers' fields was shown to increase rice yields by 15-23%, depending on the agro-ecosystem, and it is estimated that weeds may account for annual rice yield losses in sub-Saharan Africa of at least 2.2 million tonnes equating to US \$1.45 billion (Rodenburg and Johnson, 2009). The authors noted that rice yield losses due to uncontrolled weed growth was 28-74% in transplanted lowland rice, 28–89% in direct-seeded lowland rice and 48-100% in upland ecosystems.

Weeds pose one of the greatest challenges in lowland rice production systems. Grain yield losses due to weeds in lowland rice fields range from 20% to 60% in transplanted crops and from 30% to 80% in direct-seeded rice (Janiya, 2002).

The report of FAO (1997) indicated that the adoption of economically viable and environmentally friendly cropping systems is the key to successful weed management. Water management is a major component of any weed control programme in rice production, whether herbicide is used or not. The experiment was hence conducted in order to determine the water depth and seedling rate that effectively suppress weeds and enhance rice yield in lowland ecology.

## 2. Materials and Methods

The experiment was conducted in late seasons of 2011, 2012 and 2013 at Edozhigi lowland rice research field of National Cereals Research Institute, Badeggi, Nigeria, (Latitude 09º 45' N and Longitude 6º 07' E at an elevation of 75 meters above sea level) in Niger State in the southern Guinea savannah ecological zone of Nigeria. The average annual rainfall was 1287.5, 1158.3 and 1158.6 mm in 2011, 2012 and 2013 respectively, while the peak rainfall was between July to September each year (Table 1). During the three-yearfield experimentation, the rainfall season began in April (Table 1).

Table 1. Rainfall data for three years (mm)

| Months | 2011 | 2012 | 2013 |
|---|---|---|---|
| January | 0 | 0 | 0 |
| February | 0 | 9.8 | 0 |
| March | 0 | 0 | 0 |
| April | 36.7 | 53.3 | 58.6 |
| May | 173 | 101.6 | 253.9 |
| June | 106.1 | 259.4 | 144.8 |
| July | 336.3 | 206.4 | 236 |
| August | 264.9 | 146.7 | 181.9 |
| September | 130.2 | 289.7 | 199.7 |
| October | 224.2 | 101.2 | 83.7 |
| November | 14.1 | 0 | 0 |
| December | 0 | 0 | 0 |
| Total | 1285.5 | 1168.1 | 1158.8 |

Source: NCRI meteorological station.

The trial was laid out using split plot design with six levels of water (5 cm, 10 cm, 15 cm, 20 cm, saturated soil and continuous flow of water at 3 cm depth) as main plots while three seedling rates (2, 4, and 6 seedlings per stand) constituted the sub-plots. Main plot size was 10 m × 4 m and sub-plot size was 3 m × 4 m. The experiment was conducted from September to December in each year, being the late cropping season in Nigeria.

Irrigation water was supplied through a channel that had its source from River Kaduna. The water was let into the field through the alley way and a 3-inch PVC pipe was connected from the alley way to each plot to serve as water inlet pipe. White plastic indicator was fixed at the middle of each plot to monitor the water depth while 10 cm plastic hose of 3-inch diameter was connected to each plot to drain excess water when the maximum water level was attained.

### *2.1 Agronomic Practices*

The land was mechanically ploughed, harrowed and leveled but the bunds round the perimeter of the plots were manually constructed using hoe. The rice seed used for the study was obtained from the Seed Unit of National Cereals Research Institute, Badeggi. A nursery was established in August each year. The rice seedlings were transplanted 30 days after sowing (DAS) according to the treatments at the spacing of 20 × 20 cm. Each sub-plot received a uniform application of 40 kg/ha N, 40 kg/ha $P_2O_5$ and 40 kg/ha $K_2O$ one week before transplanting. Additional 40 kg/ha N was applied at panicle initiation stage. The source of N, $P_2O_5$ and $K_2O$ was urea (46% N), single super phosphate (18% $P_2O_5$) and muriate of potash (60% $K_2O$) respectively. The field was flooded to various heights as dictated by the treatments at 15 days after transplanting (DAT).

Fertilizer were applied by broadcasting after proper drainage of water from the field. The field was then flooded immediately after fertilizer application. The field was finally drained one week before harvesting and harvesting was done when the grains were hard and had turned yellow/brown, which occurred 30-45 days after flowering or one month after 50% flowering.

### *2.2 Weed Identification*

Weeds were identified and classified into three classes as grass, broad leaved weeds and sedges and there occurrence was determined,

### *2.3 Percentage Weed Control Efficiency (%WCE)*

Weed control efficiency was determined using the following formula by Das (2011).

$$\%\ \text{WCE} = \frac{(\text{WDc - WDr})}{\text{WDc}} \times 100 \quad (1)$$

where:

% WCE = percentage weed control efficiency

WDc = weed density ($m^{-2}$) in control plot

WDr = weed density ($m^{-2}$) in treated plot

### *2.4 Percentage Weed control Index (% WCI)*

Weed control index was determined using the following formula by Das (2011).

$$\%\ \text{WCI} = \frac{(\text{WDMc - WDMr})}{\text{WDMc}} \times 100 \quad (2)$$

where:

WDMc = weed dry weight ($m^{-2}$) in control plot

WDMr = weed dry weight ($m^{-2}$) in treated plot

### *2.5 Percentage Weed Composition*

This was carried out by counting the weeds within 1 $m^2$ quadrant in each plot and the weeds found were then classified into broad leaf, grasses and sedges and expressed in percentage.

### *2.6 Rice Yield Parameters*

Rice grain yield was obtained from a net plot of 2.8 m × 4 m. The chaff was separated from the grains by shocking in water for two minutes. After proper stirring, the floating chaff and the grains were collected and both dried separately and weighed using weighing balance. Percentage chaff was determined using the following formula:

$$\%\ \text{Chaff} = \frac{\text{Chaff weight}}{\text{Total harvest}} \times 100 \quad (3)$$

The weight of 1000 grains was determined by taking the measurement of 100 grains using an electrical digital weighing balance and the result was multiplied by 10 to give 1000 grains weight.

*2.7 Data Analysis*

Data collected were subjected to analysis of variance (ANOVA) using the M-Stat-C version 1.3 (Snedecor & Cochran, 1967) statistic package and significant means were separated using LSD at 5% probability.

## 3. Result

Morphologically, three classes of weeds were identified; broad leaved weed, grasses and sedges. The dominant broad leaved weeds were *Hyptis lanceolata, Sphenoclea zeylanica, Ludwigia decurrens* and *Merremia aegyptia* while grasses with high occurrence were *Echinochloa stagnina, Paspalum polystachyum* and *Pennisetum polystachion Fimbristylis littoralis* was the dominant sedge (Table 2).

Table 2. The dominant weeds found on the experimental site

| Weed species | Families | Life span | Occurrence | | |
|---|---|---|---|---|---|
| **Broad leaf** | | | 2011 | 2012 | 2013 |
| *Hyptis lanceolata* (Poir) | *Lamiaceae* | A | + | - | - |
| *Ipomoea aquatica* (Forsk ) | *Convolvulaceae* | A | ++ | + | + |
| *Indigofera hirsuta* | *Rubiaceae* | A | + | - | - |
| *Ludwigia abyssinica* (Rich) | *Onagraceae* | A | ++ | ++ | ++ |
| *Ludwigia decurrens*(Walk) | *Onagraceae* | A | ++ | ++ | ++ |
| *Merremia aegyptia* (Linn) | *Convolvulaceae* | A | + | - | - |
| *Oldenlandia corymbosa* (Linn) | *Rubiaceae* | A | - | - | - |
| *Phyllathus amarus* (Schum) | *Euphorbiaceae* | A | - | - | - |
| *Sphenoclea zeylanica* (Gaertn) | *Sphenocleaceae* | A | +++ | +++ | +++ |
| *Commelina benghalensis* | | A | + | - | - |
| *Ageratum conyzoides* | | A | ++ | - | - |
| **Grass** | | | | | |
| *Echinochloa colona* (Gaertn) | *Poaceae* | A | ++ | + | + |
| *Echinochloa stagnina* (Beauv) | *Poaceae* | A | + | + | + |
| *Lepotochloa caerulescens* (Steud) | *Poaceae* | A | + | - | - |
| *Paspalum polystachyum* (Linn) | *Poaceae* | A | + | | + |
| *Paspalum conjugatum* (Berg) | *Poaceae* | A | + | + | - |
| *Paspalum vaginatum* (Sw) | *Poaceae* | A | - | - | - |
| *Pennisetum polystachion* (Linn) | *Poaceae* | A | + | - | - |
| *Oryza barthii* (Chev) | *Poaceae* | A | + | + | + |
| *Leersia hexandra* | *poaceae* | A | | - | - |
| *Panicum laxum* | *poaceae* | A | - | - | + |
| **Sedge** | | | | | |
| *Cyperus esculentus* (Linn) | *Cyperaceae* | P | + | + | + |
| *Cyperus haspan* (Linn) | *Cyperaceae* | P | + | + | + |
| *Fimbristylis littoralis* (Gaudet) | *Cyperaceae* | A | +++ | +++ | +++ |
| *Cyperus iria* | Cyperaceae | P | - | + | ++ |

A = annual, P = perennial, - = absent + = few, ++ = many and +++ very many.

There was shift in weed types during the three year trials. Broad leaved weeds like *Commelina benghalensis* and *Ageratum conyzoides*, grasses like *Lepotochloa caerulescens* and *Pennisetum polystachion* that were available in 2011 disappeared in the subsequent years while broad leaved weeds like *Merremia aegyptia* and *Oldenlandia corymbosa* and grasses like *Panicum laxum* appeared at later years (2012-2013). Also sedges like *Cyperus iria* that were not available in 2011 appeared in 2012 and 2013 (Table 2).

The percentage weed control efficiency was significantly affected by both water depth and number of seedlings transplanted in the three-year study. The water depth of 20 cm gave significantly higher weed control efficiency than all other water depths which was consistent across the periods the sampling was taken. The weed control efficiency generally increased as the rice growth progressed between 60-75 DAT (Table 3). The number of seedlings transplanted equally had a significant effect on the weed control efficiency in the three-year study. Higher weed control efficiency was recorded in the plots with six seedlings per stand while two seedlings per stand gave significant lower weed control efficiency (Table 3).

Table 3. Effect of water depth and seedling rate on percentage weed control efficiency between 2011-2013

| | 2011 | | | | 2012 | | | | 2013 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days after transplanting | | | | | | | | | | | |
| Treatments | 30 | 45 | 60 | 75 | 30 | 45 | 60 | 75 | 30 | 45 | 60 | 75 |
| **Water level cm (W)** | | | | | | | | | | | | |
| 5 | 25.3 | 17.4 | 34.1 | 35.5 | 45.8 | 4.3 | 72.1 | 74.3 | 42.6 | 46.3 | 63.8 | 70.5 |
| 10 | 45.6 | 35.8 | 32.2 | 40.2 | 50.9 | 28.6 | 78.4 | 78.1 | 63.5 | 67.7 | 77.2 | 80.0 |
| 15 | 57.0 | 44.3 | 43.6 | 62.2 | 67.8 | 76.5 | 90.9 | 85.3 | 75.5 | 87.8 | 92.1 | 92.2 |
| 20 | 80.7 | 67.8 | 57.6 | 77.7 | 79.5 | 82.7 | 94.1 | 94.3 | 84.2 | 91.3 | 93.3 | 93.7 |
| Continuous flow | 2.8 | 5.8 | 23.5 | 8.9 | 14.3 | 4.4 | 34.8 | 35.9 | 26.5 | 21.4 | 28.3 | 25.5 |
| Saturated (check) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CV | 10.6 | 6.9 | 7.4 | 2.5 | 15.7 | 5.4 | 8.5 | 5.7 | 5.1 | 5.0 | 3.4 | 4.5 |
| SE± | 3.0 | 2.3 | 1.9 | 0.4 | 6.2 | 3.2 | 2.8 | 3.6 | 2.0 | 4.3 | 1.8 | 1.7 |
| **Seedling rate per stand (S)** | | | | | | | | | | | | |
| 2 | 38.4 | 32.4 | 40.7 | 40.2 | 20.1 | 20.4 | 53.9 | 52.4 | 32.8 | 43.7 | 52.5 | 56.3 |
| 4 | 44.6 | 38.2 | 42.4 | 44.6 | 56.7 | 44.8 | 65.1 | 65.3 | 52.0 | 53.5 | 59.9 | 60.9 |
| 6 | 65.8 | 70.4 | 70.9 | 70.7 | 55.3 | 46.6 | 66.1 | 66.3 | 61.5 | 60.0 | 65.0 | 65.7 |
| CV | 10.6 | 6.9 | 7.4 | 2.5 | 15.7 | 5.4 | 8.5 | 5.7 | 5.1 | 5.0 | 3.4 | 4.5 |
| SE± | 5.10 | 3.41 | 4.44 | 7.80 | 4.60 | 7.21 | 4.21 | 3.40 | 10.90 | 7.20 | 6.80 | 6.01 |
| **W X S** | * | ** | * | * | * | ** | * | * | * | * | * | * |

* = significant at 5 % and ** = significant at 1 %.

Weed control index followed the same trend as percentage weed control efficiency. Water depth of 20 cm gave significantly higher weed control index than any other treatment (Table 4). The weed control index increased as the rice growth progressed between 60-75 DAT. Weed control index was generally higher in 2013 than other years of the study. The effect of seedling rate on weed control index was similar to that of percentage weed control efficiency. The highest weed control index was recorded under six seedlings per stand which was significantly higher than either two of four seedlings per stand (Table 4).

The growth of the three weed types (grasses, broad leaved and sedges) was only affected by different water depths. The number of seedlings transplanted had no significantly ($p < 0.05$) effects on percentage weed composition in the three-year study. Generally, increased in water depth significantly reduced percentage weed composition of all the weed species, although grasses and sedges were better controlled by deeper water of 15 and 20 cm depth. The results of percentage weed composition as influenced by various water depth are shown in Figures 1-9.

Table 4. Effect of water depth and seedling rate on percentage weed control index between 2011-2013

| | 2011 | | | | 2012 | | | | 2013 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days after transplanting | | | | | | | | | | | |
| Treatment | 30 | 45 | 60 | 75 | 30 | 45 | 60 | 75 | 30 | 45 | 60 | 75 |
| **Water level cm (W)** | | | | | | | | | | | | |
| 5 | 44.1 | 35.6 | 34.2 | 69.1 | 54.6 | 38.6 | 47.4 | 50.6 | 63.9 | 65.5 | 96.8 | 98.3 |
| 10 | 58.5 | 52.1 | 54.6 | 70.7 | 60.3 | 48.0 | 61.1 | 65.4 | 71.2 | 71.2 | 98.3 | 98.5 |
| 15 | 74.7 | 71.5 | 72.0 | 82.5 | 72.8 | 72.5 | 78.2 | 80.9 | 82.5 | 81.2 | 99.1 | 99.5 |
| 20 | 82.4 | 83.4 | 83.9 | 73.0 | 74.9 | 29.0 | 81.1 | 82.8 | 82.5 | 81.2 | 99.1 | 99.2 |
| Continuous flow | 20.6 | 7.2 | 18.3 | 34.0 | 29.1 | 17.5 | 28.9 | 22.6 | 40.0 | 19.1 | 40.0 | 12.9 |
| Saturated | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CV | 2.6 | 7.1 | 54.8 | 11.2 | 11.5 | 4.1 | 14.7 | 5.9 | 3.4 | 5.9 | 5.9 | 4.4 |
| SE± | 0.7 | 1.7 | 12.6 | 3.4 | 2.7 | 0.7 | 3.9 | 1.0 | 1.6 | 4.8 | 36.1 | 47.2 |
| **Seedling rate per stand (S)** | | | | | | | | | | | | |
| 2 | 42.6 | 47.1 | 56.7 | 69.8 | 30.6 | 46.2 | 56.7 | 58.2 | 43.2 | 38.9 | 67.8 | 65.6 |
| 4 | 55.8 | 50.2 | 55.2 | 68.0 | 54.6 | 53.1 | 57.5 | 59.7 | 61.5 | 54.6 | 70.7 | 68.2 |
| 6 | 76.4 | 78.2 | 64.8 | 81.5 | 62.7 | 66.3 | 70.4 | 66.5 | 66.9 | 67.0 | 73.8 | 70.2 |
| CV | 2.6 | 7.1 | 14.8 | 11.2 | 11.5 | 4.1 | 14.7 | 5.9 | 3.4 | 5.9 | 5.9 | 4.4 |
| SE± | 5.61 | 4.32 | 4.01 | 3.23 | 8.10 | 5.63 | 3.42 | 2.34 | 6.73 | 4.70 | 1.72 | 3.57 |
| **W X S** | * | * | * | * | NS | * | * | * | * | * | * | * |

* = significant at 5 %, ** = significant at 1 % and NS = not significant.

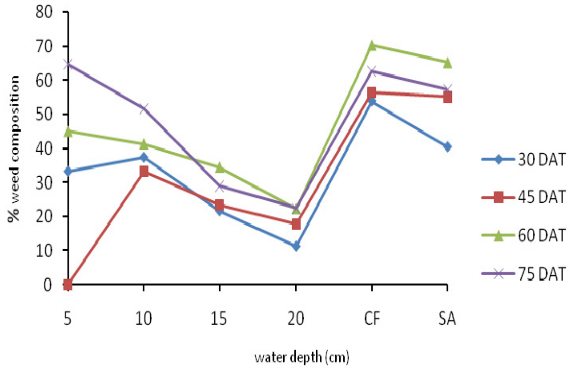


Figure 1. Percentage grass weeds as affected by various water depths in 2011

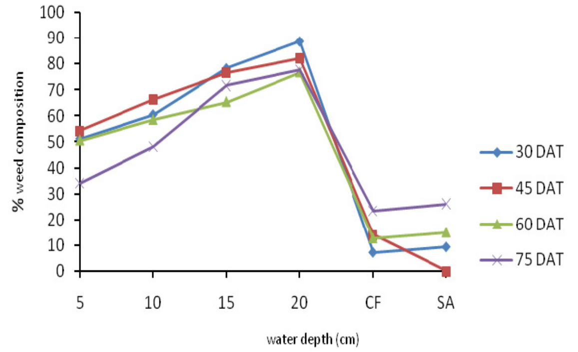


Figure 2. Percentage broad leaved weeds as affected by various water depths in 2011

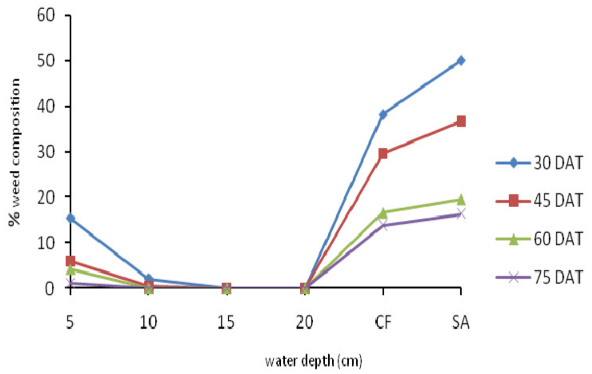


Figure 3. Percentage sedge weeds as affected by various water depths in 2011

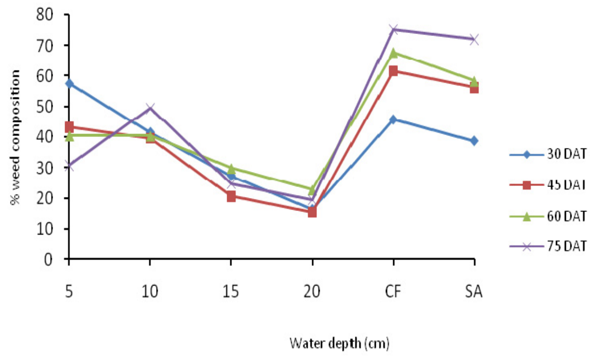


Figure 4. Percentage grass weeds as affected by various water depths in 2012

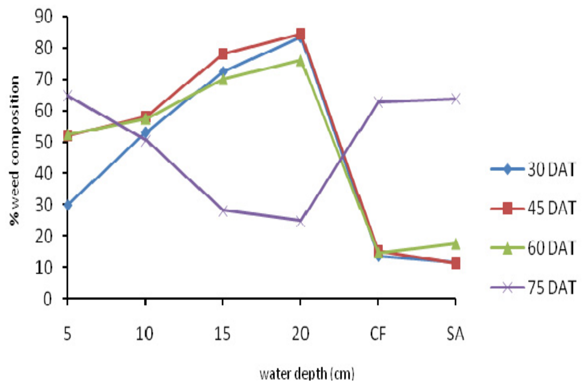


Figure 5. Percentage broad leaved weeds as affected by various water depths in 2012

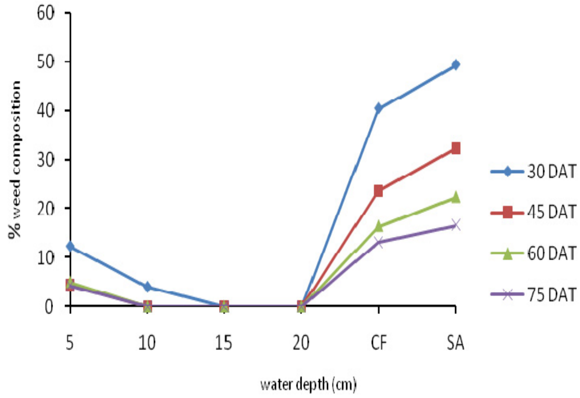


Figure 6. Percentage sedge weeds weeds as affected by various water depths in 2012

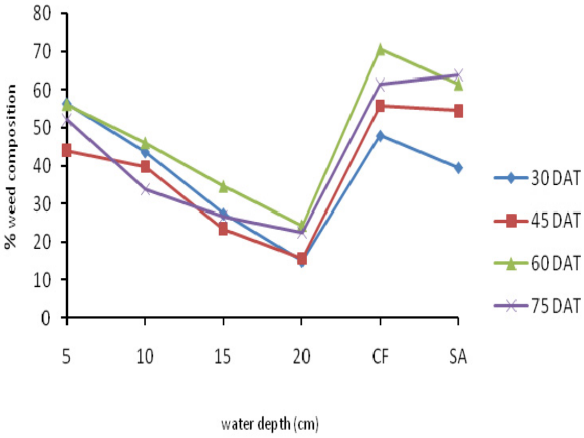


Figure 7. Percentagegrass weeds as affected by various water depths in 2013

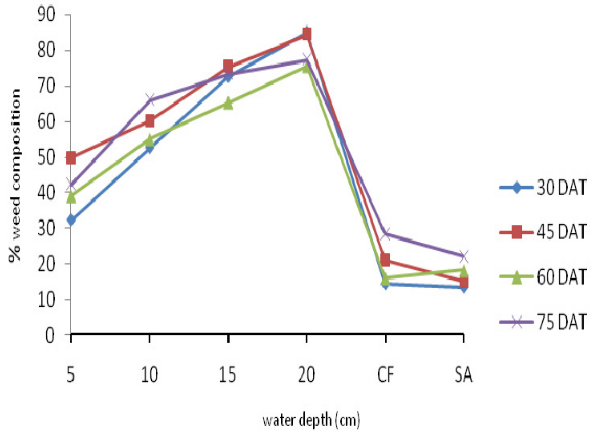


Figure 8. Percentage broad leaved weeds as affected by various water depths in 2013

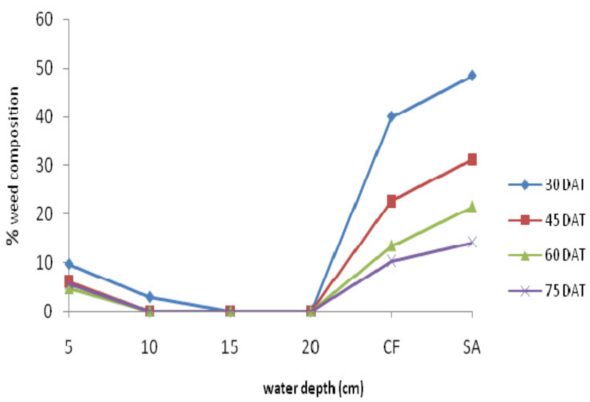


Figure 9. Percentage sedge weeds weeds as affected by various water depths in 2013

The 20 cm water depth gave significantly lower percentage grasses in the three-years study although grasses like *Oryza barthii* and *Leersia hexandra* were less affected by the various water depths. The lower percentage grass composition recorded in 20 cm water was similar to 15 cm water depth at all periods in 2013 while continuous water flow and saturated plots gave higher composition grass weed (Figures 1, 4 and 7).

The broad leaved weeds were less affected by various water depths where some of the species like *Sphenoclea zeylanica* were able to endure the various water depths. Broad leaved weeds were the common weeds found in the deep water of between 10-20 cm. The water depth of 20 cm therefore gave significantly higher number of broad leaved weeds (Figures 2, 5 and 8) than other water depths. The result of this study revealed that sedges were more sensitive to various water depths. The growth of sedges was completely suppressed at 10-20 cm water depth. While saturated soil gave significantly higher percentage of sedges at all periods the sample was taken (Figures 3, 6 and 9).

Panicle production responded differently to different water depths and seedling rate in the three years of study. There was direct linear relationship between water depth and seedling rate, that is increase in water depth resulted in corresponding increase in panicles $m^{-2}$. Panicles per $m^{-2}$ were significantly higher in 20 cm water depth while seedling rate of six gave higher number of panicles per $m^{-2}$ (Table 5).

The percentage rice chaff was significantly influenced by both water depth and seedling rate. Generally, the higher the depths of water the lower % chaff produced. The 20 cm water depth consistently gave significantly lower percentage chaff while higher % chaff was recorded in saturated plot. Two seedling/stand gave significant lower % chaff than others (Table 5). The % chaff was generally lower in 2011 than the other years which could be attributed to an abnormal extension of rainfall in this year (Table 1).

The 20 cm water depth recorded significantly heavier grains which were statistically similar with 15 cm water depth throughout the three-year study while lower grain weight was recorded in the continuous flow of water which was at par with saturated soil water condition. Two seedling/stand gave significantly higher grain weight while six seedling rates produced consistently lower grain weight.

Table 5. Effect of water depth and seedling rate on yield components and yield in 2011-2013

| | **Panicle $m^{-2}$** | | | **% chaff** | | | **1000 grain weight (g)** | | | **Grain yield (kg $h^{-1}$** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | 2011 | 2012 | 2013 | 2011 | 2012 | 2013 | 2011 | 2012 | 2013 | 2011 | 2012 | 2013 |
| **Water depth cm (W)** | | | | | | | | | | | | |
| 5 | 191.0 | 187.8 | 185.3 | 15.8 | 16.4 | 16.3 | 29.1 | 29.10 | 27.2 | 3289.1 | 3245.2 | 3141.0 |
| 10 | 290.3 | 285.7 | 269.0 | 15.7 | 15.7 | 17.1 | 30.0 | 30.01 | 28.2 | 3551.7 | 3550.0 | 3311.3 |
| 15 | 398.1 | 384.8 | 368.7 | 13.5 | 10.0 | 8.5 | 31.3 | 32.02 | 31.8 | 4702.3 | 4493.1 | 4066.0 |
| 20 | 464.7 | 441.7 | 406.6 | 6.9 | 8.7 | 7.8 | 31.8 | 32.46[a] | 31.7 | 50517.8 | 4700.4 | 4033.1 |
| Continuous flow | 121.8 | 110.7 | 90.6 | 27.3 | 28.4 | 24.2 | 28.2 | 28.24 | 26.4 | 2812.3 | 2534.3 | 2103.6 |
| Saturated | 101.8 | 53.1 | 34.3 | 29.3 | 33.1 | 35.2 | 27.6 | 27.60 | 25.8 | 990.0 | 696.2 | 607.2 |
| CV | 5.57 | 1.89 | 2.99 | 7.90 | 4.45 | 4.57 | 2.4 | 1.79 | 1.8 | 3.0 | 1.3 | 2.4 |
| SE± | 13.93 | 9.37 | 5.42 | 1.37 | 1.11 | 1.25 | 0.6 | 0.87 | 0.30 | 98.0 | 39.4 | 60.7 |
| **Seedlingrate per stand (S)** | | | | | | | | | | | | |
| 2 | 200.3 | 193.6 | 184.8 | 11.4 | 12.2 | 13.4 | 31.3 | 31.11 | 29.5 | 3128.3 | 3245.2 | 2616.9 |
| 4 | 267.7 | 255.3 | 237.7 | 18.8 | 20.1 | 19.3 | 28.9 | 29.34 | 27.9 | 3468.9 | 3550.0 | 2956.2 |
| 6 | 315.9 | 282.9 | 254.7 | 24.1 | 23.9 | 21.9 | 28.8 | 29.27 | 27.9 | 3601.4 | 4493.1 | 3058.0 |
| CV | 5.57 | 1.89 | 2.99 | 7.90 | 4.45 | 4.57 | 2.4 | 1.79 | 29.5 | 3.0 | 1.3 | 2.4 |
| SE± | 9.85 | 3.18 | 4.64 | 0.97 | 0.57 | 0.57 | 0.10 | 0.13 | 1.8 | 69.3 | 28.8 | 48.5 |
| **W X S** | * | ** | * | * | * | * | * | NS | NS | * | * | * |

* = significant at 5 %, ** = significant at 1% and NS = not significant.

Rice grain yield was significantly affected by both water depth and seedling rate and the highest grain yield was recorded when the field was under continuous flood of 20 cm water depth from 15 days after transplanting till maturity while the six seedling/stand gave significantly higher grain yield (Table 5). The saturated plot had the lowest grain yield across the three years of study.

## 4. Discussion

The prominent weeds found in the experimental plots in the three years of study included all categories of weeds. Cumulatively, broad leaved weeds were 31%, grasses 51% and sedges 18%. The presence of these weeds in the experimental plots agreed with the work of Mirza et al. (2007) that major weeds of rice include all categories. Similarly, Florez et al. (1999) observed that weed population in rice field consisted of grasses, sedges and broad leave weed species.

The higher percentage weed control efficiency recorded in 20 cm water depth and six seedlings /stand could be ascribed to inability of some weed seeds to germinate under anaerobic condition created by impounded water and suppression of already germinated weed seedlings. The combined effect of 20 cm water depth and six seedlings/stand gave 89-95.5% weed control efficiency. Similar result was recorded by Sangay et al. (2013) who observed that flooding of soil retarded the germination of weed seeds and once seedlings have established, soil may be flooded to suppress weed growth.

David (1992) observed that weed population density and total dry weight per unit area decreased as water depth increased and the experiment under lowland conditions, showed that at 8 cm height of water, the number of grasses and sedges declined and at about 16 cm water height many of them disappeared. The author concluded that the decline was explained by many weed seeds failing to germinate under anaerobic condition, and the effect of standing water in suppressing growth and development in the early stages.

The six seedlings/stand created a dense stand of rice that disallowed some weeds from growing and compete with rice. Odero and Rainbolt (2011) observed that poor stand of rice encouraged infestation by some weeds such *Commelina spp.* and *Ludwigia* spp. but in denced stand of rice, these weeds cannot compete for essential sunlight and do not become a problem. Tabbal et al. (2002) reported that maintaining continuous shallow submergence, especially during vegetative growth, effectively suppressed weed growth while poor water management often contributed to increase in biomass of weed species (Bouman et al., 2007)

The experiment conducted by Juraimi et al. (2009) indicated that submergence of rice fields hindered weed germination and suppressed the population of most germinated weeds. Similarly, Leeper 2010 observed that soon after flood were established, an anaerobic condition established at the soil surface and most weeds will not germinate.Under anaerobic conditions, water acts similar to a pre-emergent herbicide.

The six seedlings/stand created a solid (dense) stand of rice that disallowed some weeds from proliferate and compete with rice. Odero and Rainbolt (2011) observed that poor stand of rice encouraged infestation by some weeds such *Commelina spp*. and *Ludwigia spp*. but in solid stand of rice, these weeds cannot compete for essential sunlight and do not become a problem. The work of Parvez et al. (2011) to determine the seedling method and rate on weed at Malaysia reported higher weed density and dry matter in lower seedling rate.

The result of this study indicated that water depth and seedling rate had significant effect on weed control index. The result is similar to that obtained in percentage weed control efficiency where higher water depth of between 1-20 cm gave significant better control index. This is an indication that the flood depth of 15-20 cm drastically suppressed the growth of most weeds. The result was consistent for the three-year study. The analysis of interaction between weed infestation and water management in lowland rice by Jabber and Orr (2002) indicated that good water management helped in reducing weed infestation as both the seeds and growth of most weeds are suppressed by standing water. Wopereis et al. (2009) also reported that good water management in rice usually helps to reduce the weed population, as flooding prevents most weeds from germinating.

The variation of weed species composition as influenced by various water depth is an evidence that weed species differ in their response to different water depths. The lower percentage of grasses and sedges in the deeper water depth of 10-20 cm might be the consequences of the deep water on their growth. The progressive decrease of sedges to zero percent at 45-75 DAT in deeper water could be due to the fact that this class of weeds cannot survive in deep water for a long time. This is similar to the result obtained by Venkataraman and Gopalan (1995), that continuous submergence of rice field to 5 cm depth resulted in a minimum number of grassy weeds while maintaining a water depth of 6 to 8 inches for 21 to 28 days after planting can provide partial control of *Echinochloa crus-galli* (Monaco et al., 2002). In Indonesia, Haden et al. (2007) observed an increased incidence of sedges due to reduced periods of flooding.

Dominance of grasses such as *Echinochloa* species and *Leptochloa chinensis* is favoured by saturated and below saturation conditions (Bhagat et al., 1999), while increase in flooding depth and flooding duration encourages broad leaved weeds and sedges (Kent & Johnson, 2001). Grasses such as *Echinochloa crus-galli* grow at field capacity or saturation, whereas a high water table favors aquatic broadleaved weeds and sedges (Bhagat et al., 1996). Bhagat et al. (1999) reported that broadleaved weeds produced higher weed biomass than sedges and grasses in flooding regimes, while in saturated condition the opposite result was obtained. Rodenburg et al. (2011) reported that in irrigated, non-flooded rice systems, weeds are expected to become more serious specifically perennial rhizomatous weeds and species adapted to hydromorphic conditions are expected to increase in prevalence.

In deep water, the surviving weeds were mostly the C3 grass such as *Oryza barthii, Leersia hexandra* while *Sphenoclea zeylanica and Ludwigia abyssinica* were the C3 broad leave weeds that survived in the deep water of

10-20 cm. Most of the weeds that were found in those plots that were not impounded with water were mostly C4 species which might be the reason why yield attributes and yield of rice in those plots were highly reduce as C4 weeds are known to be higher competitor than C3 weeds. Therefore, the negative impact of the C4 weeds such as (*Echinochloa colona, Panicum repens* and *Fimbristylis littoralis*) on rice is always higher than that of C3 weeds (*Sphenoclea zeylanica, Cyperus difformis* and *Ludwigia abyssinica)* because rice itself is C3 plant.

Haden et al. (2007) observed that weed shifted to sedge under reduced flooding while Rodenburg and Johnson (2009) suggested that perennial C3 weed species such as *Oryza longistaminata, Leersia hexandra, Bolboschoenus maritimus* and *Sphenoclea zeylanica* will increase in irrigated rice production systems, but where water saving production systems are adopted, the hydromorphic conditions will favour C4 weed species such as *Echinochloa colona, Echinochloa pyramidalis, Digitaria horizontalisFimbristylis littoralis, Cyperus esculentus, Imperata cylindrica,*and *Paspalum scrobiculatum*. John (2010) also reported that in deep water, the most common weed growing was *Monochoria vaginalis* while at zero water depth (soil saturation) grasses such as *Echinochloa spp* and sedges such as *Fimbristylis miliacea* were predominant.

In rice system, whatever affect weed growth will definitely enhance the yield and yield components of rice, all things been equal. The plots that were not pounded with water recorded the higher weed growth which was mostly C4 weeds which resulted in higher competition which eventually lead to lower panicle production in this treatment. The higher seedling rate on the other hand had fast canopy cover that shaded up the weeds which reducted their growth and the possible competition.

The experiment conducted by Abdul et al. (2009) to determine the influence of flood density and duration on rice growth and yield indicated that the responses of rice panicle number $m^{-2}$ were significantly affected by the flooding treatments and continuous flooding till maturity gave significantly higher panicle $m^{-2}$ of 434 which was higher than that produced by either intermittent flooding till 55 or 30 DAS which produced 426 and 425 respectively. Lowest panicle production of 320 $m^{-2}$ was recorded in saturated field in their experiment. They equally attributed the higher panicle production in continuous flooding to higher tiller production in this water condition. This is in line with the finding of this study.

Beser and Sürek (1999) also observed higher panicle number in experiment to determine the effect of water stress on grain and total biological yield of rice. Jahan (2004) and Sariam (2004) recorded higher panicle production from continuous flooding field while Sariam (2004) and Siti Mardina (2005) on the other hand reported that significant higher panicle production was recorded when rice was grown under field capacity (unflooded field).

Chaff is a negative attribute of yield and what causes stress in rice field most especially at the crucial stage will definitely result to higher percentage chaff. Therefore, the higher percentage chaff recorded in the nonflooded plots could then be attributed to higher stress caused by higher weeds infestation and water deficit at the critical period of rice growth.

Abdul et al. (2009) recorded similar result of higher spikelets from continuous flooded field and the number decreased with decreased in flood depth. The result of this work also agreement with that of Sariam (2004) who observed higher number of spikelets in continuous flooding while rice under field capacity recorded the least number of spikelets. Upadhaya (1996) reported that less biomass and number in grain production under the reduced water regimes could be caused by the lack in water availability at the anthesis (flowering) stage, which restricted rice pollination process and caused the rice to produce infertile and empty rice grain.

Weight of 1000seeds is one of the major yield components and the significant higher grain weight recorded in the deeper water at fewer seedling rates could be attributed to less competition from weeds as a result of suppression of weeds by the continuous flooding at deeper water of between 15-20 cm. Beser and Sürek (1999), recorded similar result of higher grain weight in continuous flooded field than saturated or intermittent irrigation system. Talpur et al. (2013) also recorded higher 1000 grain weight of 24.85 g in the continuous flooded field.

Rice plant needs more water during the reproductive stage particularly during the grain formation and continuous flooding provide the plant enough water at this stage of development for optimum grain development. The saturated soil might not be able to provide the plant with the required moisture for good grain formation. Abdul et al. (2009) reported higher grain weight in continuous flooded field than that recorded in continuous field capacity.

Jahan (2004), in his study on rice production under glasshouse condition, indicated contrary results where no significant difference of 1000-grain weight was observed under the different flooding regimes. Meanwhile, Sariam (2004) reported that 1000-grain weight varied significantly with water management, where lower grain weight was observed under the field capacity condition as compared to flooded conditions. Zenolabedin et al. (2008) reported 17% 1000 grain weight reduction when water stress occurred at grain filling stage.

The grain yield of rice is dependence of yield components like tiller, panicle production, grain weight and percentage filled grain. In rice production system, whatever happened to any of these components will directly translate to total grain yield. The significant higher grain yield recorded in deeper water at six seedling rates could be as result of less competition from weeds in this treatment combination also the rice plant didn't suffer from water deficit at any stage of its growth. In those plots that received no flooding recorded higher weed growth which affected the yield components. Zinolabedin et al. (2008) also reported that water deficit during the vegetative, flowering and grain filling stage reduced grain yield by 21, 50 and 21%respectively. Evaluating the effect of different during of water stress at various growth stage of rice showed that water stress at any stage would reduced yield of rice (Salam et al., 2001; IRRI, 2002).

Tabbal et al. (1992) observed no significant yield difference between rice grown in standing water and those grown under saturated field conditions in the 1988-1989 dry seasons; however, yields under saturated soils were statistically lower in the 1990-1991 dry seasons because of more weed growth, as compared to flooded field. IRRI (2009) acknowledged that improve water management in lowland rice ecology reduced weed infestation by 40% and the labour requirement to weed one hectare is therefore reduced from 21 to 5 manday which translated to 75% decrease in labour requirement.

The negligible grain yield recorded in nonponded plots might be due to severe weed pressure in this treatment, which agreed with the work of De Datta et al. (1986) who observed that weeds are major limiting factor in rice production systems in the world and that yield reduction due to unchecked weed growth varies from 40-85% but with severe weed competition complete loss is possible. Similarly, Ahmed et al. (2005) and Alam et al. (1996) observed lower grain yield from unweeded plots due to severe weed pressure. Pandey (2009) as well reported that weeds are at present the major biotic constraint to increased rice production worldwide. Improving weed control in farmers' fields was shown to increase rice yields by 15-23%, depending on the agro-ecosystem and it is estimated that weeds may account for annual rice yield losses in Sub Saharan Africa of at least 2.2 million tones equating to US $1.45 billion (Rodenburg & Johnson, 2009).

## 5. Conclusion and Recommendations

Based on the result of this study, it could be concluded that flooding of lowland rice field to depth of between 15–20 cm gave better weed control and enhanced the yield and yield components of lowland rice. We therefore recommend the adoption of flooding of lowland rice field to a depth of 15-20 cm for effective weed control. Integration of hand weeding with flooding is also advisable since some weeds like *Oryza barthii*, *Echinochloa spp.* and *Sphenoclea zeylanica* which were not controled by the various water depths.

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