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# Effects of spacing and water control on growth and yield performance of irrigated rice in Guinea savannah Agro-ecological zone

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## ABSTRACT

*The adoption of some attributes of the system of rice intensification (SRI) like water control and planting distance may help improve the productivity of rice. The aim of this study was to use water supply and plant density, components of SRI, to improve rice yield and reduce water use. The study was conducted at Golinga irrigation scheme. Continuous and Intermittent flooding served as main plots in a split-plot design. Four plant spacing, 20 x 20, 25 x 25, 30 x 30 and 40 x 40 cm, were used as subplot treatments. Water control and planting distance interaction significantly (P=0.001) influenced plant height where intermittent flooding promoted taller plants in narrow and wider planting distance (20 x 20 cm and 40 x 40 cm). Days to 50% flowering lengthened with increasing planting distance. Tiller and reproductive tiller number per plant were influenced by only planting distance (P=0.001) and the numbers increased with increasing planting distance. Dry root weight was significantly influenced by both water control (P=0.001) and planting distance (P=0.001). Intermittent flooding induced better root development. (0.678 kg/hill) than continuously flooding (0.598 kg/hill). Root development also improved with increasing planting distance, from 0.37-0.90 kg/hill. Panicle number per unit area, paddy grain yield and straw weight were significantly influenced (P=0.001) by planting distance with 25 x 25 cm giving the best performance. Paddy yield of 5.2 ton/ha at a planting distance of 25 x 25 cm was above the national average and within the potential yield of the variety. It can be concluded that intermittent and continuous flooding gave a similar performance. Increasing plant spacing helps to improve individual hill performance but beyond 25 x 25 cm planting distance, the benefits at the individual hill performance are offset by reduced plant density.*

**Keywords:** *System of Rice Intensification, planting distance, intermittent flooding, continuous flooding*

## INTRODUCTION

In Africa, rice is increasingly gaining more importance. The continent now consumes far more rice than it produces, a situation that has led to huge imports to the continent, (CSIR-SARI, 2012). Per capita consumption of rice in Ghana has increased by about 140% in a decade from 15.4 to 34.5 kg per year (CSIR-SARI, 2012) and this is expected to increase further to 40 kg by the year 2020. Rice import in many African countries keeps on increasing and most countries are making an effort to reduce it. These efforts are not yielding significant effort and the cost keep increasing (FARA, 2009). Ghana has a high potential for the development of rice and there is an opportunity for it to be used for import substitution to save the country from using hard-earned foreign exchange to import rice. The Northern Region of Ghana has conditions suitable for the production of rice. The region was the second producer region of the crop in 2016 (SRID/MOFA, 2017). Researchers are devising means to improve rice production by breeding for high yielding varieties with reduced water requirement and also improve on agronomic practices. The mean yield of paddy rice in Ghana stands at 2.92 tons/ha while the potential yield is about 6 tons/ha (SRID/MOFA, 2017).

Paddy rice yields reported for the System of Rice Intensification (SRI) method is similar to the yields obtained under conventional system yet production requires reduced water use. Rice crop is traditionally cultivated under continuous submerged condition and measures to minimize the water use efficiency of rice crop will improve productivity. In this aspect, some attributes of SRI offer a good approach to minimize water consumption for rice cultivation and to increase its productivity (Laulanie, 1993). Rahman and Ando (2012) reported that continuous irrigation of rice fields promotes anaerobic-conditions which negatively affects crop root development and activity. Kassam *et al.* (2012) reported that rice roots cultivated under submerged soil conditions do not develop fully and suffer some abnormalities. It has been observed that roots that developed suffered degeneration at the early stages and that affected their functionality and effectiveness (Mishra and Salokhe 2011; Thakur *et al*. 2010). According to Thakur *et al*. (2010) aeration of rice field does not only promote higher root growth, but it also induces root function. Uptake of nutrients increases in aerated crops (Thakur *et al*., 2010). Tao *et al*. (2002) also evaluated the effects of intermittent and continuous flooding on the physiology and growth of two rice varieties. They posited that, although intermittent flooded plants had a much deeper root system, larger root and total plant dry matter per hill than plants grown under continuous flooding, the total shoot dry matter production was not significantly different in continuous and intermittent flooding.

It has been reported that prolonged flooding negatively affects plant height and tiller number. It was reported that rice plants grown under intermittent flooding were 22 and 24% taller than corresponding crops cultivated under continuous flooding condition. Tiller development emanates from adventitious roots development and remains active in the moisture regime that allows the soil to be aerated. Productive tiller numbers doubled under intermittent flooding conditions and the low productive tiller number in the continuous irrigated field could be attributed to lack of aeration causing the roots to be degenerated (Thakur *et al*., 2010). Intermittent flooding has been reported to have increased yield in rice (Li, 2001; Tuong *et al*., 2005; Zhang *et al*., 2008; Zhang *et al*., 2009) while other authors (Mishra *et al*., 1990; Tabbal *et al*., 2002; Belder *et al*., 2004; Yang *et al*., 2007) have reported yield reduction when compared with continuously flooded conditions. Grain yields of 10–12 ton/ha have been achieved in tropical conditions whereas higher yields of about 13–15 ton/ha have been measured at sites having subtropical conditions (Kropff *et al*., 1994; Horie *et al*., 1997**;** Ying *et al*., 1998; Sheehy *et al*., 2000). Plant biomass production correlates with the amount of water transpired, and it has been observed that higher water use efficiency is often a trade-off against lower biomass production (Zhang *et al*., 2004).

Plant spacing is an important production factor in transplanted rice (Gorgy *et al*., 2010). Mohapatra *et al*. (1989) reported that closer plant spacing of 20 × 20 cm was better than those of 25 × 20 or 25 × 25 cm under normal lowland soil for rice production. Patel (1999) observed that hill spacing of 20 × 20 cm recorded higher panicle number and grain yield than when the planting distance was reduced to 20 × 15 cm and 20 × 10 cm. Anwar *et al*. (2019) reported that **p**lanting distance had significant effects on tillers number, leaf greeness, non-filled grain, total grain, and 1000 grains weight. They observed that the spacing of 25 x 25 cm produced the highest performance for most of the agro-morphological traits evaluated.

In densely populated rice field the inter-specific competition between plants is high in which sometimes results in gradual shading and lodging and thus increase production of straw instead of grain. It is, therefore, necessary to determine the optimum plant spacing and number of seedling per hill for high yield (Ghosh and Singh, 1998; Hossain *et al*., 2003).

The objective of the study was to determine the effect of two SIR practice (planting distance and water control) on growth performance and yield of Jasmine rice.

## MATERIALS AND METHODS

### Site description

The study was carried out at the Golinga irrigation site in the Tolon district of Guinea savannah zone of Ghana between October 2014 and January 2015. It was done during the dry season. Golinga is located at 10 km west of Tamale and lies approximately on latitude $0^0 56'.678''$W and longitude $9^0 21'.346''$N. The area has a unimodal rainfall pattern with the rainy season stretching from April or May to October. The mean annual rainfall of the area is about 1157 mm. The temperature distribution is not uniform with mean monthly temperature ranging from 23.4 $^0$C (minimum) and 40.5 $^0$C (maximum). Relative humidity of the area generally varies greatly, rising during the rainy season (SARI, 2001).

### Land preparation and raising of seedlings

The experimental area was ploughed and harrowed with a tractor after excess water had completely been drained off. Nursery beds were raised using a hoe. Seedbed was kept moist for three days before paddy seeds that have been pre-germinated were sown on the nursery beds. The nursery bed was kept moist until full emergence and then regularly irrigated as needed without flooding. Industrially produced compost made from chicken droppings were applied to the experimental area at 5 t/ha and worked into the soil during harrowing. The seedlings were transplanted (one seedling per hill) at the two-leaf stage ten days after emergence.

### Experimental design

The factors were water control at two levels and planting distance at four levels. The water control levels were continuous flooding and intermittent flooding. In the continuous flooding, water was kept on the field at the depth of 5 cm. In the intermittently flooded fields, the transplanted seedlings were kept wet like the continuous flooding.

After that, once every two weeks the soil was allowed to completely dry out for a week before water was restored to a depth of 5 cm. Water was applied again after all water has dried away. The levels of the planting distance were 20 x 20 cm, 25 x 25 cm, 30 x 30 cm and 40 x 40 cm. The treatment combinations were laid out in a split-plot design with three replications. The water control went into the main plot while the plant spacing was assigned to sub-plot. Each sub-plot measures 5 x 4 m. Bunds were made around the plots to regulate water drainage.
The rice variety used was Jasmine 85 also called Gbewaa, which according to the catalogue of crop varieties released and registered in Ghana, is an improved variety with a maturity period of 115 days. It has a yield potential of about 5-6 ton/ha. It is aromatic and has high consumer acceptability.

**Cultural practices**
Weeding was done manually at two weeks interval using the hand hoe. When the rice flowered, more water was allowed to flood the fields up to 8 cm depth. Three weeks before harvest, no irrigation was done and the field was maintained dry.

**Data collection and analysis**
Data were collected on the following parameters: Plant height (cm), days to 50% flowering, tiller number per plant at 60 days after transplanting (DAT), number of productive tillers per hill and dry root weight at 60 DAT. Other data taken were panicle number per $m^{2,}$ grain number per panicle, dry straw yield (kg/ha) and paddy yield (kg/ha). Data were taken from five plants in the case of height, tiller number and productive tillers. For root dry weight all tillers on a hill were taken at 60 days after planting. The samples were oven-dried for 24 hours at 70 $^0$C and weighed. Panicle number was taken from 1 $m^2$ quadrants. Harvesting was done at physiological maturity (120 days) with a sickle. The yield was measured from an inner plot measuring 5 $m^{2.}$ Harvested paddy was threshed, winnowed, dried and weighed at 15 % moisture content. The paddy yield was converted to kg per hectare. The straw from each plot was harvested, dried in oven at 70 $^0$C for 24 hr and the weight was converted to kg per hectare.

Genstat Teaching and Learning Edition was used for the analysis of variance. Where a factor was significant (P<0.05) the treatment means were separated using LSD at 5% probability.

## RESULTS

**Effects of planting distance and water control on rice plant height**
Plant spacing and water control interaction had a significant effect (P < 0.001) on plant height (Table 1). Plants receiving wider planting distance treatment (40 x 40 cm) mostly grew taller than narrow spaced, 20 x 20 cm and 25 x 25 cm. At narrow planting distance of 20 x 20 cm it was observed that intermittent flooding generally promoted longer plant height than continuous flooding. The same was observed in plants planted at 25 x 25 cm up to 30 days after planting (DAP). The opposite was observed in plants planted at 30 x 30 cm, plants on continuously flooded plots recorded taller plants up to 30 days thereafter the intermittently flooded plants took over (Table 1). However, at 40 x 40 cm, the intermittently flooded plants generally grew taller than continuously flooded plants.

TABLE 1. **Effects of of planting distance and water control interaction on plant height at different days after planting**

| | | Days after planting | | | | | |
|---|---|---|---|---|---|---|---|
| Planting distance | Water Control | 15 | 30 | 45 | 60 | 75 | 90 |
| 20 x 20 cm | Continuous | 26.33 | 53.33 | 60.00 | 65.00 | 73.33 | 81.80 |
| | Intermittent | 29.00 | 56.00 | 69.30 | 76.70 | 82.33 | 93.30 |
| 25 x 25 cm | Continuous | 13.67 | 40.67 | 78.00 | 89.70 | 96.00 | 98.70 |
| | Intermittent | 26.00 | 53.00 | 61.70 | 69.40 | 74.00 | 79.70 |
| 30 x 30 cm | Continuous | 39.33 | 66.33 | 70.00 | 78.00 | 82.00 | 87.70 |
| | Intermittent | 24.00 | 51.00 | 75.70 | 88.20 | 96.00 | 106.50 |
| 40 x 40 cm | Continuous | 31.33 | 58.33 | 82.70 | 87.30 | 91.67 | 96.70 |
| | Intermittent | 41.67 | 68.67 | 79.70 | 87.30 | 94.67 | 103.20 |
| **LSD (0.05)** | | **2.39** | **2.39** | **9.59** | **10.40** | **7.38** | **9.39** |

**Effects of of planting distance and water control on days to 50 % flowering in rice**

The interaction between plant spacing and water control did not significantly influence days to 50 % flowering (P = 0.143). Water control did not have a significant effect (P = 0.161) on days to 50% flowering. However, days to 50 % flowering was significantly influenced (P< 0.001) by planting distance. The days to 50 % flowering increased with increasing planting distance (Figure 1).

**Effects of of planting distance and water control on Tiller and reproductive number per plant**

Water control did not significantly (P= 0.184) influence tillering. Continuous flooding recorded more tiller number than intermittent though the difference was not significant. Tiller number was also not influenced significantly by water control and planting distance interaction (P= 0.675). However, tiller number was significantly influenced (P = 0.001) by planting distance. Tiller number increased with increasing planting distance (Figure 2). The reproductive tiller number per plant followed the same pattern as the tiller number. Reproductive tiller number, however, was less than tiller number (Figure 3).

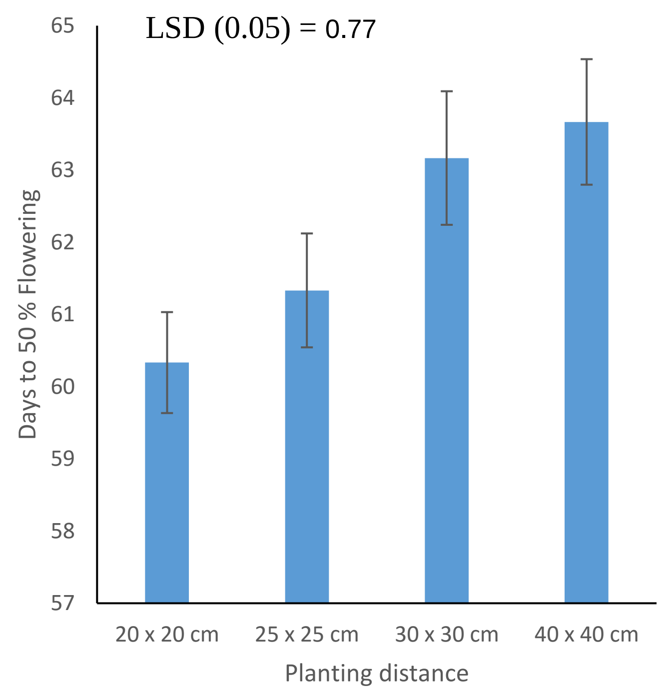


FIGURE 1. **Effect of planting distance on Days to 50% flowering in rice. Error bars represent SEM.**

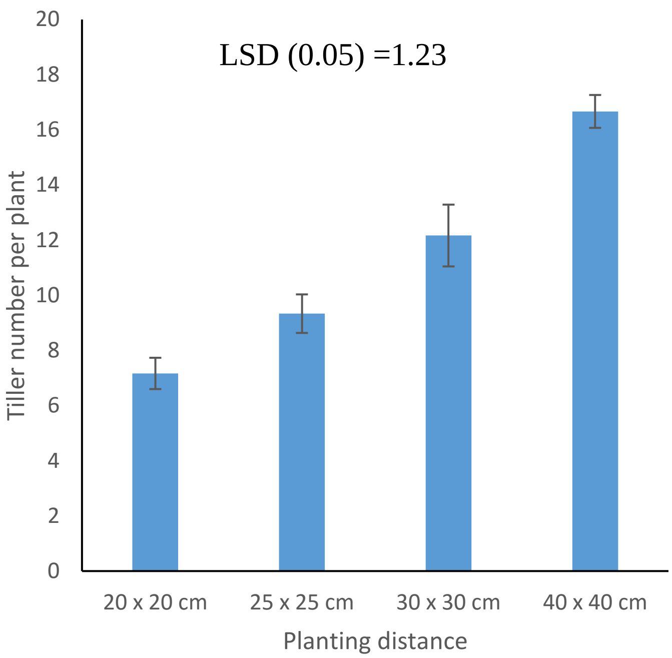


FIGURE 2. **Effect of planting distance on the tiller number of rice. Error bars represent SEM.**

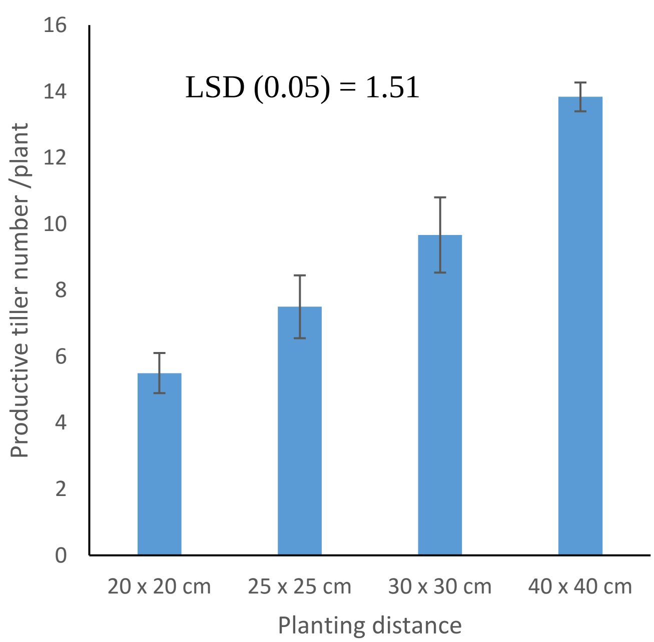


FIGURE 3. **Influence of planting distance on the number of productive tillers of rice. Error bars represent SEM.**

**Dry root weight per plant**

Water control and planting distance interaction did not have significant (P= 0.083) effect on root mass (Figure 4). Water control had a significant influence (P= 0.001) on root dry weight, 60 DAP. Continuous flooding led to 0.598 kg of root per hill as compared to 0.678 kg obtained in intermittent flooding. Planting distance also significantly influenced root mass (P<0.001). Root mass increased with increasing planting distance (Figure 4).

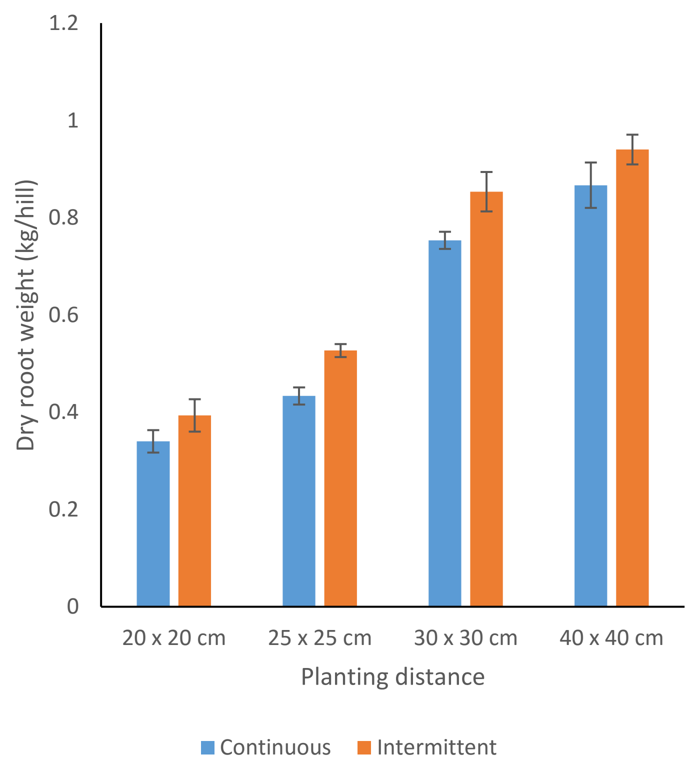


FIGURE 4. **Influence of water control and planting distance on root dry weight per hill, 60 DAP. Error bars represent SEM.**

**Effects of planting distance and water control on panicle number per unit area and grain number per panicle**

The panicle number per unit area was not significantly influenced (P = 0.960) by the interaction between plant spacing and water control. Water control also did not have a significant effect (P = 0.661) on panicle number per unit area. Planting distance, however, significantly (P=0.001) influenced panicle number (Figure 5). Panicle number increased from 20 x 20 cm to 25 x 25 cm and declined. There was no significant difference between 30 x 30 cm and 40 x 40 cm in panicle number. Water control and planting distance interaction did not significantly (P > 0.05) affect the number of grains per panicle. On the average, the number of grains obtained in the study was 127.2 per panicle.

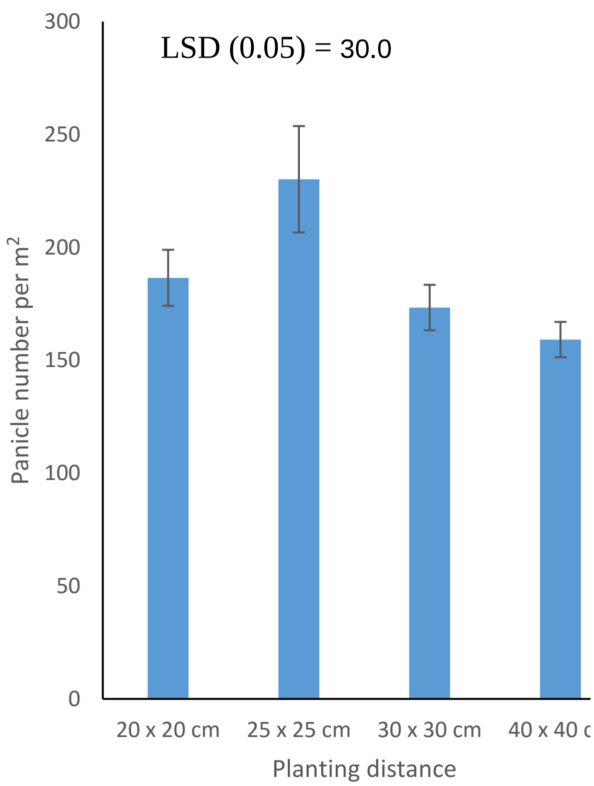


FIGURE 5. **Influence of planting distance on panicle number/m$^2$. Bars represent SEM.**

**Effects of planting distance and water control on rice dry straw yield (kg/ha)**

The straw yield was not significantly influenced (P = 0.859) by the interaction between planting distance and water control. Water control also did not have a significant effect (P = 0.380) on straw yield per hectare. Planting distance, however, significantly influenced straw yield (P = 0.001). The straw weight increased from 20 x 20 cm to 25 x 25 cm and declined. There was significant difference between 20 x 20 cm and 25 x 25 cm in straw weight. The 25 x 25 cm treatment recorded higher straw yield than that of 20 x 20 cm. Similar observation was made for 30 x 30 cm and 40 x 40 cm in straw weight (Figure 6)

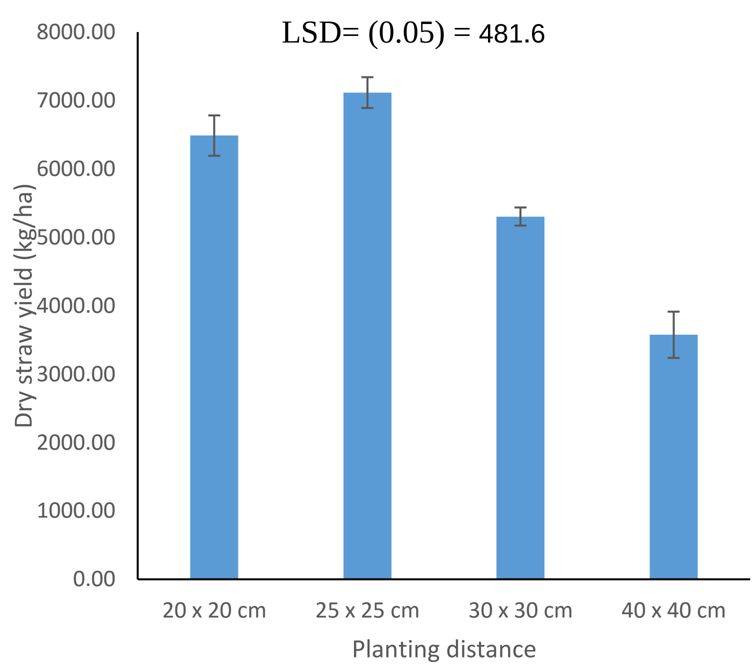


FIGURE 6. **Influence of planting distance on rice straw yield. Bars represent SEM**

**Effects of planting distance and water control on rice paddy yield**

Water control did not have significant (P= 0.981) influence on paddy grain yield. Water control and planting distance interaction also did not significantly (P= 0.981) influence rice grain yield however, planting distance significantly influenced (P< 0.001) grain yield. Yield increased from 20 x 20 cm to 25 x 25 cm and declined. Paddy grain yield recorded on 20 x 20 cm and 25 x 25 cm plots were not statistically different however the yield difference between 30 x 30 cm and 40 x 40 cm were significant (Figure 7)

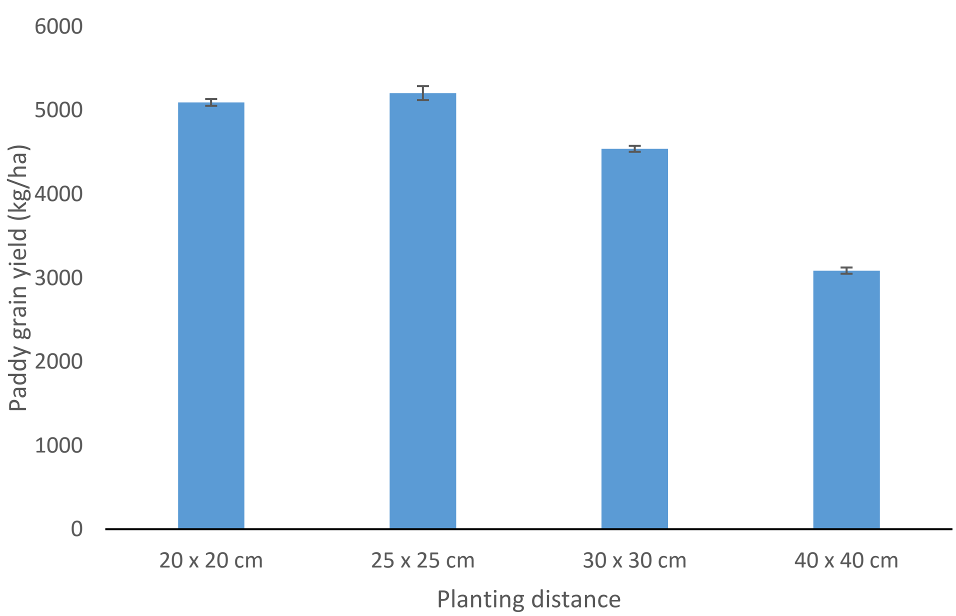


FIGURE 7. **Influence of planting distance on rice paddy yield. Bars represent SEM**

## DISCUSSIONS

Plant with relatively wider spacing (40 x 40 cm) grew much taller than smaller spacing (20 x 20 cm). Taller plants produced by wider spacing may be attributed to adequate resources like nutrients and moisture available for rapid vegetative growth. At planting distance of 20 x 20 cm and 40 x 40 cm intermittent flooding elicited taller height than continuous flooding. However, the pattern of plant spacing and water control interaction was not consistent at plant spacing of 25 x 25 cm and 30 x 30 cm. It appears that intermittent flooding had an edge over continuous flooding. Shrirame *et al*. (2000) have reported that vegetative growth in the form of the number of functional leaves and leaf area were higher at a wider spacing which promoted photosynthetic rate leading to taller plants.

The result of this study shows that the number of days to 50 % flowering increased with increasing plant spacing in both continuous flooding and intermittent flooding. The differences in days to 50 % flowering may be due to rapid vegetative growth in closer plant spacing resulting in competition for light, nutrient, spacing and then resulting in an early switch over to reproductive phase. This result is consistent with this finding of Krupakar (2004) and Udayakumar (2005) They reported that close plant spacing results in quick vegetative growth leading to early switch over to the reproductive phase.

Tiller and productive tiller number per plant increased with increasing space. The plants with more space have enough resources to produce and sustain more tillers. Shrirame *et al*. (2000) in a study in rice also reported that the total number of tillers per hill were higher at wider spacing as a result of increasing plant spacing and photosynthetic rate.

At the reproductive stage, some of the tillers degenerated resulting in reduced tillers. The reduced productive tiller number observed on smaller planting space may also be due to a major condition of poor stem reserves of sufficient carbohydrate storage before grain filling. Veeramani (2011) reported a significant higher number of productive tillers/plant at wider row spacing compared with closer pacing which is in agreement with this study. Continuous flooding and intermittent flooding did not show any difference. This means that intermittent flooding is beneficial since it saves water resources.

Water control affected root development, the results showed that intermittently flooded plants developed roots better than continuously flooded plants. It is believed that continuous flooding creates the anaerobic condition. One of the most important principles of draining in intermittent flooding is to ensure aeration of the soil. Rahman and Ando (2012) have submitted that continuous irrigation of rice fields promotes anaerobic conditions which negatively affects crop root development and activity. Satyanarayana *et al.* (2007) have reported that under continuous flooding condition, up to 75 % of the roots degrade before flowering occurs. The findings are also in conformity with research by Mishra and Salokhe (2011) and Thakur *et al*. (2010) that stated that roots under flooded conditions do not develop very well and have a shorter life span. Under intermittent flooding, roots reach deeper and achieve double the volume compared to plants in continuous flooded planted (Thakur *et al*. 2010). Plants with wider spacing developed a massive root system that also supported tillering. The observation by Thakur *et al*. (2011) that hills that have been spaced wider had larger root dry weight is consistent with our finding.

Water control did not affect panicle number but planting distance influenced panicle number. Grain number per panicle was not influenced by the factors studied, the decreasing panicle number/$m^2$ with increasing plant spacing may be due to reduced plant density. Though productive tiller increased with increasing planting distance the tillers produced per plant could not compensate for the reduced plant density at wider planting distance. 25 x 25 cm plant spacing recorded higher panicle number than 20 x 20 cm and this may be attributed to higher tillering ability at 25 x 25 cm that compensated for the reduced plant density. This contrasts the observation made by Patel (1999) that panicle number per $m^2$ and the number of grains per panicle are not affected by hill spacing. However, Thakur *et al.* (2011) reported that wider spacing improved output at the individual hill but on a hectare basis closer spacing recorded more panicle. Patel's (1999) observation that grain number per panicle is not affected by hill spacing agrees with our study.

Rice paddy yield and straw yield followed the same pattern; they were influenced by planting distance. Yield from 25 x 25 cm plot was similar to that of 20 x 20 cm because the difference in plant density was not vast and the 25 x 25 cm had more space to cater for more tillers than 20 x 20 cm. The higher performance of 25 x 25 cm at individual hill level in terms of root dry weight and productive tiller number compensated for the lower plant density thereby producing similar yield as 20 x 20 cm which had higher plant density. Productive tiller number has been reported by Mohammed (2006) to have much bearing on grain yield and its improvement at the hill level influences grain yield. However, when plant spacing was increased further to

30 x 30 cm the individual better hill performance could not compensate for the reduced plant density and yield further reduced when planting distance was increased to 40 x 40 cm. Giving rice plant wider space to tiller is good but it has its limitation, planting distance beyond 25 x 25 cm becomes disadvantageous. Thakur *et al.* (2011) concluded that wide spacing beyond the optimum plant population does not give higher grain yield on a unit area basis.

The use of intermittent flooding has been reported to have increased grain yield of rice (Zhang *et al*., 2009; Zhang *et al*., 2008 but work of other authors revealed reduction in yield (Yang *et al*., 2007; Belder *et al*., 2004) when compared with continuously flooded conditions. The differences in the studies have been attributed to the variations in the hydrology of the area and the timing of the irrigation method used (Belder *et al*., 2004). In our study, continuous flooding did not induce higher yield than intermittent flooding. The results show that water can be saved in irrigation sites thereby reducing the cost of production due to water consumption.

## CONCLUSION AND RECOMMENDATION

In conclusion, the study shows that wider spacing improves individual hill performance but if the plant density is low the higher individual hill performance cannot compensate for the reduced plant density. Intermittent flooding of rice does not put the crop in a disadvantageous position as it elicited similar response as continuous flooded condition. Farmers are recommended to increase planting distance of rice to between 20 x 20 cm and 25 x 25 cm and apply water intermittently.

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