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Effect of plant spacing and intermittent flooding on growth and yield of selected lowland rice varieties in Kenya

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Abstract

A study was carried out with specific objectives of: (1) to determine the effect of intermittent flooding on growth and yield of selected rice varieties; and (2) to determine the effect of spacing on growth and yield of selected rice varieties. The treatments, comprising two irrigation regimes (intermittent flooding and continuous flooding), three varieties (TXD 306, Basmati 370 and IR-2793-80-1) and four different plant spacing arrangements (15cm ×15cm, 20cm ×15cm, 25cm ×15cm and 30cm ×15cm) were laid out in a randomized complete block design with a split-split plot arrangement. In the first season, IR-2793-80-1 had significantly higher net grain yield than Basmati 370 and TXD 306, while in the second season TXD 306 had significantly higher net grain yield than the other two varieties. Plant spacing of 30×15cm had the highest number of panicles per plant in both seasons, while 15×15cm plant spacing had higher net grain yield than 25×15cm and 30×15cm in both seasons. Intermittent flooding didn't only lead to higher net grain yield but also helped to save 44.4% irrigation water compared to continuous flooding. This study has demonstrated that cultivation of the recently introduced variety TXD 306, intermittent flooding and use of 15×15cm plant spacing have a potential to improve rice productivity with less water consumption in Mwea Irrigation Scheme.

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Introduction

Rice production in Kenya is based on a conventional practice of continuously flooding of the paddy fields (Republic of Kenya, 2008). This method is not sustainable due to the already existing competition for water among farmers within and outside the Scheme (Mati *et al.*, 2011). Kenya is classified as water scarce, which arises from the uneven distribution of water resources and frequency of extreme weather events (UN-WATER/WWAP, 2006).

The pressure to reduce water use in irrigated agriculture is mounting, thus rice is an obvious target for water conservation. Producing more rice using less water is very important in water scarce areas so as to feed the growing population. A reduction of 10% of water used in irrigated rice would free 150,000 million m^3, corresponding to about 20% of total fresh water used globally for non-agricultural purposes (Kleem *et al.*, 1999). To achieve good yields, there is need for coming up with water use-efficient practices (Chapagain *et al.*, 2010).

Intermittent flooding is a promising method in irrigated rice cultivation with benefits of both water and environmental savings while maintaining rice yields at the same level (Yang *et al.*, 2009). Studies in Kenya indicate that intermittent irrigation could result in water saving of up to 25% (Mati, 2012; Ndiiri *et al.*, 2012). In Madagascar it has been reported that water saving through intermittent flooding can increase yield by 25-100% while reducing water used by 25-50% (Satyanarayana *et al.*, 2007). In China it has been reported that up to 46% of water saving was attained and yield increase of similar value (Xiaoyun *et al.*, 2005).

Plant spacing is an important production factor in transplanted rice (Gorgy *et al.*, 2010). Optimum spacing ensures efficient utilization of solar radiation by plants hence optimum production of yields (Mohaddesi *et al.,* 2011). It also ensures that plants grow properly both in their aerial and underground parts (Shirtliffe *et al.*, 2002). Plant spacing affects plant population, biomass, tillering of rice hills and number of grains per panicle (Hasanuzzaman *et al.*, 2009).

Materials and mathods

Study site

Field trials were conducted during March to July 2015 and August to December 2015 seasons in Mwea Irrigation Scheme [0°39′N, 37°17′E, 1195m above sea level] in Kirinyaga South district, in Kenya. The location was chosen because it is a major rice growing area under irrigation in Kenya. The site is located about 100km North East of Nairobi. The Scheme is one of the seven public schemes under the management of the National Irrigation Board. The site lies in the agro-ecological zone 3 and receives 1000 mm of rainfall in a year, 600mm in the long rains and 400 mm in short rains with 66% reliability. The average temperature in the area is 22°C, with minimum and maximum temperatures of 17°C and 28°C respectively. The area experiences a relative humidity of 54.7% to 87.2%. Mwea Irrigation Scheme has a gazzeted area of 30,350 acres. Of these, 16,000 acres have been developed for paddy rice production. In addition, the Scheme has a total of 4,000 acres of out grower and "jua kali" (non-out grower) areas under paddy rice production. It is divided into seven sections with a total of 77 units and about 5,000 farmer households. Each farmer holds about 2.8 acres according to a survey done by Rice Mapp in 2012. Each farmer produces 2500-3000kg per acre (JICA, 2012). The Scheme is served by Nyamindi and Thiba rivers which have fixed intake weirs. The irrigation water is abstracted from the rivers by gravity and is conveyed and distributed in the scheme via unlined open channels. A link canal joins the two rivers which transfers water from Nyamindi to Thiba River, which serves about 80% of the Scheme (Mburu *et al.,* 2011). Soils in the area are black cotton soils (vertisols) that shrink and swell with changes in moisture content (Sombroek *et al.*, 1982). Soil at the experimental field was sampled at depths of 0-15cm and 15-30cm and analyzed for pH, N, K, Ca, Mg and cation exchange. The experimental design was a randomized complete block with a split-split plot arrangement, replicated three times. The subplot measured 3m by 3m while the total area covered by the experiment was $1596m^2$ with 2m between blocks and 1m between plots. The study involved three factors namely: spacing, variety and irrigation regime.

The spacing treatments comprised 15x15cm, 20x15cm, 25x15cm and 30x15cm; varieties comprised Basmati 370, TXD 306 and IR 2793-80-1; and irrigation regimes comprised intermittent flooding and continuous flooding. Variety Basmati 370 and IR-2793-80-1 are locally grown varieties while TXD 306 is an improved and recently released variety. Land preparation was done by first flooding the fields for three days, then puddling to soften and mix the mud (Wanjogu *et al.,* 1995). A nursery of 1 m by 2m for each of the three varieties was prepared.

The nursery was watered daily, except on days when there was rainfall, to keep the soil saturated but not flooded. The nursery was adjacent to the main experimental field for transplanting to be performed quickly to minimize stress for the young plants (WBI, 2008). Twenty one day old seedlings were transplanted at a rate of one seedling per hill for all the plant spacing. Plots received the same basal fertilizer supply of 46kg P_2O_5/ha as triple super-phosphate and 60kg K_2O/ha as muriate of potash one day before transplanting.

All plots received an additional 120kg/ha of sulphate of ammonia with split applications of 1:2:2 at 10, 30 and 60 days after transplanting as elaborated by Wanjogu *et al.,* (1995). Mechanical weeding (hand weeding) was used to control weeds effectively and provide aeration to the soil. Plots were hand weeded three times during the vegetative stage (twice) and reproductive stage (once). Water was supplied through a concrete channel to the main plots and subsequently up to the sub sub-plots. Each main plot was irrigated separately and a water depth level of 5cm was maintained in the continuously flooded plots while water was added only after the water level reached a depth of less than 1cm in the intermittently flooded plots. Irrigation schedules were assigned to the main plots, variety to sub-plots and spacing to the sub sub-plots. Each main plot was surrounded by bunds lined with 0.5m deep plastic sheets to prevent seepage of water and 2m wide channels for irrigation.

All plots were drained two weeks before harvesting to promote ripening of the grain and harden the soil for effective harvesting.

Data collection

Data was collected according to the standard evaluation system of rice (IRRI 2002) using a transect line of 10 plants that were retained for the whole season. Data collected included: number of total tillers, number of effective tillers, panicle length, number of panicles per plant, 1000-grain weight and net grain yield.

The number of tillers at 35, 45, 55 and 75 days after transplanting and at harvesting stage was determined by visual counts. Panicle length was measured as the length from the base of the panicle to the tip of the last grain at the top of the panicle using a 30cm rule (Surajit, 1981). Ten hills in each plot were randomly marked at the time of planting and number of tiller per plant counted periodically at intervals of 10 days up to the panicle initiation stage. All the panicles from one of the 10 plants in each plot were clipped and put in a separate paper for counting. The process of harvesting involved cutting the rice plants using a sickle at 15cm above the ground and threshing the rice immediately on a mat (IRRI, 1978). In order to get a good estimate of grain yield by minimizing grain damage and quality deterioration, the threshing was done immediately following Surajit (1981) guidelines. Grains were dried after harvesting and moisture content measured using a moisture meter. Grain weight was adjusted to 14% grain moisture content. One thousand grains were counted using a 1000 grain counter and their weight was taken using a sensitive weighing scale.

Data analysis

Water saved was calculated as follows:

Water saved (%) =

$$\frac{\text{water applied in CF plot} - \text{water applied in IF plot}}{\text{Water applied in CF plot}} \times 100$$

Data collected were subjected to analysis of variance using Genstat 15th edition and treatment means were compared using the least significant difference (LSD) test at $p \leq 0.05$.

Results

Effect of rice variety on panicle length, number of panicles per plant, 1000-grain weight and net grain yield

There were significant varietal differences in panicle length in both seasons (Table 1). Basmati 370 had significantly higher panicle length than IR-2793-80-1 and TXD 306 in both seasons. However, IR-2793-80-1 had significantly higher panicle length than Basmati 370 in the second season. Panicle length ranged from 22cm (IR-2793-80-1) to 24.4cm (Basmati 370).

In both seasons, there were significant varietal differences in the number of panicles per plant (Table 1). Variety IR-2793-80-1 had significantly higher number of panicles per plant than TXD 306 and Basmati 370 in both seasons. In the first season, IR-2793-80-1 had significantly higher number of panicles per plant than TXD 306 and Basmati 370 while in the second season Basmati 370 had a significantly higher number of panicles per plant than TXD 306. The number of panicles per plant ranged from 12.9 to 18.1 in the first season and 14.3 to 19.1 in the second season.

There were significant varietal differences in net grain yield in both seasons (Table 1). In the first season, IR-2793-80-1 had significantly higher net grain yield than TXD 306 and Basmati while in the second season TXD 306 had significantly higher net grain yield than IR-2793-80-1 and Basmati. Basmati 370 had significantly the lowest net grain yield in both seasons. TXD 306 and IR 2793-80-1 out-yielded Basmati 370 in both seasons. The net grain yield ranged from 2.1t/ha (Basmati 370) to 4.8t/ha (IR-2793-80-1) in the first season and 4.7t/ha (Basmati 370) to 9t/ha (TXD 306) in the second season.

Variety had a significant effect on 1000-grain weight in both seasons (Table 1). In both seasons, Basmati 370 had significantly lower1000 grain weight than TXD 306 and IR-2793-80-1. In the second season, TXD 306 had significantly higher 1000 grain weight than IR-2793-80-1, but the two varieties were not significantly different in 1000 grain weight in the first season.

A thousand grain weight ranged from 22.4g (Basmati 370) to 29.3g (IR-2793-80-1) in the first season and 25.5g (Basmati 370) to 32.1g (TXD 306) in the second season.

Effect of plant spacing on panicle on length, number of rice panicles per plant, 1000-grain weight and net grain yield

Plant spacing did not have a significant effect on rice panicle length in both seasons (Table 2). Panicle length ranged from 22.3cm (15×15cm plant spacing) to 23.2 cm (25×15cm plant spacing) in the first season and 23.1cm (15×15cm plant spacing) to 23.7cm (25×15cm plant spacing) in the second season.

The number of rice panicles per plant was significantly affected by plant spacing in both seasons (Table 2). Plant spacing of 30×15cm had significantly higher number of panicles per plant than most other plant spacing treatments in both seasons. Narrowing the intra and inter-row spacing (decrease in plant spacing) led to a significant decrease in the number of panicles per plant, except for the decrease from 25×15cm to 30×15cm in the first season. The number of panicles per plant ranged from 11.3 (15×15cm) to 18.1 (30×15cm) in the first season and 14.1 (15×15 cm) to 20.5 (30×15cm) in the second season.

There were significant differences in net grain yield among the plant spacings in both seasons (Table 2). Plant spacing of 15×15cm had significantly higher net grain yield than 20×15cm, 25×15cm and 30×15cm in the first and second season. Plant spacing of 30×15cm had lower net grain yield than all other plant spacings in the first season. No significant differences were noted between 15×15cm and 20×15cm in both seasons and between 25×15cm and 30×15cm in the second season. Net grain yield ranged from 3.0t/ha (30×15cm plant spacing) to 4.3t/ha (15×15cm plant spacing) in the first season and 6.9 (30×15cm and 25×15cm plant spacing) to 7.6t/ha (15×15cm and 20×15cm) in the second season (Table 2).

Plant spacing significantly affected 1000-grain weight in the second season, but had no effect in the first season.

Plant spacing of 30×15cm resulted in significantly lower 1000 grain weight than plant spacing of 20×15cm and 15×15cm. No significant differences were noted among plant spacing treatments of 25×15cm, 20×15cm and 15×15cm (Table 2).

Table 1. Effect of rice variety on panicle length, number of panicles per plant, 1000-grain weight and net grain yield.

Variety	Panicle length (cm)	No. of panicles/plant	1000-grain weight(g)	Net grain yield (t/ha)
Season 1				
Basmati 370	24.4	12.9	22.4	2.1
TXD 306	21.9	14.0	28.8	4.2
IR 2793-80-1	22.0	18.1	29.3	4.8
p-value	0.007	0.004	<.001	0.003
LSD (p=0.05)	1.5	2.6	2.9	1.2
CV (%)	4.9	13.0	8.0	26.3
Season 2				
Basmati 370	25.3	12.1	25.5	4.7
TXD 306	21.9	14.3	32.1	9.0
IR 2793-80-1	22.9	18.1	28.4	8.0
p-value	<.001	<.001	<.001	<.001
LSD (p=0.05)	0.9	1.8	1.1	0.2
CV (%)	3.0	7.7	3.0	2.9

Table 2. Effect of plant spacing on panicle on length, number of rice panicles per plant, 1000-grain weight and net grain yield.

Spacing	Panicle length (cm)	No. of panicles/plant	1000 grain weight (g)	Net grain yield (t/ha)
Season 1				
15 cm× 15 cm	22.3	11.3	26.6	4.3
20 cm× 15 cm	23.0	14.2	26.7	4.0
25 cm× 15 cm	23.2	16.5	26.5	3.7
30 cm× 15 cm	22.6	18.1	27.5	3.0
p-value	0.150	<.001	0.334	<.001
LSD (p=0.05)	0.8	1.6	1.3	0.5
CV (%)	5.3	15.7	7.1	23.1
Season 2				
15 cm× 15 cm	23.1	14.1	29.0	7.6
20 cm× 15 cm	23.3	15.8	29.3	7.6
25 cm× 15 cm	23.7	18.2	28.6	6.9
30 cm× 15 cm	23.3	20.5	27.8	6.9
p-value	0.229	<.001	0.020	0.002
LSD (p=0.05)	0.6	1.5	0.9	0.4
CV (%)	3.6	5.3	4.9	8.5

Effect of irrigation regime on panicle length, number of panicles per plant, 1000 grain weight and net grain yield

The irrigation regime did not have a significant effect on panicle length, number of panicles per plant and 1000-grain weight in both seasons (Table 3). Panicle length ranged from 22.5cm (intermittent flooding) to 23cm (continuous flooding) in the first season and 23.3cm (intermittent flooding) to 23.4cm (continuous flooding) in the second season.

The number of panicles per plant ranged from 14.8 (continuous flooding) to 15.2 (intermittent flooding) in the first season and 16.7 (intermittent flooding) to 17.7 (continuous flooding) in the second season.

One thousand grain weight ranged from 26.5 (continuous flooding) to 27.1 (intermittent flooding) in the first season and 28.4 (intermittent flooding) to 28.9 (continuous flooding) in the second season.

The irrigation regime had a significant effect on net grain yield in the second season but not in the first season. In the second season, intermittent flooding gave significantly higher net grain yield than continuous flooding.

Net grain yield ranged from 3.6t/ha (continuous flooding) to 3.9t/ha (intermittent flooding) in the first season and 7.1t/ha (continuous flooding) and 7.3 t/ha (intermittent flooding) in the second season.

Table 3. Effect of irrigation regime on panicle length, number of panicles per plant, 1000 grain weight and net grain yield.

Regime	Panicle length (cm)	No. of panicles/plant	1000 grain Weight (g)	Net grain yield
Season 1				
IF	22.5	15.2	27.1	3.9
CF	23.0	14.8	26.5	3.6
p-value	0.498	0.591	0.195	0.282
LSD (p=0.05)	NS	NS	NS	NS
CV (%)	3.2	4.6	1.3	7.4
Season 2				
IF	23.3	16.7	28.4	7.3
CF	23.4	17.7	28.9	7.1
p-value	0.878	0.305	0.632	0.004
LSD (p=0.005)	NS	NS	NS	0.034
CV (%)	3.7	5.3	3.2	0.1

Where, IF and CF is intermittent flooding and continuous flooding respectively.

Effect of plant spacing, variety and irrigation on the number of tillers per plant

The main effect of variety and plant spacing on the number of tillers per plant was significant in both seasons (Table 4). However, variety and plant spacing interaction significantly influenced the number of tillers per plant in the first season only. In the first season, increasing the plant spacing from 15×15cm to 20×15cm and above resulted in a significant increase in tiller number in Basmati 370 and IR-2793-80-1. In variety TXD 306, only 30×15cm had significantly higher number of tillers per plant than other plant spacing treatment. Basmati 370 had significantly lower tiller numbers than IR-2793-80-1 at all plant spacings than TXD 306 in 15×15cm plant spacing.

VarietyIR-2793-80-1 had significantly higher tiller numbers than all other varieties at all plant spacing except treatments in 15×15cm. In the second season, mean number of tillers per plant were significantly higher in IR-2793-80-1 than in TXD 306 which, in turn, had higher tiller numbers per plant than Basmati 370. An increase in plant spacing led to a significant increase in the number of tillers per plant. Intermittent flooding did not have a significant effect on number of tillers per plant.

Table 4. Effect of plant spacing, variety and irrigation on the number of tillers per plant of selected varieties at Mwea Irrigation Scheme.

	No. of tillers (Season 1)					No. of tillers (Season 2)				
Variety	15×15	20×15	25×15	30×15	MEAN	15×15	20×15	25×15	30×15	MEAN
Basmati 370	10.4	15.3	17.5	19.6	15.7	15.8	19.2	19.7	25.8	20.1
TXD 306	14.4	15.2	17.0	19.7	16.5	16.0	23.5	27.0	28.8	23.8
IR 2793-80-1	14.2	20.5	24.2	25.7	21.1	22.7	27.4	32.5	33.8	29.1
MEAN	13.0	17.0	19.5	21.6	17.8	18.2	23.3	26.4	29.4	24.3
p-value V	0.007					0.002				
p-value S	<.001					<.001				
p-value V × S	0.032					0.118				
LSD V	3.1					0.6				
LSD S	1.7					0.5				
LSD V× S	3.8					0.9				
CV (%)	14.1					12.5				

Discussion

Plant spacing 25×15cm had the highest panicle length in both seasons. There was also an increase in number of tillers with increase in plant spacing in both seasons. This is in agreement with similar findings reported by several authors such as Srinivasan (1990), Shah *et al.*, (1991) and Patra and Nayak, 2001.

According to Patra and Nayak (2001) the rice crop planted with a plant spacing 20×15cm produced more tillers per hill than rice crop of spacing 15×15cm. Baloch *et al.*, (2010) reported that low yields were as a result of wider spacing that allowed plants to produce more tillers but provide smaller number of hills per unit area. Increase in plant spacing is associated with increase in number of tillers because the plant has more area to draw nutrients required for tiller formation. Plant spacing of 30×15cm had significantly higher number of panicles per plant than other plant spacing treatments in both seasons. Plant spacing of 15×15cm had significantly higher net grain yield than the other spacings in both seasons.

This concurs with a study by Bhowmik *et al.*, (2012) who found out that plant spacing of 15×15cm had the highest grain yield and 25×15 had the lowest grain yield. Nyang'au *et al.*, (2010) also reported that 15×15cm spacing proved beneficial to Mwea farmers practicing intermittent flooding as it yielded 6t/ha. Mohapatra *et al.*, (1989) also reported that 30×15cm was better than 15cm ×15cm under normal soil for rice production. Proper spacing ensures good water management (Mazid *et al.*, 2003) and photosynthetic activities and assimilate partitioning (Kundu *et al.*, 1993), thereby resulting in good yield in well-spaced rice fields. This implies that plant spacing linearly affect performance of individual plants because of the area around to draw nutrients and have more water solar radiation to absorb for better photosynthetic activity (Baloch *et al.*, 2002).

Plants subjected to intermittent flooding gave significantly higher net grain yield than those grown under continuous flooding. This concurs with a study by Ndiiri *et al.*, (2012) who reported that water saving through intermittent flooding gave yield increase by 0.6t/ha and 1.5t/ha for Basmati 370 and IR 2793-80-1 respectively. Keisuke *et al.*, 2007 also recorded reductions in irrigation water by 40-70%, while increasing yields under alternate wetting and drying (intermittent flooding) compared to continuous flooding of rice crop. Intermittent flooding saved up to 44% of water during the experiment. This concurs with Mostafazadeh-Fard *et al.*, (2010) who reported that decreasing the depth of ponded water on the soil surface in irrigated rice reduced the water use by 23%. Bouman *et al.*, 2005 has also studied that the use of modern irrigation techniques like intermittent flooding can also lead to water savings of more than 50%. This implies that intermittent flooding is important in maintaining the sustainability of rice production (Arif *et al.*, 2012).

Variety and spacing interaction significantly affected the number of tillers and panicles per plant in both seasons. This concurs with results by Naser *et al.*, (2011) who found interaction of plant spacing and variety had the highest amount of grain yield in plant spacing of 15×15cm and lowest in plant spacing of 30×15cm. According to Hamid *et al* ., (2011) interactions of plant spacing and variety on grain yield had significant differences, highest grain yield was obtained from plant spacing of 30×15cm (3612kg/ha) and lowest from plant spacing of 15×15cm. Interaction between irrigation regime, variety and spacing had no significant effect on panicle length in season two. This implies that combination of two favorable growth parameters is likely to improve the yields of rice varieties.

Conclusion

The findings of the study showed that plant spacing of 15×15cm had the highest net grain yield. The study also showed that TXD 306 and IR-2793-80-1 had the highest net grain yield in both seasons. Intermittent flooding gave higher net grain yield than continuous flooding in both seasons. By applying appropriate irrigation management in rice cultivation, a large volume of water can be saved which would help bring more land under cultivation using same available amount of water. The study therefore demonstrated that cultivation of the recently introduced variety TXD 306 and intermittent flooding have the potential to improve rice productivity in Mwea Irrigation Scheme.

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