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Effect of Withholding Irrigation Water after Complete Heading on Rice Yield and Components in Mwea-Kenya

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ABSTRACT Rice is a major source of calories and protein in many countries of Africa. In Kenya, rice production is practiced in large scale rice irrigation schemes but water shortages continue to impede productivity in those areas. Therefore, the research investigated effect of withholding water after complete heading on yield and its components. A split plot arrangements in Randomized Complete Block Design (RCBD) with three replicates were used in two sites. Water withholding regimes were the main plots while varieties were the sub plots. Data was scored on various variables. ANOVA was done using SAS program version 9.2. Results from the study indicated that there were no significant difference (p>0.05) on the yield and yield components across sites when water was withheld. There were significant differences (p<0.05) for varieties which indicated that they were distinct. Water applied in paddy rice may be effectively rationed thereby increasing the acreage and production.

INTRODUCTION

Rice is major source of calories intake particularly in West Africa and comes third after maize and cassava in Africa (AfricaRice 2010; Diagne et al. 2010). It is steadily becoming a major staple food for many households in Kenya as consumption now stands at 12 %; compared to 4% for wheat and 1% for maize hence, increasing its productivity is important as change in eating habits increases especially among the youth (MOA 2008; MOA 2009)**.** Despite the increased demand of rice worldwide, its production is vulnerable to climate change that is characterized by drought and floods that increases the risk of poverty, hunger and malnutrition in many developing countries (Nelson et al. 2009). To reduce the deficit whose demand estimated at 410,000 metric tons compared with local production of 110,000 metric tons imports fill the widening gap between supply and demand of 73.2% (MOA 2010). Rice is currently the most expensive cereal in the country occasioned by the heavy import bill (Mati, 2012). One of the many ways to unlock this barrier will be through the exploitation of idle lands, arid and semi arid lands with the practice of intermittent irrigations, enabling saved water to expand production areas and thereby increasing production and productivity. Performance of rice varieties under water stress varies greatly with some varieties being susceptible at vegetative stage and others at flowering and grain filling period (Pantuwan et al. 2002). Bourman and Tuong (2001) reported that different varieties may have different responses to the same drought stress timing and intensity. Kipkorir et al. (2011) reported that the yield of Basmatic-370 was not affected under System of Rice Intensification (SRI) practice. In Kenya rice production is practiced in large scale rice irrigation schemes in Central Mwea, Tebere, Ahero, South West Kano and Bunyala, but water shortages continue to impede production in those areas (USAID, 2010). With appropriate contemporary innovative water management technologies, there is potential of increasing irrigated areas thereby enabling Kenya to be food secure (MOA 2010). A trial was conducted in Mwea, Kenya to study the effect of withholding irrigation water after complete heading on rice yield and it components in two sites.

Objectives

The objectives of the trial were:

1. To determine the effect of withholding irrigation water on the morphological characters of rice.
2. To determine the effect of withholding irrigation water after complete heading on yield and components.

MATERIAL AND METHODS

Description of Trial Sites

The trials were conducted in two sites KARI-Mwea and MIAD-Mwea in Kirinyaga County, Kenya.

KARI-Mwea

It is one of the satellite research stations of Kenya Agricultural Research Institute (KARI) that has updated irrigation facilities and has been involved in the development of rice varieties and the rice industry in Kenya. It lies on the Latitude 0^0 37' S Longitude 37^0 20' E at an elevation of 1159 m above sea level (masl). Average annual rainfall is about 850 mm with a range of 500 – 1250 mm. The long rains start in March and end in June with an average of 350 mm. The rainfall is characterized by uneven distribution in intensity, time and space. The temperature ranges from 15.6 ^{0}C to 28.6 ^{0}C with a mean of about 22^0 C (FURP 1987; Jaetzoid et al. 2005). It has soil type classified as red sandy loam that has the properties of 0.119 % N, 107.0% P (ppm) and 0.085 % K me/140g with pH of 6.18.

MIAD

The Mwea Irrigation Agricultural Development (MIAD) Center whose main research is on rice is located on the latitude of 0^0 39' S and longitude 37^0 17' E at an altitude of 1195 masl. MIAD works in collaboration with other institutions such as National Irrigation Board (NIB), Kenya Agricultural Research Institute (KARI) and Universities. The sole responsibility of NIB is to supply water resources to all food and horticultural crops. The soil types are classified as black cotton soil that has the properties of 0.112 % N, 12.0 % P and 0.170 % K me/140g with pH of 7.53. According to FAO classification, black cotton soils are grouped under Vertisols-soils that are dark montmorillonite-rich and are poorly drained cracking clays of the top and bottomlands (Jaetzoid et al. 2005).

Experimental Description and Field Management

The trials comprised of field trials and laboratory trials. Split plot arrangements in Randomized Complete Block Design (RCBD) with three replicates were used. Water regimes were the main plot while the varieties were the sub plots. The water regimes were: (i) Continuous flooding (ii) Withdrawing of water 10 days after complete heading (iii) Withholding of water 15 days after complete heading (iv) Withholding of water 20 days after complete heading. The varieties were the subplots and included: (i) Nerica-1 (ii) Nerica-4 (iii) Nerica-10 (iv) Basmati-370. The experiment was conducted in a micro-environment of 34 m x 17 m (578 m^2) land size, bounded with drainage of 50 cm depth, well developed levee 20 cm high, to minimize any foreign water from getting into the experimental plot. Every regime plot of 8.8 m × 1.6 m (14.08 m^2) had spatial isolation of 1 m and was fortified with plastic sheet (buried 35cm deep and 20 cm high above soil surface) that was reinforced with sub soils serving as a bund/levee. The aim was to serve as a hindrance to entry and exit of water from one main plot to the others. Rice seeds of the four varieties were soaked in plain water for 48 hrs, water drained and incubated (kept under moist) for 48 hrs to spark and accelerate germination. The trial was managed using recommended agronomic package.

Data Analyses

The sample area (m2) was taken using quadrat calibrated 1 m x 1 m (m2). Variables from the field were scored from five (5) tagged mother plants. Field data were recorded on morphological (flag leaf length, number of matured tillers per hill, panicle length, single panicle weight, number of filled grain per panicle, grain size and straw weight) and yield components (tillers per hill, panicle length, filled grain per panicle and 1,000 grain weight). ANOVA was done using SAS version 9.2 and means separated using LSD at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Combined analysis revealed that varieties were significantly different ($P<0.05$) across sites for variables except for number of unfilled grain per panicle, unfilled grain weight per panicle, grain weight per hill and moisture content. The sites were significantly different for flag leaf length, tillers per hill, panicle length, single panicle weight, number of filled grain per panicle and filled grain weight per panicle. The differences between the two sites may be attributed to differences in hydrological conditions of different soil types since KARI has red loam soil while MIAD has black cotton soils that are classified as Vertisols soils that are dark montmorillonite-rich. There was significant site by variety interaction for panicle length and percent moisture content. Inspite of differences in soil types combined analysis revealed that there were no significant differences ($P>0.05$) for all variables scored for regimes across sites (Table 1).

ANOVA revealed that filled grain per panicle was significantly different ($p<0.05$) for the regimes at KARI. However, other variables were not significantly different ($p>0.05$). ANOVA revealed that flag leaf length, number of matured tillers per hill, panicle length, single panicle weight, number of filled grain per panicle, filled grain weight per panicle, unfilled grain per panicle, unfilled grain weight per panicle, grain size, 1,000 grain weight, straw weight per hill and percent moisture content were significantly different ($p<0.05$) for the varieties at KARI. However, grain weight per hill was not significantly different ($p>0.05$).

ANOVA revealed that number of unfilled grain per panicle, grain weight per hill and 1,000 grain weight were significantly different ($p<0.05$) for the regimes at MIAD while other variables were not significantly different ($P>0.05$). For the varieties, ANOVA revealed that most of the variables except grain weight per were significantly different ($p>0.05$). There was an interaction between regimes and varieties for grain weight per hill and grain size and therefore varietal performance depended on the regime.

At KARI, filled grain per panicle for regime 20 (119.97) was significantly different ($p<0.05$) from regime zero (104.73) and but not significantly different ($p>0.05$) from regime 10 (110.15) and regime 15 (Table 2). Results revealed that withholding of water was beneficial since the number of filled grain per panicle increased significantly ($P<0.05$) from 104.73 when flooding was continuous to 119.97 when irrigation was withheld 20 days after complete heading. Similar results were obtained from MIAD although they were not significantly different.

Flag leaf length, matured tillers per hill, panicle length, single panicle weight, filled grain weight per panicle, unfilled grain per panicle, unfilled grain weight per panicle, grain weight per hill, grain size, 1,000 grain weight, straw weight per hill and percent moisture content were not significantly different ($p>0.05$) and therefore the variables were not adversely affected by withholding of water. Sadeghi and Danesh (2011) also reported no significant differences when irrigation was withheld before panicle exertion from the sheath, flowering, at seed dough stage compared to continuous irrigation. Similarly, Abou-khalifa, (2012) reported that there was no significant difference in regimes treatment when two varieties were subjected to water withholding.

At MIAD, with holding of water was significantly different from continuous flooding (regime 0) when water was withdrawn early that

Table 1: Flag leaf length, number of matured tillers per hill, panicle length, single panicle weight, number of filled grain per panicle, filled grain weight per panicle, unfilled grain per panicle, unfilled grain weight per panicle, grain weight per hill, grain size, 1,000 grain weight, straw weight per hill, and Moisture content % for different regimes across sites.

Regime	*Flag leaf length, (cm)*	*Tillers per hill (No.)*	*Panicle length (CM)*	*Single panicle weight (g)*	*Number of filled grain per panicle, (No.)*	*Filled grain weight per panicle (g)*	*Unfilled grain per panicle (No.)*	*Unfilled grain weight per panicle (g)*	*Grain weight per hill (g)*	*Grain size (mm)*	*1,000 grain weight (g)*	*Straw weight per hill (g)*	*Moisture content %*
0	23.13a	7.71a	21.03a	3.10a	111.90a	2.90a	11.51a	0.13a	15.10a	24.10a	21.99a	7390a	11.30a
10	23.70a	7.63a	21.23a	3.20a	122.42a	3.03a	11.21a	0.10a	14.60a	24.10a	21.80a	73.54a	1121a
15	23.90a	8.42a	21.70a	3.24a	117.40a	3.03a	13.70a	0.10a	17.12a	24.00a	22.40a	86.13a	11.30a
20	24.90a	8.50a	20.90a	3.30a	118.93a	3.01a	12.70a	0.10a	13.60a	23.70a	21.65a	82.13a	11.43a

Numbers with same letter in the same column are not significantly different at $\alpha=0.05$

Table 2: Flag leaf length, number of matured tillers per hill, panicle length, single panicle weight, number of filled grain per panicle, filled grain weight per panicle, unfilled grain per panicle, unfilled grain weight per panicle, grain weight per hill, grain size, 1,000 grain weight, straw weight per hill, and Moisture content % for different regimes at KARI

Regime	*Flag leaf length, (cm)*	*Tillers per hill (No.)*	*Panicle length (CM)*	*Single panicle weight (g)*	*Number of filled grain per panicle, (No.)*	*Filled grain weight per panicle (g)*	*Unfilled grain per panicle (No.)*	*Unfilled grain weight per panicle (g)*	*Grain weight per hill (g)*	*Grain size (mm)*	*1,000 grain weight (g)*	*Straw weight per hill (g)*	*Moisture content %*
0	25.40a	8.70a	22.13a	2.77a	104.73b	2.60a	10.50a	0.10a	14.24a	22.62a	21.73a	68.83a	11.23a
10	25.34a	9.25a	22.12a	2.92a	114.70ab	2.75a	13.40a	0.10a	16.99a	24.22a	21.83a	78.60a	11.10a
15	26.23a	9.25a	22.66a	2.90a	110.15ab	2.68a	13.40a	0.10a	17.40a	24.03a	22.40a	86.20a	11.31a
20	26.70a	9.42a	21.30a	3.20a	119.97a	2.95a	13.70a	0.10a	14.20a	22.84a	21.43a	70.00a	11.40a

Numbers with same letter in the same column are not significantly different at α=0.05

is 5 days after complete heading but was not significantly different from regime zero for other regimes (regime 15 and regime 20) for unfilled grain per panicle and grain weight per hill (Table 3). Thousand (1,000) grain weight was highest (22.44) when water was withheld for 15 days but was not significantly different from regime 0 (22.27). Water was withheld for the longest time for regime 5 and that may explain the differences observed for unfilled grain per panicle, grain weight per hill and 1,000 grain weight at MIAD. KARI-Mwea has red sandy loam soils while MIAD has black cotton soils whose water become unavailable when the soil dries. Since grain weight per square meter-a measure of grain yield, was not significantly different for different regimes, withholding of water after complete heading would be recommended. The differences observed between regimes in different sites when site analyses were done may be attributed to differences in soil types. Although many variables including yield were not adversely affected by withholding water the frequency and intensity of withholding water may be dependent on agroecologies and would have to be determined empirically. RRTC (1999) established that withholding water at certain growth stages may save some of the irrigation water without affecting the yield significantly. RRTC (2001) also reported later that continuous saturation throughout the growth period without flooding could save about 23 % water with minimal reduction in yield resulting in high water use efficiency. In Kenya if farmers near the source of water rationalized their water use other farmers in the periphery would benefit

Table 3: Flag leaf length, number of matured tillers per hill, panicle length, single panicle weight, number of filled grain per panicle, filled grain weight per panicle, unfilled grain per panicle, unfilled grain weight per panicle, grain weight per hill, grain size, 1,000 grain weight, straw weight per hill, and moisture content % for different regimes at MIAD

Regime	*Flag leaf length, (cm)*	*Tillers per hill (No.)*	*Panicle length (CM)*	*Single panicle weight (g)*	*Number of filled grain per panicle, (No.)*	*Filled grain weight per panicle (g)*	*Unfilled grain per panicle (No.)*	*Unfilled grain weight per panicle (g)*	*Grain weight per hill (g)*	*Grain size (mm)*	*1,000 grain weight (g)*	*Straw weight per hill (g)*	*Moisture content %*
0	20.86a	6.75a	19.94a	3.35a	119.10a	3.20a	12.52ab	15.88ab	307.48a	24.50a	22.27ab	78.92a	11.33a
10	21.96a	6.00a	20.34a	3.50a	130.13a	3.32a	9.03c	12.14c	288.67a	23.92a	21.65b	68.50a	11.40a
15	21.50a	7.58a	20.67a	3.64a	124.60a	3.38a	13.95a	16.86a	323.87a	23.98a	22.44a	86.10a	11.30a
20	23.03a	7.58a	20.51a	3.28a	117.88a	3.10a	11.83b	12.97cb	277.43a	24.53a	21.87ab	94.30a	11.50a

Numbers with same letter in the same column are not significantly different at α=0.05

Table 4: Flag leaf length, number of matured tillers per hill, panicle length, single panicle weight, number of filled grain per panicle, filled grain weight per panicle, unfilled grain per panicle, unfilled grain weight per panicle, grain weight per hill, grain size, 1,000 grain weight, straw weight per hill, and moisture content % for different varieties at KARI.

Regime	*Flag leaf length, (cm)*	*Tillers per hill (No.)*	*Panicle length (CM)*	*Single panicle weight (g)*	*Number of filled grain per panicle, (No.)*	*Filled grain weight per panicle (g)*	*Unfilled grain per panicle (No.)*	*Unfilled grain weight per panicle (g)*	*Grain weight per hill (g)*	*Grain size (mm)*	*1,000 grain weight (g)*	*Straw weight per hill (g)*	*Moisture content %*
N-1	25.90a	7.42b	21.30b	3.17b	108.70b	2.98b	14.70a	0.07a	15.53a	26.16a	24.61a	60.42b	11.10b
N-4	27.60a	7.42b	21.76b	3.60a	129.98a	3.30a	13.40a	0.08a	14.61a	25.40ab	22.78b	68.33b	11.18b
N-10	28.15a	8.60b	21.43b	3.11b	120.57a	2.90b	13.10a	0.07a	16.80a	24.35b	22.23b	70.60b	10.96b
BS-370	22.03b	13.20a	23.73a	1.95c	90.32c	1.80c	9.83b	0.04b	15.89a	18.81c	17.74c	104.23a	11.78a

Numbers with same letter in the same column are not significantly different at α=0.05

Table 5: Flag leaf length, number of matured tillers per hill, panicle length, single panicle weight, number of filled grain per panicle, filled grain weight per panicle, unfilled grain per panicle, unfilled grain weight per panicle, grain weight per hill, grain size, 1,000 grain weight, straw weight per hill, and moisture content % for different varieties at MIAD

Regime	*Flag leaf length, (cm)*	*Tillers per hill (No.)*	*Panicle length (CM)*	*Single panicle weight (g)*	*Number of filled grain per panicle, (No.)*	*Filled grain weight per panicle (g)*	*Unfilled grain per panicle (No.)*	*Unfilled grain weight per panicle (g)*	*Grain weight per hill (g)*	*Grain size (mm)*	*1,000 grain weight (g)*	*Straw weight per hill (g)*	*Moisture content %*
N-1	20.93cb	5.10b	18.88c	3.75ab	120.30bc	3.53ab	13.30a	16.50a	316.73a	26.96a	24.73a	72.92b	11.58a
N-4	24.30a	5.42b	20.21b	4.11a	139.43a	3.87a	11.30ab	14.40a	298.15a	25.23b	22.95b	81.92ab	11.62a
N-10	22.55ab	5.75b	19.20bc	3.55b	123.88b	3.35b	12.58a	10.69b	261.58a	24.59b	21.77c	69.00b	11.40a
BS-370	19.58c	11.67a	23.22a	2.40c	108.10c	2.22c	10.18b	16.30a	320.99a	20.20c	18.78d	103.92a	10.88b

Numbers with same letter in the same column are not significantly different at α=0.05

from water saved and in turn harvest a crop of rice.

At KARI results revealed that varieties were significantly different for all variables except grain weight per hill (Table 4). Nerica-1(N1) had the biggest grain of 26.16 mm compared with BS-370 that had significantly smallest grain (18.81 mm). Also N1 had the highest 1,000 grain weight of 24.61 grams compared with BS-370 which had significantly smallest grains of 17.74 g. Basmati (BS-0370) had the highest straw weight of 104.32 grams compared with N-1 that had significantly lower straw weight of 60.42 grams. At MIAD all variables were significantly different except grain weight per square metre (Table 5). Nerica-1(N-1) had the biggest grain of 26.96 mm compared with BS-370 that had significantly smallest grain (20.20 mm). Also N-1 had the highest 1,000 grain weight of 24.73 grams compared with BS-370 which had significantly smallest grains of 18.78 g. Basmati (BS-0370) had the highest straw weight of 103.92 grams compared with N-1 that had significantly lower straw weight of 72.92 grams. Basmati accumulated more biomass since it had significantly more tillers at KARI and MIAD when compared with the other varieties. Similarly, Kipkorir et al (2012) reported that Basmati (BS-370) is a tall variety that is prone to lodging. Since rice varieties are adapted to wide range of hydrological conditions ranging from rainfed, rainfed lowland, irrigated lowland, lowland deep water, floating and mangrove swamps, irrigation frequencies and levels of soil water saturation may be specific to varieties (Gupta and Toole, 1986). Upland rice varieties (Nerica-1, Nerica-4, Nerica-10) grown under irrigation with aim of increasing productivity may require less water and hence cover a larger area compared with Basmati-370, therefore individual water requirements for groups of varieties is empirical.

CONCLUSION

Results across sites indicated that withholding irrigation water after complete heading:

- Has no effect on the yield and yield components such as tillers per hill, panicle length, filled grain per panicle and 1,000 grain weight, therefore area under rice production may be increased when less water is used per unit area.
- Has no effect on morphological characters of rice such as flag leaf length, number of matured tillers per hill, panicle length, single panicle weight, number of filled grain per panicle, grain size and straw weight.
- Results also indicated that varieties were distinct from each other
- There is need to determine the level of withholding water depending on the sites.

RECOMMENDATIONS

Withholding irrigation water during rice production needs to be scaled up so that water is withheld at 10, 15 and 20 days in large acreage of land in order to validate and adopt findings of the research in different agro-ecologies. More research is needed to determine irrigation frequencies especially for NERICA varieties which are upland varieties and therefore may be considered to have some levels of drought tolerance and whose yield may be increased under irrigation.

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