**INTRODUCTION**

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.

**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° 37' S Longitude 37° 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°C to 28.6°C with a mean of about 22°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° 39’ S and longitude 37° 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 m²) 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 m²) 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 α = 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
EFFECT OF WITHHOLDING IRRIGATION WATER AFTER COMPLETE HEADING ON RICE YIELD

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. Despite 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 not 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 panicle, grain weight per hill and 1,000 grain weight were not 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, withholding 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.

<table>
<thead>
<tr>
<th>Regime</th>
<th>Flag leaf length, (cm)</th>
<th>Tillers per hill (No.)</th>
<th>Panicle length (cm)</th>
<th>Single panicle weight (g)</th>
<th>Number of filled grain per panicle, (No.)</th>
<th>Filled grain weight per panicle (g)</th>
<th>Unfilled grain weight per panicle (g)</th>
<th>Grains size (mm)</th>
<th>1,000 grain weight (g)</th>
<th>Straw weight per hill (g)</th>
<th>Moisture content %</th>
</tr>
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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>
<thead>
<tr>
<th>Regime</th>
<th>Flag leaf length (cm)</th>
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<th>Panicle length (CM)</th>
<th>Single panicle weight (g)</th>
<th>Number of filled grain per panicle (No.)</th>
<th>Filled grain weight per panicle (g)</th>
<th>Unfilled grain weight per panicle (g)</th>
<th>Grain weight per hill (g)</th>
<th>1,000 grain weight (g)</th>
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Numbers with same letter in the same column are not significantly different at α=0.05

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

<table>
<thead>
<tr>
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<th>Tiller length (No.)</th>
<th>Panicle length (CM)</th>
<th>Single panicle weight (g)</th>
<th>Number of filled grain per panicle (No.)</th>
<th>Filled grain weight per panicle (g)</th>
<th>Unfilled grain weight per panicle (g)</th>
<th>Grain weight per hill (g)</th>
<th>1,000 grain weight (g)</th>
<th>Straw weight per hill (g)</th>
<th>Moisture content %</th>
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<td>24.53a 21.87ab 94.30a</td>
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</table>

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.

<table>
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<tr>
<th>Regime</th>
<th>Flag leaf length, (cm)</th>
<th>Tillers (No.)</th>
<th>Panicle length (CM)</th>
<th>Single panicle weight (g)</th>
<th>Number of filled grain per panicle (No.)</th>
<th>Filled grain weight per panicle (g)</th>
<th>Unfilled grain weight per panicle (g)</th>
<th>Grain weight per hill (g)</th>
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<th>1,000 grain weight (g)</th>
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<td>1.80c</td>
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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.

<table>
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<tr>
<th>Regime</th>
<th>Flag leaf length, (cm)</th>
<th>Tillers (No.)</th>
<th>Panicle length (CM)</th>
<th>Single panicle weight (g)</th>
<th>Number of filled grain per panicle (No.)</th>
<th>Filled grain weight per panicle (g)</th>
<th>Unfilled grain weight per panicle (g)</th>
<th>Grain weight per hill (g)</th>
<th>Grain size (mm)</th>
<th>1,000 grain weight (g)</th>
<th>Straw weight per hill (g)</th>
<th>Moisture content %</th>
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</tbody>
</table>

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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 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 increas-
ing 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.

ACKNOWLEDGEMENT

I present my fervent thanks and appreciation to Forum for Agricultural Research in Africa (FARA) under Promotion for Science and Technology in Agricultural Development (PSTAD) project and their entire team for their full sponsorship. I am grateful to Dr. Wilson M. Thagona and Dr. Mukiri Wa Githendu who are my supervisors for their scientific guidance and financial support in publishing this work. I acknowledge the moral support of Dr. J. Qwelibo Subah. I am thankful to KARI and MIAD research institutions for allowing me access to their facilities and all other scientists and technicians for their invaluable support during the research.

REFERENCES


EFFECT OF WITHHOLDING IRRIGATION WATER AFTER COMPLETE HEADING ON RICE YIELD


