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EFFECTS OF WATER DEFICIT ON DAYS TO MATURITY AND YIELD OF THREE NERICA RAINFED RICE VARIETIES

Sikuku P. A., Netondo G. W., Musyimi D. M. and Onyango J. C.
Department of Botany and Horticulture, Faculty of Science, Maseno University, Maseno, Kenya
E-Mail: davidmusyimi2002@yahoo.com

ABSTRACT

Water deficit is a major problem in rice grown under rainfed conditions. It affects plant growth and development and ultimately leads to a considerable yield reduction or crop failure. Although the rice crop is susceptible to water deficit, there is a marked genotypic variation in response to water deficit. The objective of this research was to investigate the effects of water deficit on days to maturity and yield development of three recently developed rainfed rice varieties that is, New Rice for Africa (NERICA coded as N_2, N_4 and N_{11}) with a view of establishing the most drought tolerant rice variety that can be grown under rainfed conditions in Kenya. This study was carried out in the University Botanic Garden, Maseno during 2005- 2006. Plants were subjected to water deficit treatments in the green house a factorial set up. The seeds of the three NERICA cultivars of rice were planted in 20 Litre PVC pots arranged in a completely randomized block design (CRBD) with four treatments and four replications. The treatments included watering a litre of water once a day (control), Watering every 2, 4 and 6 days. The parameters measured included tiller number, days to 50% heading and flowering, days to harvesting, panicle length and yield. The water stressed plants took the longest to mature and N_2 took the least number of days to maturity (109) while N_{11} took 114 days and N_4 took 118 days. The yield component declined with the increase in water deficit, N_2 had the highest yield at higher soil moisture deficit (1500 kg/ha) followed by N_4 (818 kg/ha) and then N_{11} (736 kg/ha). Results indicate that under moisture deficit conditions N_2 is least affected and had the least reduction in panicle length, tiller number and yield component hence can be recommended for growing under rainfed conditions in Kenya. This will ultimately help in poverty alleviation through increased income and increase in food security.

Keywords: NERICA rice, water deficit, heading, flowering, tiller, and yield.

INTRODUCTION

It is estimated that 48% of the worlds 141 million hectares of rice is cultured in rain-fed fields where inadequate water at one growth stage or another limits yield. The development of new cultivars with greater drought resistance and the potential to increase and stabilize yields for this rain-fed sector is of significant concern (Steponkus *et al.,* 1990). Drought stress is a serious limiting factor to rice production and yield stability in rain-fed rice areas. In rice the effect of drought varies with the variety, degree and duration of stress and its coincidence with different growth stages (Kato, 2004). Rice is more susceptible to drought than other cereals because it is unable to regulate its transpirational water loss as effectively as other cereals (Austin, 1989). As a result droughted rice rapidly becomes damaged by the effects of low tissue water potential (Kato, 2004). Rice leaves in general have a very high transpiration rate, thus under high radiation levels rice plant may suffer due to midday wilting (Jongdee *et al.,* 1998). A rice plant can transpire its potential rate even when moisture was around field capacity (Jose *et al.*, 2004). In general a rice plant uses less than 5% of the water absorbed through roots from the soil (Jose *et al.*, 2004). The rest is lost through transpiration which helps to maintain leaf energy balance of the crop. Decreased leaf water potential leads to stomatal closure and ultimately results in low transpiration which in turn increases leaf temperature (Fukai *et al.*, 1999). The degree of drought tolerance differs in cultivars, under increasing water deficit, the growth of the plant is prevented and the size of the various plant parts decrease (Zeigler *et al.*, 1994). Water deficit during the vegetative stage may have relatively little effect on grain yield perhaps owing to the compensatory growth or changed partitioning of dry matter after the stress is relieved (Fukai and Lilley, 1994). There is need for increased and diversified production of food both for family consumption and as a source of income (FAO, 1997). Sustainable crop production can be attained through technology that makes effective and efficient use of the erratic rainfall resource (Ogindo, 2003). Farming systems research can contribute to the nutritional well being and food security of households in a number of ways and so research must continue to assist the intensification of high potential areas, but on a more environmentally friendly basis. At the same time, more research is needed in lower potential areas where rural poverty and associated resource degradation is increasingly concentrated (Musyimi, 2005). The full yield potential of a crop on any site in any season is probably never realized. Periods of unsuitable weather causes drought hence reduce the yield (Forbes and Watson, 1994). This means that research must come up with some crop varieties which are somehow tolerant to water deficit to improve food security. Identification of water tolerant crops for example NERICA rainfed rice can be an important contribution (Heyer *et al.,* 1976). Rice is particularly susceptible to water deficit at the reproductive stage (Pirdashti *et al.*, 2004; Fukai and Lilley, 1994; Zeigler, 1994) and drought causes the greatest reduction in grain yield when stress coincides with the irreversible reproductive process (Cruz and O' Toole, 1984). The booting stage and anthesis through flowering are the most sensitive stages (McKersie and Ya'acov, 1994). Yield reduction related to water deficit after anthesis occurs due equally to reduced panicle numbers and increased sterility (Zeigler *et al.*, 1994). The third sensitive stage is the early stage of grain ripening and drought inhibits the ripening process. The NERICA rice varieties are developed for high potential areas, which also suffer occasional water deficit. The main objective of this experiment was to evaluate varietal performance of three NERICA rainfed rice varieties in terms of yield and yield components as affected by water deficit.

MATERIAL AND METHODS

The study was carried out in a green house at the Botanic Garden, Maseno University. Maseno University is situated in Western Kenya. The area receives a mean annual precipitation of 1750 mm with a bimodal distribution. The mean temperature of Maseno is 28.7^{O}C and it is approximately 1500 m above sea level. Maseno lies at latitude 0^{o}1'N - 0'12'S and longitude 34^{o}25'E-47'E. The soils at Maseno are classified as acrisol being well drained, deep reddish brown clay with pH ranging between 4.6 and 5.4 (Mwai, 2001). The potted plants were grown in a naturally illuminated green house where the light, CO_2 concentration and temperature conditions were uncontrolled. Day temperature ranged from 20 - 40^{O}C, relative humidity, 45 - 90%. Maximum photosynthetic photon flux density (PPFD) or Photosynthetic active radiation (PAR) was 250 - 600 µmol $m^{-2}s^{-1}$, measured at the upper leaf surface. The natural light intensity was not supplemented. Air circulation in the green house was maintained by partially opening the windows. The study was conducted between September 2005 and July 2006. Seeds of 3 NERICA rice *(Oryza sativa* L.), varieties namely NERICA 2, 4 and 11 coded as N_2, N_{11}, and N_4 were obtained from the NERICA adaptability trials in the University Botanic garden, Maseno. The seeds had been developed for rain-fed culture by African Rice Centre in West Africa. The soil was dug from the garden then solarized for one week after which the soil was filled into 20 litre PVC pots with perforated bottoms upto ¾ full. The seeds were soaked for a day prior to planting to facilitate germination. The 3 NERICA varieties were planted with 4 treatments and 4 replications. Diamonium phosphate (DAP) Fertilizer was applied in the pots during planting at recommended rate of 52 kg/ha. Top dressing was done using Calcium ammonium nitrate (CAN) fertilizer in split application of 26 kg/ha at 21 days and 26 kg/ha at panicle initiation. The experimental design was a completely randomized block design (CRBD). The pots were watered to field capacity before planting. After germination the pots were irrigated daily with one litre of water until they were three weeks old. The treatments were; watering once in a day (control), watering after every 2 days, watering after 4 days and watering after 6 days. Four seeds per hill were sown and there were 4 hills per pot with a spacing of 15 x 25 cm. The pots were kept weed free by hand picking the weeds.

Measurement of parameters

Tiller number

Tiller number for all the varieties and the treatments was determined by observing, counting and recording all emerging shoots in the hills from the time of planting to the flowering stage.

Days to heading

This was determined by counting the number of heading plants per pot in all the varieties. Days to first heading was noted. Days to 50% heading was determined by counting the number of days taken by at least half of the plants in the pot to reach booting stage.

Days to flowering

This was determined after every 2 days after the plants had started heading. This was done by counting the flowering plants per pot and expressing them as a percentage of the total plants in the pot;

$$\text{Days to 50\% flowering} = \frac{\text{Number of flowering plants}}{\text{Number of plants in a pot}}$$

The data was obtained by scoring for the percentage of flowering plants in each pot when the first inflorescences were observed and when half of all the plants had already flowered.

Days to maturity

This was done by counting the days from planting date to harvesting date.

Panicle length

This was measured using a metre rule.

Filled grain percentage

Panicles were counted per pot for filled and unfilled grains and the percentage of filled grains calculated.

Yield at 14% water content: This was determined by measuring the moisture content of the grains immediately after harvesting using a grain moisture tester model AF 34086 and then converting the yield of the grains to 14%.

Statistical analysis

Analysis of variance (ANOVA) was done using a statistical computer package (SAS) to determine whether the treatments effects were significant. The treatment and variety means were separated using the least significant differences (LSD) test.

RESULTS

Tiller number

The tiller number was significantly different ($P \leq 0.05$) among the watering regimes. Tiller numbers tended to decrease with increasing water deficit (Figure-1). NERICA 11 and NERICA 4 recorded a significant drop in tiller number between the pots of plants watered daily and those watered after every two days followed by an increase in the pots watered after every four days then the tiller number reduced in pots watered after every six days. In NERICA 2 the tiller number decreased with increased water deficit up to the pots that were watered after every four days but increased in pots watered after every six days.

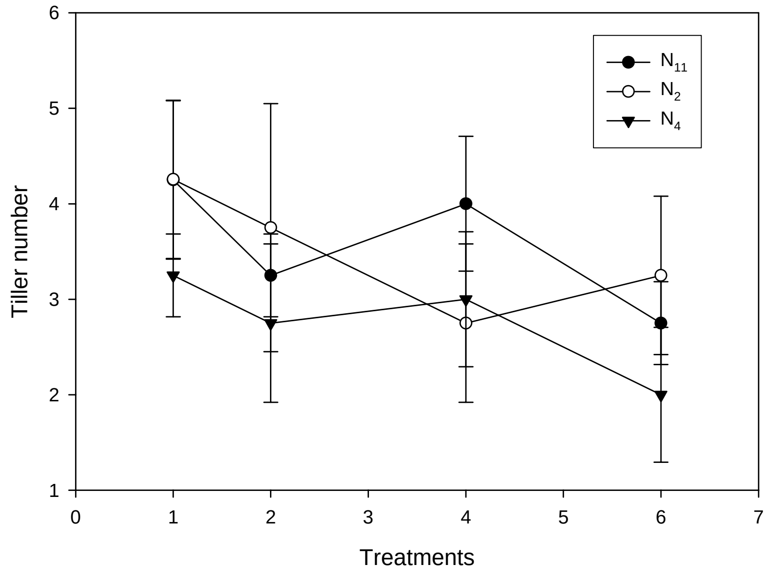

Figure-1. Effects of different treatments on tiller number of three NERICA rice varieties. Each point represents the mean of four replications ± STD DEV.

Days to 50% heading

The varieties had significant difference ($P \leq 0.05$) on the days to heading. There was also a significant difference among the varieties on DAS to 50% heading. NERICA 11 was the most affected by water deficit in that it took the shortest time to reach 50% heading in the plants watered daily and the plants watered after every two days but took the most number of days than NERICA 4 and NERICA 2 in plants watered after six days to reach 50% heading. NERICA 2 took the least number of days to attain 50% heading in the plants watered after every 4 and 6 days as shown in Figure-2.

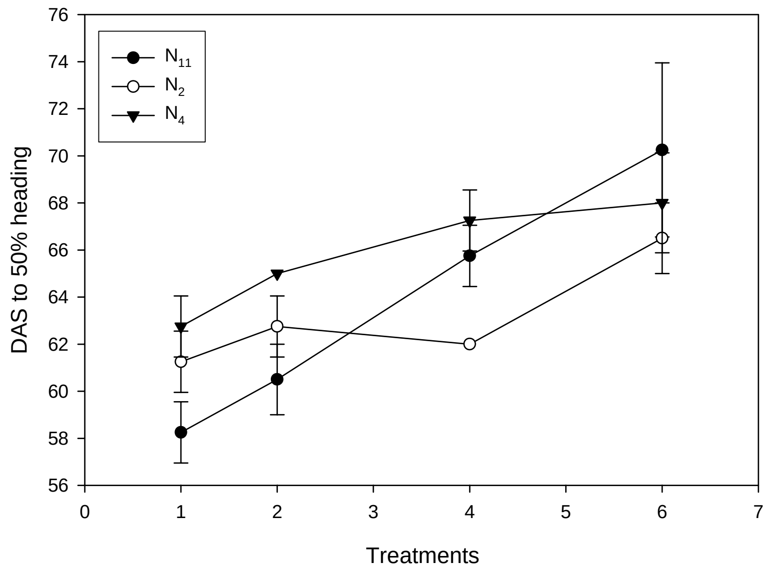

Figure-2. Effects of different treatments on 50% heading of three NERICA rice varieties. each point represents the mean of four replications ± STD DEV.

Days to 50% flowering

The varieties had significant difference (P≤0.05) in days to flowering. The watering regimes affected the number of days taken by the plants to reach 50% flowering. The plants watered daily (control) took the least days to attain 50% flowering while plants watered after every six days which were the most stressed plants took the longest duration to attain 50% flowering as shown in Figure-3. NERICA 2 was the least affected by water deficit because it took the least number of days to attain 50% flowering in the plants watered after every 2, 4 and 6 days. NERICA 11 was the most affected by water deficit and took the most number of days to reach 50% flowering in plants watered after six days.

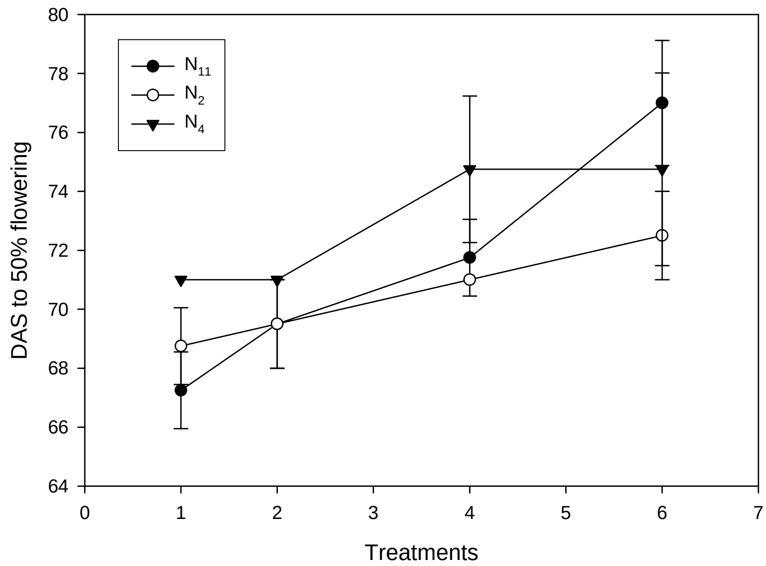

Figure-3. Effects of different treatments on days to 50% flowering of three NERICA rice varieties. Each point represents the mean of four replications ± STD DEV.

Days to harvesting

Rice plants took longer to mature with the increase in water deficit. There was significant difference in days to harvesting (P≤0.05) between NERICA 11and the other two varieties (N_2 and N_4). The watering regimes affected the number of days taken by the plants to reach harvesting. The effect was most pronounced in NERICA 11 while NERICA 4 was the least affected (Figure-4). NERICA 2 took the least number of days to maturity in both experiment I (Table-1a) and in experiment II (Table-1b).

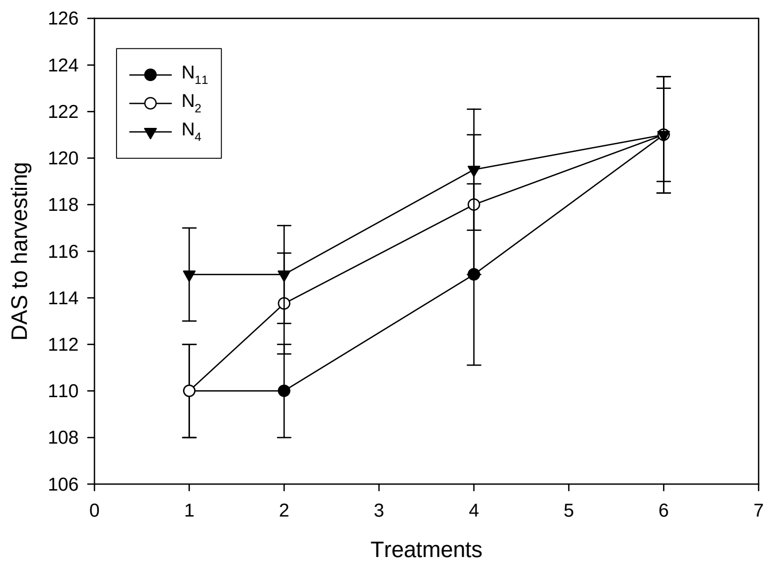

Figure-4. The effects of different treatments on days to harvesting of three NERICA rice varieties. Each point represents the mean of four replications ± STD DEV.

Panicle length

Plant panicle length was affected by water deficit. There was no significant difference ($P \leq 0.05$) in panicle length among the varieties. Plants watered daily had longer panicles than plants watered after every 2, 4 and 6 days (Figure-5). NERICA 2 was the least affected by water deficit and it had the longest panicle in plants watered after 4 and 6 days. NERICA 4 had the most pronounced reduction in panicle length at the highest water deficit compared to the control.

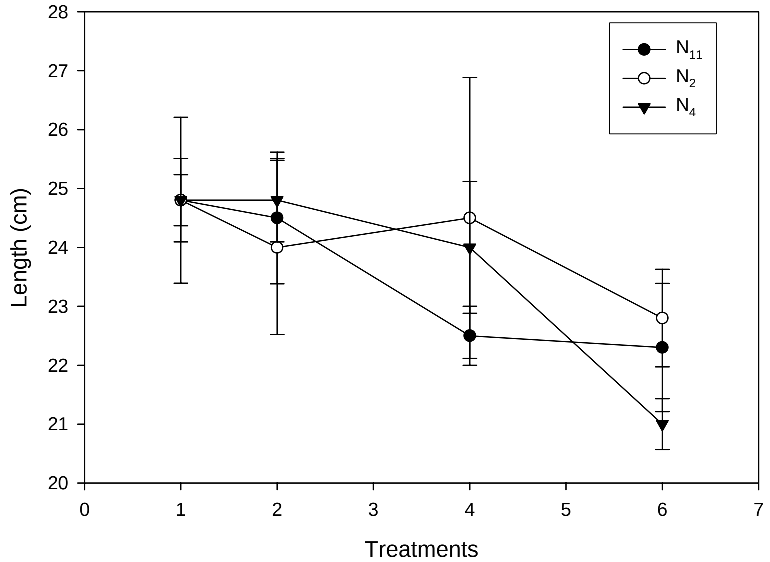

Figure-5. Effects of different treatments on panicle length of three NERICA rice varieties. Each point represents the mean of four replications ± STD DEV.

Filled grain ratio percentage

There was a significant difference ($P \leq 0.05$) in filled grain ratio percentage among the watering regimes. NERICA 2 had the highest filled grain ratio in the plants watered after 2, 4 and 6 days. NERICA 4 was the most affected by water deficit and had the lowest filled grain ratio percentage in all the watering regimes as shown by Figure-6.

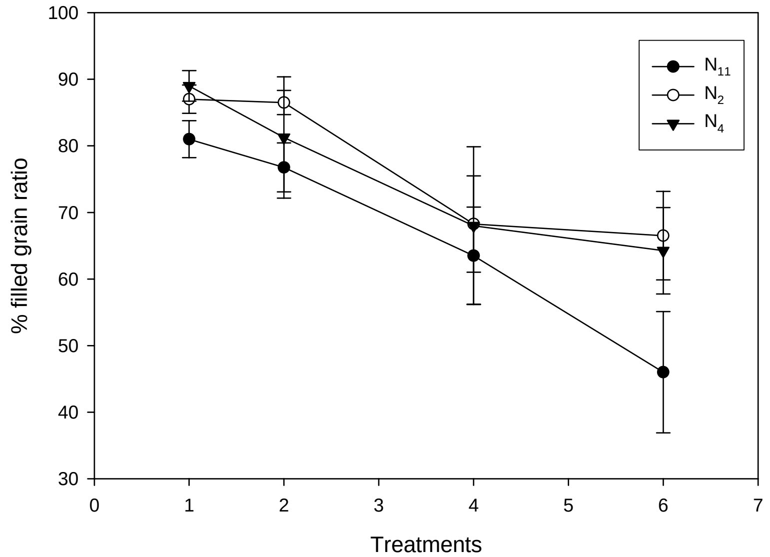

Figure-6. Effects of different treatments on filled grain ratio percentage of three NERICA rice varieties. Each point represents the mean of four replications ± STD DEV.

Yield components

The grain yield was significantly different ($P \leq 0.05$) among the treatments. There was pronounced decrease in yield of NERICA rice varieties with increase in water deficit (Figure-7a). The most pronounced decrease was in NERICA ±11 and it recorded the highest percentage yield reduction from the control. NERICA 2 was the least affected by water deficit and had the least percentage change from the control in yield in the plants watered after every six days (Figure-7b). NERICA 4 had the most number of grains/panicle followed by NERICA 2 and lastly NERICA11 (Tables 1a and 1b).

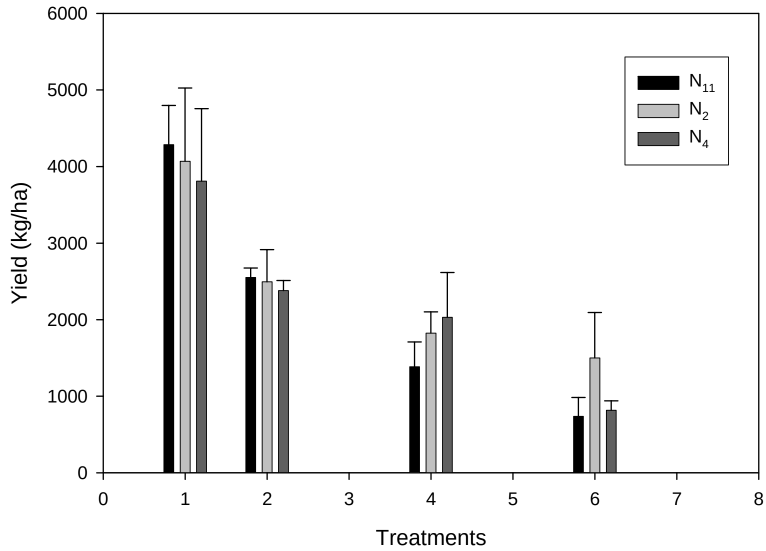

Figure-7a. Effects of different treatment on the yield from yield components of three NERICA rice varieties. Each point represents the mean of four replications ± STD DEV.

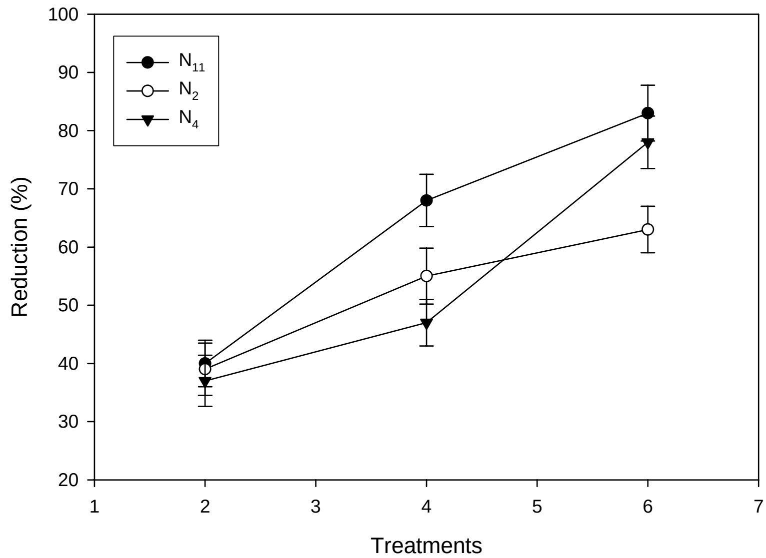

Figure-7b. Effects of different treatments on percentage yield reduction from the Control of three NERICA rice varieties. Each point represents the mean of four replications ± STD DEV.

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Table-1a. Yield components of three NERICA rice varieties (Experiment I). Each value represents the mean of four replications.

Variety	Days to maturity	Number of grains/ panicle	1000 grain weight
N_{11}	111	71	32
N_2	110	93	26
N_4	118	106	25
LSD	2.43	15.00	1.6
CV	2.93	23.14	8.3

Table-1b. Yield components of three NERICA rice varieties (Experiment II). Each value represents the mean of four replications.

Variety	Days to maturity	Number of grains/ panicle	1000 grain weight
N_{11}	114	52	35
N_2	109	93	25
N_4	118	99	24
LSD	1.47	7.4	1.65
CV	1.76	12.6	8.13

Yield at 14% moisture content

The yield at 14% moisture content of the NERICA rice remarkably reduced with increase in water deficit (Figure-8). NERICA 11 was most affected by water deficit than NERICA 2 and NERICA 4. NERICA 2 had the highest yield at the most water stressed treatment. There were no significant differences ($P \geq 0.05$) in yield at 14% moisture content among the varieties but the difference among the watering regimes was significant ($P \leq 0.05$).

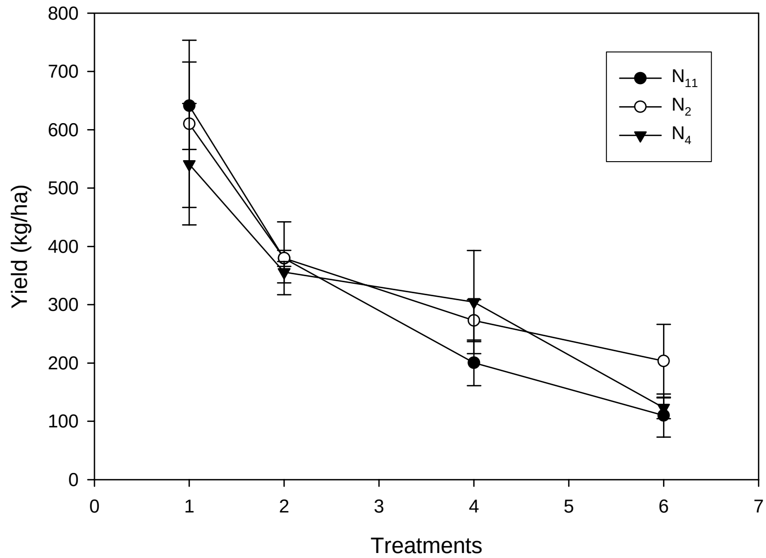

Figure-8. Effects of different treatments on the yield at 14% moisture content of three NERICA rice varieties. Each point represents the mean of four replications ± STD DEV.

DISCUSSIONS

Water deficit during vegetative stage reduces tiller number. Bouman and Toung (2001) found that drought before or during tillering reduce the number of tillers. NERICA 4 and 11 recorded a reduction in tiller density at higher soil moisture deficit watering regimes while NERICA 2 increased the tiller density in plants watered after every six days. NERICA 2 is drought tolerant and is able to maintain higher tiller density than NERICA 4 and 11 under drought conditions. Turgeon (1980) observed that the number of aerial shoots per unit area depends on genotype, environment and cultural practices. The extent of tillering indicates favourable rainfall amounts, temperature and response to available nitrogen. Variation in plant growth parameters among varieties was assumed to be one character determining the difference in drought tolerance among the varieties. In terms of growth parameters, NERICA 2 is the most tolerant variety among the three NERICA varieties.

In this study, the days taken to maturity by the three NERICA rice varieties were affected by water deficit. Plants that were stressed took longer to flower and to mature as compared to plants that were well watered. Levitt (1980) observed that wheat exposed to mild water deficit can advance flowering by up to one week with corresponding decreases in the number of spikeletes and in pollen fertility. Ontogenic characters especially appropriate flowering time play an important role in drought avoidance of rainfed lowland rice (Fukai *et al*., 1999). Timing, intensity and occurrence of water deficit have been associated with the delay of heading or flowering (Fukai *et al*., 1999). NERICA 2 took the least number of days to attain 50% flowering and also the least number of days to harvesting indicating that this variety rapidly completes its life cycle, or at least its reproductive cycle early hence can escape periods of drought and grow during periods of favourable soil moisture. The delay in flowering under soil moisture deficit observed in NERICA 11 is deleterious and indicates poor adaptation to drought stress Mckersie and Ya'acov (1994).

The well watered plants had, more yield (kg/ha), a higher filled grain ratio percentage and higher yields at 14% moisture content as compared to those subjected to water deficit. Similar results were reported by Yeo *et al.* (1996) who observed that water deficit reduced yield in *Oryza sativa*. Bouman and Toung (2001) also had similar results and concluded that rice crops are susceptible to drought which causes large yield losses in many countries. Yield depends on accumulation of dry matter and on its partitioning (Baruah *et al,* 2006). Grain yield of rice may be limited by the supply of assimilates to the developing grain (source limitation) or by the capacity of the reproductive organ to accept assimilates (sink capacity).In a s much as cultivar differ greatly in inherent yielding ability, yield losses from the normal level due to water deficit are useful in assessing drought tolerance (Pirdashti *et al.,* 2004). Low yield of NERICA 4 and 11 under water deficit treatments may be due to less number of ear bearing tillers per hill, reduction in total grain number per panicle (increase in unfilled grain and a greatly decreased proportion of filled grain) and 1000- grain weight respectively. NERICA 2 exhibited superior sink capacity under soil moisture deficit in terms of higher panicle length, 1000 grain weight, spikelets per panicle and filled grain ratio percentage. NERICA 2 exhibited the lowest yield reduction at higher soil moisture deficit and as an early maturing variety, the variety posess physiological traits that helps it hence maintain growth during drought. Water deficit affected the plants and lowered the yields hence it is evident that water deficit leads to a reduction in grain yield by decreasing tiller number, panicle length, and filled grain percentage.

CONCLUSIONS

This study showed that water deficit affects the days to maturity and grain yield by decreasing tiller number, panicle length and field grain percentage of the three NERICA rice varieties. NERICA 2 exhibited the highest tolerance to water deficit and is an early maturing variety.

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REFERENCES

Austin R.B. 1989. Prospects for improving crop production in stressful environments. In: H.G Jones. T.J. Flowers and M.B. Jones, eds: Plant under stress. pp. 235-248. Cambridge University Press, Cambridge.

Baruah K.K, Rajkhowa S.C and Das K. 2006. Physiological analysis of growth, yield development and grain quality of some deep water rice cultivars. Agron and Crop Science. 192: 228-232.

Bouman B.A.M. and Toung T.P. 2001. Field water management to save water and increase its productivity in irrigated low land rice. Agriculture water management. 49: 11-30.

Cruz R.T. and O'Toole J.C. 1984. Dryland rice response to an irrigation gradient at flowering stage Agron. Journal. 76: 178-183.

FAO. 1997. Agriculture food and nutrition for Africa. Resources book for teachers of Agriculture, Food and Agricultural Organization, Rome.

Forbes J.C. and Watson R.D. 1994. Plants in Agriculture, Cambridge, Britain. pp. 72-78.

Fukai S. Pantuwan G., Jongdee b. and Cooper M. 1999. Screening for drought resistance in rainfed lowland rice. Field Crop Res. 64: 61-74.

Fukai S. andLilley J.M. 1994. Effects of timing and severity of water deficit on four diverse rice cultivars. Phenological dev, Crop growth and grain yield. Field Crop Res. 37: 225-234.

Heyer J., Maitha J.K. and Senga W.M. 1976. Agricultural development in Kenya- An economic Assessment. Oxford University Press, Nairobi, Kenya. pp. 2-281.

Jongdee B., Fukai S. and Cooper M. 1998. Genotypic variation for grain yield of rice under water deficit conditions. Proceedings of the Australian agronomy conference. Field Crop Res. 40: 67-86.

Jose M., Mohanasarida K., Resmi O.W. 2004. Water scarcity in dry seeded lowland rice. Proceedings of the 4th international crop science congress, Brisbane, Australia.

Kato Y., Satoshi H., Akiniko K., Abe J. Urasaki K. and Yamagishi J. 2004. Enhancing grain yield of rice (*Oryza sativa* L.) under upland conditions in Japan. 4th International Crop Science Congress, Brisbane, Australia.

Levitt J.J. 1980. Responses of plants to environmental stresses, Radiation, salt and other stresses. 2nd Edition. Academic press Inc. London, United Kingdom. pp. 365-488.

McKersie B.D. and Ya'acov Y.L. 1994. Stress and stress coping in cultivated plants. Kluwer Academic press. USA. pp. 148-177.

Musyimi D.M. 2005. Evaluation of young Avocado plants (Persea Americana Mill.) for tolerance to soil salinity by physiological parameters. M.Sc. Thesis. Maseno University, Kenya.

Mwai G.N. 2001. Growth response of spider plant (*Cleome gynandra* L.) to salinity. M.Sc.Thesis. Maseno University, Kenya.

Ogindo H.O. 2003. Comparing the precipitation use efficiency of Maize - Bean intercropping with sole cropping in a semi- arid ecotype. PhD Thesis. University of Free state, South Africa.

Pirdashti H., Tahmasebi S.Z. and Nematza D.G. 2004. Study of water stress effects in different growth stages on yield and yield components of different rice cultivars. 4th International Crop Science Congress, Brisbane, Australia.

Yeo M.E., Cuartero J., Flowers T.J. and Yeo A.R. 1996. Gas Exchange, Water loss and biomass production in rice and wild Oryza Species in well- watered and water imiting growth conditions. In: The International Journal of the German Botanical Society (1997). 110: 32-41.

Zeigler R.S., Leong S.A. Teng P.S. 1994. Rice blast disease. IRRI, Manila Philippines. pp. 7-10.