Enhancing Seed Yield and Quality of Nerica by Timely Harvesting

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Abstract

Rice is one of the new crops in the seed certification system in Kenya. New Rice for Africa (NERICA), which is upland rice, has been developed and four varieties released for multiplication in Kenya. Evaluation of Nerica varieties for adaptability has been done and varieties recommended for different ecological zones. However, due to the scarcity of information on right stage of harvesting of NERICA grown for seed production, yield and quality of seeds may not be currently reaching the highest potential. This study was therefore to investigate the effect of stage of harvesting on the yield and seed quality of NERICA. The experiment was carried out in two sites :-Marigat in Baringo county and Mwea in Kirinyaga County for one season from October 2014 to March 2015 and seed testing in KEPHIS-Nakuru seed testing laboratory. The field trial was a Randomized Complete Block Design (RCBD) in a split plot arrangement and each treatment was replicated three times in each site with each plot measuring 3x1M. The soil in experimental plots was analyzed for total N, available P (Bray I), exchangeable K, organic C and pH before application of treatments. Percentage of seedling emergence, plant height, number of tillers were measured as growth parameters while grain moisture content and grain yield were determined at harvest and seed quality determined after harvest. The data obtained was subjected to analysis of Variance (ANOVA) and the effects of treatments were separated using Least Significant Difference (LSD) test at $p \leq 0.05$. The stage of harvesting good quality seeds of NERICA rice was determined. The stage of harvesting had a significant effect on seed quality; however the effect was not significant on yield. At 138 Days after Planting at Mwea seeds attained maximum qauality and 124DAP at Marigat. The study therefore recommends harvesting at 138 and 124 Days After Planting respectively for high quality seed production and high yields.

Keywords: Seed Quality, NERICA, Stage of harvesting

1. Introduction

Rice *(oryza sativa L.*) belongs to the grass family Poaceae, genus oryza and tribe oryzae. There are 25 species of Oryza in the tropical and sub-tropical regions of Africa, Asia, Australia and South America. The largest number of species (9) is found in Africa, which is considered to be the centre of diversity of the genus. The two cultivated species are *oryza sativa* and *oryza glaberrima.* It is currently the third most important cereal crop after maize and wheat (USDA, 2013). In Kenya it is grown mainly by small-scale farmers as a commercial and food crop. About 80% of the rice grown in Kenya is from irrigation schemes established by Government while the remaining 20% is produced under rain-fed conditions. Despite its long association with Kenya, rice production has remained far behind other cereals such as maize, wheat. In order to narrow the gap between import and production of rice, The New Rice for Africa (NERICA), the inter-specific hybridization between Oryza sativa (Asian rice) and Oryza glaberrima (African rice) was introduced (Atera et al, 2011). The progeny was developed by West Africa Rice Development Association (WARDA) combining traits from the hardy African rice resistant to pests, weeds and problematic soils and the high yielding, good response to mineral fertilization and non-shattering characteristics of the Asian rice (Dzomeku et al., 2007; Kijima et al., 2006; WARDA, 2001). The seed planted by farmers is one of the most limiting factors in rice cultivation. Lack of appropriate seed for planting in the relevant production ecosystem is a major drawback in its cultivation. Four varieties of rain fed rice (Nerica 1, Nerica 4, Nerica 10 and Nerica 11) have been tested and released for multiplication and seed production is at its initial stages in Kenya. Population increase and changes in feeding habits have resulted in increased demand for rice.

Seed marks the beginning of each plant production and therefore ensuring its quality is the priority of modern seed science and a prerequisite for obtaining high yields of all plant species. The quality and quantity of seed depend upon different factors include soil, climate and performance of agricultural operations during the growth of the mother plant from planting to harvest (McDonald & Copeland,1997).Seed vigor and germination ability directly affect yield and seed quality also affect seedling emergence(Tekrony & Egli, 1991). Seeds are composed of many different types of biochemical components like all living organisms, but seeds are unique because they are a storehouse of compounds that are used as food reserves for the next generation plant (Ferguson & Mchughlin, 2009).Fertilizer application is one of the primary methods for improving the availability of soil nutrients to plants. Fertilizer application can change rates of plant growth, maturity time, size of plant parts, phytochemical content of plants and seed capabilities (Mevi-Schütz et al., 2003).Previous studies revealed that proper use of fertilizer can increase the yield and improve the quality of rice significantly (Awan *et al.*, 2003; Ahmed *et al*., 2005; Oikeh *et al*., 2008). In this case, fertilization influence would occur basically on the number of seeds produced, and it would not affect the quality. According to Carvalho and Nakagawa (2000), a well-nourished plant is able to produce more well-formed seeds. However, Delouche (1980) states that the seeds produced under marginal conditions are usually so viable and as those produced under more favorable. In this case, the influence of fertilization would be basically on the number of seeds produced, not even affecting quality. Some reports stated that nutritional effect on the quality of seeds can be observed after some period of seed storage (Kano et al., 2011; Magro et al., 2012).In the seed, phosphorus is stored in the salts of phytic acid, constituting phytin, which, during germination, is degraded to release these nutrients in order to be used in the development of embryo and seedling (Carvalho & Nakagawa, 2000).In general, fertilization can be positive in the production of seeds, generally explained because of the better development of the plants provided by fertilizer application. However, relations with the potential characteristics of the seeds have not been consistent by research findings. Phosphorus deficiency usually causes delay in flowering and reduction in number of seeds and fruits in many species. Germination and seedling vigor are the main factors for plant establishment and making optimum plant density and plant production. Several factors like; genetic constitution, environment and nutrition of mother plant, maturity at harvest, seed weight and size, mechanical integrity, deterioration, ageing and pathogens are known to influence seed vigor (Perry, 1980).High quality seed is an essential factor to ensure good crop establishment. The seed must be viable and possess physiological traits that allow rapid germination and seedling establishment. Important aspects of good seed are high vigor, steady germination and good and fast establishment in the farm under a wide range of environmental conditions (Lopez-Canstaneda et al., 1996; Soltani et al., 2002; Latifi et al., 2004).For many crops, one of the main problems observed in the field is poor stand establishment, which can be influenced by seed quality, adverse climatic conditions, and poor field management (Maiti and Carrillo Gutierrez, 1989). Due to the scarcity of information on nutritional requirements of NERICA grown for seed production, yield and quality of seeds may not be currently reaching the highest potential. So, this research aimed to evaluate the influence of rates of phosphorus and the appropriate stage of maturity for harvesting on the production and quality of NERICA varieties.

2. Materials and Methods

Two varieties of NERICA (NERICA 4 and 11) were sourced from KALRO Mwea from the April 2013 cropping season under irrigation. The seed was stored in normal room temperature (24^0C).Laboratory tests were conducted in the seed testing laboratory and the field experiment in two locations i.e KALRO-Perkerra, Marigat and KALRO-Mwea. The seeds were divided into two parts a) One for the laboratory tests and b) One for the field experiment as follows:-

2.1Experimenta Sites

KALRO – Perkerra, Marigat

The Centre is located in Marigat Township in Baringo County. Position: 0°28'0" N 36°1'0" E. It lies at an altitude of 1067m above sea level. Soils are volcanic fluvisols of sandy/silt clay loam texture, slightly acid to slightly alkaline. Annual rainfall mean is 654 mm and temperature range is 16 - 34^oC (Ministry of Agriculture, Marigat, 2012).

KALRO-Mwea Research station (Kirogo farm)

KALRO- Mwea is located in Mwea Division, Kirinyaga County. It lies on Latitude 0 37' S and Longitude 37 20' E at an elevation of 1159 m above sea level (ASL).The soil type is vertisols with a pH of 5.07. The average rainfall is about 850 mm with a range of 500 - 1250 mm divided into long rains (March – June with an average of 450 mm) and short rains (Mid-

October to December with an average of 350 mm). The rainfall is characterized by uneven distribution in total amounts, time and space. The temperature ranges from 15.6º C to 28.6º C with a mean of about 22ºC.

2.2 Treatments

2.2.1 The treatments consisted of two varieties (NERICA 4 and 11). These were selected from the four released varieties of NERICA in Kenya and were chosen because they were recommended for the two sites.

Table 1. Characteristics of NERICA 4 and NERICA 11

	NERICA 4	NERICA 11
Type	Interspecific	Interspecific
Species	Oryza sativa x O. glaberrima	Oryza sativa x O. glaberrima
Maturity period	95 – 100 days	75 – 85 days
1000-grain wt	➢ 29 g	➢ 28.4 g
Potential yield	5 tons/ha	7 tons/ha

Source: Somado *et al*. 2008

2.2.2. Stages of harvesting

Harvesting was done at three different stages at H1 (124DAP), H2 (138 DAP) and H3 (152 DAP) from the three middle rows of each plot. The seed harvested from the experiment were evaluated using the standard germination test. Results of the first count and the final germination capacity were recorded

2.3 Experimental Design

The field experiment was a Randomized Complete Block Design (RCBD) in a split plot arrangement.

The experiment consisted of 3 main plots(Harvesting stages) and 8 sub-plots(combination of fertilizer level and variety).The experiment was carried out in two sites and was replicated three times in each site with each plot measuring 3m by 1.0m.Spacing between the plots was 50cm and between the blocks was 1m.

2.4 Data Collection and Analysis

2.4.1 Field experiment

Percentage of seedling emergence in the field. The count was performed once, 14 days after sowing when seedlings had differentiated leaves.

Five plants were randomly selected in each experimental unit from the three middle rows and used for measuring plant height and counting number of productive tillers.

a) Plant height was taken once at dough stage. A ruler was used for measuring height from ground level to the top of the highest leaf.

b) Tiller number: - visual counting of tillers on the five selected plants in each plot was made once at dough stage.

c) Grain yield:-Rice grains were harvested at three different harvesting stages i.e. 124,138 and 152 DAP. At stage 1 the grains were characterized by deep green colour. At stage 2 and 3 the grains were characterized by brown colour and were threshed immediately at harvesting and moisture content taken at the different harvesting dates using a moisture meter.

The SAS statistical package was used to analyze the experimental data. Treatments were compared using analysis of variance at $P \leq 0.05$ whereas their means were separated using Least Significant Difference at the same probability level.

2.4.2 Laboratory tests

The laboratory tests included tetrazolium test, standard germination test, and Accelerated aging test and were done at the Kenya Plant Health Inspectorate Service Seed Testing Laboratory in Nakuru. The tests were performed on the two varieties (Nerica 4 and 11) All laboratory tests were conducted as per the ISTA Rules. The experimental design for the laboratory tests was Complete Randomized Design (CRD) with four replicates each.

Tetrazolium Test

Four replicates of 50 seeds each were drawn from the pure seed fraction of the two varieties (Nerica 4 and 11). They were soaked in water for 12 hours. The seeds were then removed from water and cut longitudinally through the middle of the embryonic axis. The cut seeds were soaked in a 1% solution of 2, 3, 5tryphenyltetrazolium chloride at a temperature of 30^0C for 2 hours. Seeds were briefly washed in distilled water and examined under magnification. They were kept moist until evaluation was complete. Evaluation for the seeds was done on the basis of staining pattern and colour intensity. Among stained seeds, seeds with bright red staining are completely viable while partially stained seeds may produce either normal or abnormal seedlings. Completely unstained seeds are non-viable. The percentage for each category was based on the total number of seed used. The seeds were classified as viable or non-viable according to the staining pattern of the embryo.

Standard Germination Test

From a pure seed fraction seed germination was measured by placing four replicates of 100 seeds each on Top of Paper and incubated at 20-30^0C.The first count was done after 5 days and final count after 14 days. The special treatment applied during the test was soaking of seeds in water for 24 hours before germination. Germination was assessed as percent of seeds producing normal seedlings as defined by ISTA Rules (ISTA, 2014) abnormal seedlings and dead seeds were recorded also.

Accelerated Aging Test

The initial moisture content of the two seedlots was determined using the oven method. Seed was uniformly distributed on wire mesh trays inside covered plastic boxes containing 50 ml of water. The plastic boxes (inner chamber) were placed inside an accelerated aging chamber (outer chamber) and kept at 41ºC for 72 hours. Following the aging period, seed samples were removed and weighed immediately to the nearest mg, oven-dried, and re-weighed to determine seed moisture content (wet - weight basis).The standard germination test was conducted on four replications of 100 seeds per variety and the numbers of normal seedlings was counted (ISTA, 2015) and abnormal and dead seeds were also recorded.

Data Analysis

Seed germination % for standard germination and Accelerated aging test was calculated by the following formula:-

$$\text{Germination \%} = \frac{\text{Number of seed germinated}}{\text{Total number of seed sown}} \times 100$$

$$\text{\%of Viable seed} = \frac{\text{Number of viable seed}}{\text{Total number of seed}} \times 100$$

3. Results

3.1 Laboratory quality test results of NERICA varieties before planting

Results of laboratory quality tests of the two NERICA varieties that were performed before planting in the field are shown in Table 3. Nerica 4 had a germination percentage above 80% while Nerica 11 had a germination percentage below 70%. The tetrazolium viability of the two samples was above 80% while the germination test after accelerated aging test for N4 was above 80% while for N11 went below 60% and had a high percentage of dead seeds.

Table 2 Results of the tetrazolium, Accelerated aging and standard germination test. Two varieties used were Nerica 4 (N4) and Nerica 11 (N11)

Treatment	Tetrazolium		Accelerated aging test			Standard Germination test		
	Viable	Non-viable	Normal	Abnormal	Dead	Normal	Abnormal	Dead
N4	92	8	81	6	13	88	4	8
N11	82	18	58	6	36	67	8	25

Table 3 Influence of stage of harvesting and variety on grain yield (tons/ha)

Location	variety	Stage of Harvesting			**Mean**
		124(DAP)	138(DAP)	152(DAP)	
Mwea	Nerica4	3.2	2.0	2.7	**2.6a**
	Nerica 11	2.6	2.3	3.1	**2.7a**
Mean		**3.0a**	**2.1b**	**2.9ab**	
Marigat	Nerica4	1.0	1.0	0.5	**0.9a**
	Nerica 11	1.0	0.9	0.8	**0.9a**
Mean		**0.98a**	**0.98a**	**0.62a**	

Key: Means within a row or column with different letters are significantly different ($p \leq 0.05$)

Note: DAP-Days After Planting

Table 4 Influence of stage of harvesting and variety on quality (%germination) of NERICA

Location	variety	Stage of Harvesting			**Mean**
		124(DAP)	138(DAP)	152(DAP)	
Mwea	Nerica4	91.0	95.4	83.6	**90.0a**
	Nerica 11	90.7	95.6	83.5	**89.9a**
Mean		**90.8b**	**95.5a**	**83.5c**	
Marigat	Nerica4	98.0	98.7	99.1	**98.6b**
	Nerica 11	98.3	98.8	99.3	**98.8a**
Mean		**98.2c**	**98.6b**	**99.2a**	

Key: Means within a row or column with different letters are significantly different ($p \leq 0.05$)

Note: DAP-Days After Planting.

4. Discussion

4.1 seed quality testing before planting

The results of the current study show that all seed quality tests performed before planting were high (above 80%) for NERICA 4, It had a TZ value of 92%, AA value of 81% and standard germination of 88%. The seedlot maintained values above 80% which is the minimum standard germination as per Seeds and Plant varieties Act cap 326 of the laws of Kenya even after AA test and this shows that the seedlot had high vigor. Vigor testing not only measures the percentage of viable seeds in a sample; it also reflects the ability of those seeds to produce normal seedlings under the less-than-optimum or adverse growing conditions that may occur in the field (ISTA, 2005) and this agrees with results of the current study because NERICA 4 had better field emergence than NERICA 11in both sites.

NERICA 11 had Tetrazolium value of 82%, Accelerated aging value of 58% and Standard germination of 67%. The results indicate that the final germination percentage of seeds of the seedlot decreased when the seed was subjected to accelerated aging test and therefore was of low vigor. Similar results have also been found in wheat seeds by Guy and Black (1998), in Beta vulgaris seeds by Song et al. (2001), and in eggplant, cucumber, and melon seeds by Demir et al. (2004).

4.2 Significance of stage of harvesting and variety on yield (tons/ha)

The stage of harvesting did not significantly affect the yield across the two sites, the highest yield of 3.0t/ha was recorded from the first harvest at 124DAP in while the lowest yield of 0.62t/ha was from the third harvest at 152 DAP. This could be attributed to shattering due to the adverse weather conditions experienced in Marigat. The results agree with findings of Boudreaux and Griffin (2008) who found that that leaving soybean plants in the field past maturity exposes seed to adverse weather conditions that can reduce yield and quality

4.3 Significance of stage of harvesting and variety on the quality of NERICA seed

The stage at which seed is harvested has an effect on the quality of seed produced. From the findings of the present study there is a significant difference in the three stages that the seed was harvested. The results revealed that the highest germination percentage of 95.5% was recorded in H2 (138DAP) and the lowest of 83.5% in H3 (152DAP) in Mwea while in Marigat the highest germination percentage of 98.0% was realized at H1 (152DAP).This could be attributed to the fact that maturity is attained early in hotter areas than in colder areas and thus physiological maturity attained early in Marigat than Mwea In Mwea the seed harvested at H3 (152DAP) had lower germination capacity and this could be attributed to the adverse effects of weather like rains that occurred around the harvesting period. Mwea recorded rainfall of between 41.3mm and 19.7mm between the month of February and March 2015 and harvesting was done from early to late March 2015.The results agrees with the findings of (Greven et al. 2004) who reported that timing of harvest is an important factor since both seed immaturity and rewetting reduce seed quality, rain during harvest may reduce seed quality, especially for seeds with <25% seed moisture content. This indicates that seed quality can already be reduced by rewetting before harvest maturity is reached. Muasya (2001) reported that both high temperature and less rainfall could reduce seed quality of common bean. The germination rate of the seeds from the two sites were between 80% and 99% for all varieties which characterize high quality seed. High quality seed has a direct effect on production because it allows not only the use of the most economical seeding rates, but also better emergence rates in the field, better uniformity of plants, maturity and production. These results also correspond to the minimum legal standards for rice (80%) set in the Seeds and Plant Varieties Act CAP 326 of the laws of Kenya and applied by KEPHIS in order to declare rice seed as quality seed.

5. Conclusions

This study aimed to evaluate the influence of the stage of harvesting on the yield and seed quality of NERICA. Physiological maturity is influenced by the environment and therefore for Marigat harvesting is recommended at 124DAP while for Mwea at 132DAP.

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