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Developmental features and yields of three promising upland rice varieties in Zimbabwe

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Three upland rice varieties: NERICA 1, 3 and 7 that were proved to be promising by previous trails in Zimbabwe, were selected as experimental materials to evaluate their developmental features and yields in irrigated conditions. The results indicate that plant height increased sharply first, and then slowly until the highest values that kept invariant. Tiller number per hill showed S-shaped curves which increased and reached relatively stable values first, then decreased slightly and finally increased again to produce the second time tiller. The leaf number per plant was apparently went up and down, which ascended to the peak values and then started to descend. NERICA 1 had many features which differed from NERICA 3 and NERICA 7, such as early maturing, short plant height, multiple tiller and multiple leave. It had the highest number of panicles and grains among the three varieties though it had nearly the same grain weight with NERICA 3 and NERICA 7. These results will be helpful to release these varieties in Zimbabwe.

Key words: Developmental feature, upland rice variety, yield, yield components, Zimbabwe.

INTRODUCTION

New Rice for Africa (NERICA) varieties, the germplasm from the Africa Rice Center (WARDA), performs well under upland conditions; have high yield potential and short growth cycle (WARDA, 2006; Somado et al., 2008). Several of them possess early vigor during the vegetative growth phase and this is a potentially useful trait for weed competitiveness. Likewise, a number of them are resistant to African pests and diseases, such as the devastating blast, to rice stem borers and termites. They also have higher protein content and amino acid balance than most of the imported rice varieties (WARDA, 2007; Somado et al., 2008). Participatory varietal selection (PVS) trials in rainfed environments have met with an enthusiastic response from farmers (Balasubramanian et al., 2007).

In 2004, Zim started a project plan for the Japanese International Cooperation Agency (JICA). NERICA varieties were introduced into Zim and a rice variety evaluation programme with NERICA was initiated. In 2005/2006, 2006/2007 and 2008/2009 rainy seasons, three experiments were conducted to test NERICA varieties under upland conditions for their adaptability to Zimbabwean conditions, to determine the appropriate nitrogen level and the optimum spacing for NERICA. Experiments were carried out at six research stations across the whole country under supplementary irrigation. On farm variety trials are also being carried out with selected experienced rice farmers with the aim of testing upland rice performance under farm conditions. Trial results from the past

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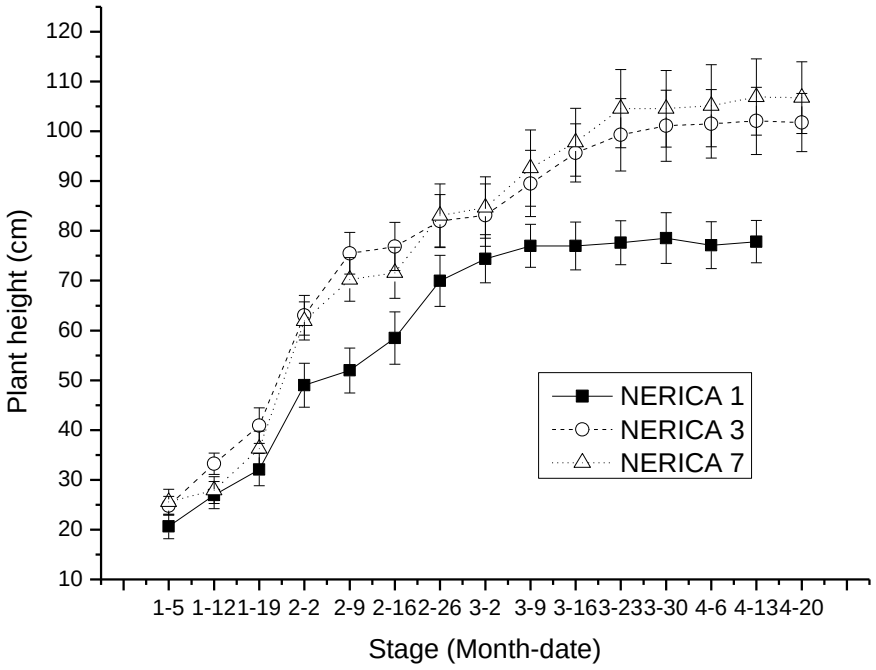

Figure 1. The dynamic of plant height for the three varieties.

three seasons have indicated that NERICAs 1, 3 and 7 are promising varieties.

However, information about these trails is not reported yet because of many constrained conditions. The performances of these three varieties in Zim are still unclear. In 2009/2010 rainy season, trails were specially conducted in the three varieties of Zim with the aim to realize their growth and developmental dynamics, and their yields and yield components.

MATERIALS AND METHODS

NERICA 1, 3 and 7, varieties developed from crosses between Asian rice, *Oryza sativa* L. and Africa rice, *Oryza glaberrima* Steud. (Jones, 1998), were selected as experimental materials. These three varieties were proved by previous trails to be the most adapted to growth in Zim among NERICA series.

Phenotype experiments were conducted at the experimental farm in Department of Research and Specialist Services, Harare (at 25°14' - 33°04' east longitude and 15°37' - 22°24' south latitude), Zimbabwe in rainy season (from November, 2009 to May, 2010). Germinated seeds were sown in a seedling bed on November 24th, and then seedlings were transplanted to a paddy field on December 21st, 27 days after sowing, with one plant per hill spaced at 16.7 x 20.0 cm. Each plot consisted of five rows with 27 plants and all plots were arranged in a randomized complete block design with three replications. The management of the field experiments was in accordance with local standard practices and there was enough water for irrigation. Two types of traits, developmental traits and yield traits, were investigated during the rice growth period. The developmental traits included plant height (PH), tiller number per plant (TN) and leaf number per plant (LN). From seven days after transplanting onwards, these traits were measured every seven days in 20 central plants (fixed through all measuring stages) from each plot until all lines had matured. At a total of 15 different stages, these traits were continuously recorded during the whole rice growth period. The yield traits included yield per plant (g, YD) and its components, panicle numbers per plant (PN), filled grain numbers per plant (GN) and 100-grain weight (g, GW). These traits were measured in the laboratory after harvesting. Weighing was conducted under 11 to 13% moisture of seeds, and data was transformed under 12% moisture. The averages of 20 plants in each plot at each measuring stage were used as raw data in the analysis.

Data was analyzed by the SAS (Statistical Analysis Systems) software for analysis of variance and correlation. Duncan's multi-test was adopted in the significant tests of differences among varieties at 0.05 level of probability.

RESULTS

Ontogenetic changes on developmental traits

Plant height (PH)

Averages of PH over 20 single plants at 15 measuring stages for three varieties are presented in Figure 1. At the last measuring stage, data from NERICA 1 was missing because the variety was mature. Plant height showed curve of increase progressively. Generally, plant height increased sharply first, and then slowly until the highest PH that kept invariant. The fast increase of PH appeared before February 26th, about 67 days after transplanting, and then the speed of rise decreased until the highest PH stage. In fact, at the stage of jointing and heading, the growth of plant was rapid. The three curves exhibited a slightness difference. PH of NERICA 1 was always the shortest among the three varieties. The difference values between NERICA 3 or NERICA 7 and NERICA 1 were originally small, then increased, and after

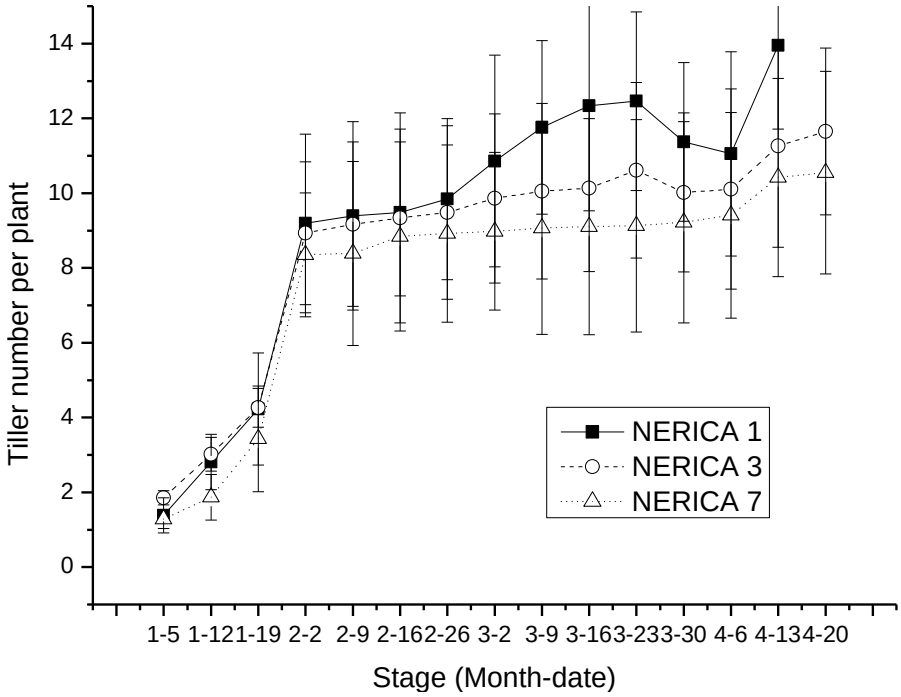

Figure 2. Dynamic of tiller number per plant for the three varieties.

then declined again. Lastly, the differences reached the largest value. The changes of PH between NERICA 3 and NERICA 7 were basically consistent, but NERICA 7 was higher than NERICA 3 at mid-late periods. The procedure resulted from synch on the ontogeny of varieties. NERICA 1 exhibited earlier maturation than NERICA 3 and NERICA 7.

Tiller number per plant (TN)

Tiller number per hill showed S-shaped curves (Figure 2). For the three varieties, TN continued to increase and reached relatively stable values, then decreased slightly (besides NERICA 7) and finally ascended again to produce the second time tiller. That some ineffective tiller simply died maybe as a result of TN decrease. The fast increase in TN appeared before February 2nd and after April 6th, respectively. The changes indicated that 14 to 50 days (from January 5th to February 2nd) after transplanting corresponded to the flourishing tiller stage. The three curves almost exhibited consistently before February 26th and then the differences appeared. Tiller number of NERICA 1 was always larger than that of NERICA 3 and NERICA 7 at a certain stage after February 2nd. The second time tiller appeared after April 6th. NERICA 1 produced more second time tiller than NERICA 3 and NERICA 7.

Leaf number per plant (LN)

LN for the three varieties was apparently fluctuating (Figure 3). It increased to their peak values and then started to decrease. Before February26th, LN was nearly consistent for the three varieties, and then their values differed. NERICA 1 had the highest LN among three varieties since March 2nd. NERICA 1, 7 and 3 reached their peak values successively. After March 30th, LN of NERICA 7 was more than that of NERICA 3.

Correlation relationships among three developmental traits

Correlation coefficients among three developmental traits were significant at 0.01 probability level (Table 1). Phenotypic correlation coefficients estimated between any two traits were similar for different varieties. The results indicate that indirect selection of one trait can affect the three traits in breeding programs.

Yield and its components

Yield (YD)

Yield is one important indicator to evaluate promising varieties. In this trail, NERICA 1 showed the higher YD among three varieties, even with no significant difference with NERICA 7 (Figure 4). NERICA 3 had the lowest YD among three varieties though it was also without significant difference with NERICA 7. NERICA 1 had many features different from NERICA 3 and NERICA 7, such as early maturing, short plant height and mutiple tiller and leave, which could result in higher YD in this trail.

Yield components

Three yield components, panicle number per plant (PN),

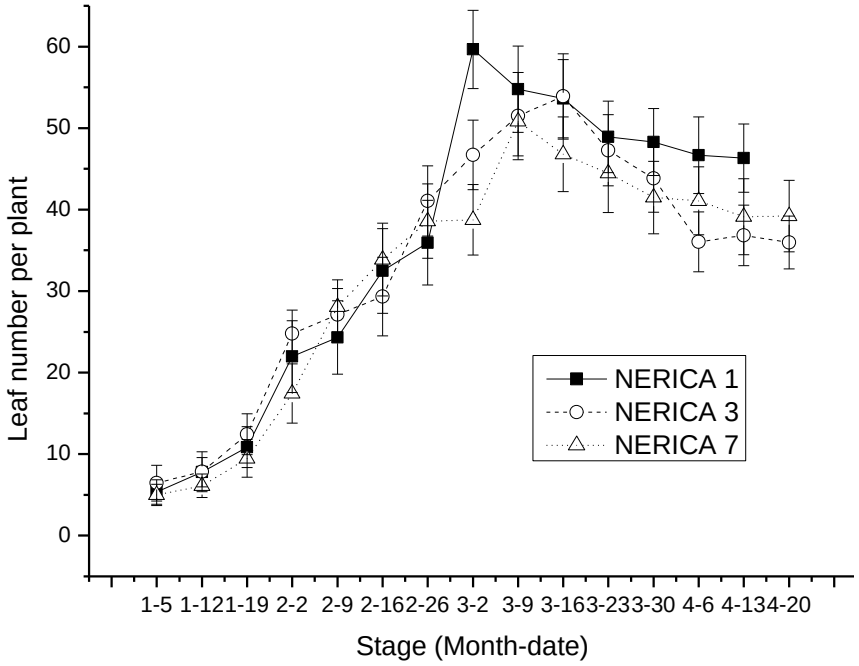

Figure 3. Dynamic of leaf number per plant for the three varieties.

Table 1. Correlation coefficients among three developmental traits of the three varieties.

Variety	Trait	TN	LN
NERICA 1	PH	0.9631**	0.9626**
	TN		0.8832**
NERICA 3	PH	0.9566**	0.8838**
	TN		0.8360**
NERICA 7	PH	0.9566**	0.8838**
	TN		0.8360**

** Indicate significance at 0.01 probability level.

grain number per panicle (GN) and 100-grain weight (GW), were simultaneously compared for the three varieties (Figure 4). Among these indicators of yield, NERICA 1 had better performances than others. It had the higher PN and GN among the three varieties though it had nearly the same GW of NERICA 3 and NERICA 7. These advantages were perhaps direct causes resulting in high yield for NERICA 1 in this trail.

Relationships between yield and one of its components

Yield was directly determined by the formula of panicle number per plant multiplied by grain number per panicle multiplied by grain weight. Using the data of three varieties with three replications, correlation coefficients between yield and one of yield components were estimated. The correlation coefficients between YD and PN, GN, GW were 0.7469, 0.9027 and -0.2991, respectively. The results suggest that increasing panicle number per plant, grain number per panicle and decreasing 100-grain weight could enhance YD per plant.

DISCUSSION

WARDA's breakthrough in producing NERICA offers relief to Africa's rice farmers. It is a new and unique opportunity for sustainable agricultural development in the rainfed environments where most of Africa's rice farmers earn a living. The NERICA seeds offer hope to millions of poor rice farmers, and for countless others who struggle in urban squalor, spending most on their meager income from rice (WARDA, 2006, 2007; Balasubramanian et al., 2007). The NERICAs have been evaluated and characterized for a range of agronomic traits. It was proved that NERICA is a new group of upland rice varieties that perfectly adapt to the rainfed ecology in sub-Saharan Africa (SSA). The new varieties with higher yield potential are spreading fast in West Central, East and Southern Africa. NERICA varieties have already been released, or are in the pipeline for release, and being grown under rainfed upland conditions by farmers in various countries in SSA (Dingkuhn et al., 1998; Futakuchi et al., 1998; Somado et al., 2006). This study aimed to provide the basis of releasing three NERICA varieties in Zimbabwe, a landlocked country in South Africa.

In Zimbabwe, rice was determined as strategic crop of food safety in 2004. Since then, Zimbabwe government gave the same emphasis on maize and wheat. The NERICAs

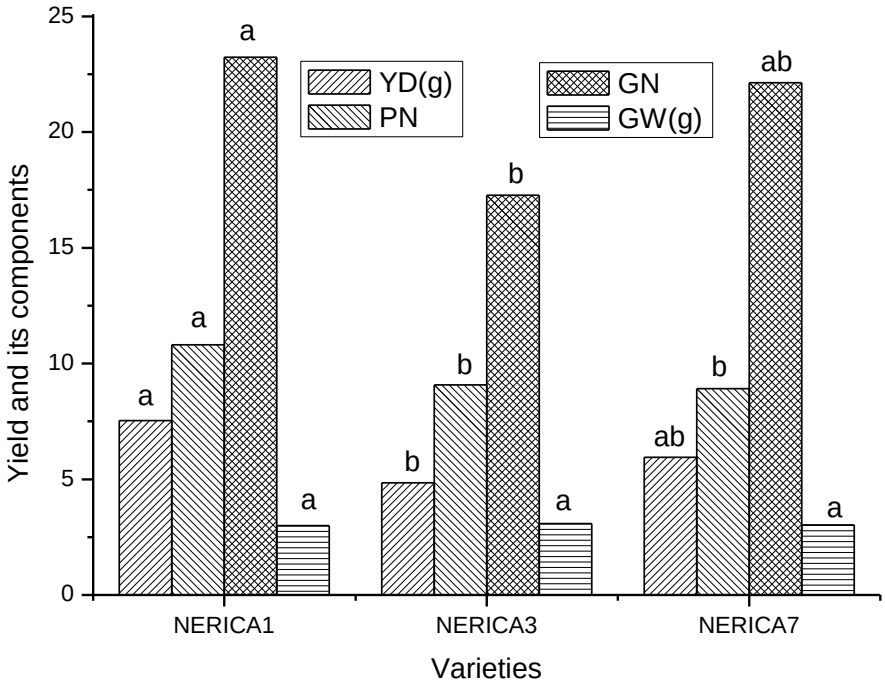

Figure 4. Yields and yield components for three varieties. Letters indicate the significance of trait difference at 0.05 probability level among the three varieties. YD, PN, GN and GW are the abbreviations for yield per plant, panicle number per plant, filled grain number per plant and 100-grain weight, respectively.

had been introduced into Zimbabwe and many trails for them were also conducted under rainfed or irrigated upland during the past several years. The results indicate that three varieties of NERICAs (1, 3 and 7) had better performances than others, and were considered as promising varieties with plan to be released into the whole country. However, past trails adopted the manner to sow directly six seeds per hill and a plot as unit of traits measured. Missing seedling often occurs and basic seedlings were always inconsistent among plots and varieties compared. Moreover, traits were measured only at a certain stage, which could not evaluate the developmental procedures of individuals. In this trail, we ensured the same basic seedlings for each plot since one seedling per hill was grown when transplanting. We investigated three developmental traits of plant height, tiller number and leaf number at sequential fifteen stages during growing period of plant. Yield per plant and its components were also recorded and analyzed after harvesting. This trail gave some information about dynamics of individuals' development and reliable data about yields and yield components for the three promising varieties. It is helpful to understand features of these varieties for release in Zimbabwe. However, this trail had several disadvantages also. The trail was conducted in irrigated fields rather than in real rainfed uplands. The trail was evaluated only in single environment, which cannot estimate interactions of varieties with environments. Further trails were needed to overcome these faults exiting in this trail.

Our trail showed that the three varieties are also fit to be cropped in irrigated fields. NERICA 1 had better performances than NERICA 3 and NERICA 7 such as early maturing, short plant height, multiple tiller and multiple leave. It had the highest number of panicles and grains among the three varieties, though it had nearly the same grain weight with NERICA 3 and NERICA 7. These results will be helpful to release these varieties in Zimbabwe.

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