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Effect of Seed Priming Method on Agronomic Performance and Cost Effectiveness of Rainfed, Dry-seeded NERICA Rice

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ABSTRACT

Priming is a seed enhancement method that might improve seed performance under stress conditions such as drought or freshly harvested or aged seeds which might fail to germinate. A field experiment was conducted in randomized complete block design in 2009 and 2010 at the Research Farm of the University of Calabar, Calabar to evaluate the effect of a range of priming techniques on agronomic performance of New Rice for Africa (NERICA) and to quantify their benefits to farmers. Treatments were on-farm priming, hydropriming, Osmopriming, vitamin (Ascorbate) priming, hardening, osmohardening, as well as a non-primed control. Results showed that seed priming had significant effect on germination, seedling emergence, days to heading, duration to plant maturity, number of tillers, number of fertile panicles and grain yield ($p = 0.05$). However, plant height at maturity and weight of 1000 grains were not similarly affected. Seed germination and seedling emergence consistently occurred sooner in primed seeds compared to non-primed seeds but differences existed between priming methods. The time to 50% germination was least in hardened, hydro-primed, on-farm-primed and Ascorbate-primed seeds compared with other priming methods evaluated and percentage seedling emergence followed the same pattern. Primed seeds gave plants that matured earlier with hardened, hydro-primed and on-farm primed seeds not being statistically different. The grain yield from hardened, hydro-primed and on-farm primed seeds was statistically similar but higher than that of other priming methods studied. Based on net returns, the most cost-effective priming method for NERICA rice is hardening, followed closely by on-farm priming and hydropriming.

Key words: Seed priming method, seed germination, seedling emergence, NERICA rice

INTRODUCTION

Direct seeded upland rice (*Oryza sativa* L.) is an important production system for resource-poor farmers in Sub-Saharan African (SSA) countries (De Datta, 1975) and is expected to assume even more importance following the release and rapid adoption of New Rice for Africa (NERICA) varieties that have high yield potential and short growth cycle (WARDA, 2008). For instance, about 244,000 ha of land was cultivated to these varieties in Nigeria in 2009 (Africa Rice, 2010). NERICA varieties are inter-specific hybrids of *Oryza sativa* and *Oryza glaberrima* and adapt well to rainfed upland ecology in SSA where small holder farmers lack the means to irrigate or apply chemical fertilizers or pesticides.

Rice yields under these conditions are constrained by drought, poor quality seeds and inadequate, untimely agronomy, the effects of which manifest themselves as sparse stands of stressed seedlings. Germination and seedling establishment are critical stages in the plant life cycle.

Cheng and Bradford (1999) observed that stand establishment determines plant density, uniformity and management options. Under upland conditions, the water needed for germination may be available for only a short period and consequently, successful crop establishment would depend not only on the rapid and uniform germination of the seed but also on ability of the seed to germinate under low water availability (Fisher and Turner, 1978).

The seeds of some NERICA varieties show dormancy characteristics inherited from their parent *O. glaberrima* (Guei *et al.*, 2002) and thus, dormancy would have to be broken to permit germination, uniform seedling emergence and establishment. Others may germinate rather slowly and may have to be primed (Harris and Jones, 1997) or pre-germinated before sowing (WARDA, 2008). Seed priming is a pre-sowing strategy for influencing seedling development by modulating pre-germination metabolic activity prior to emergence of the radical and generally enhancing germination rate and plant performance (Bradford, 1986). During priming, seeds are partially hydrated so that pre-germinative metabolic activities proceed, while radical protrusion is prevented. The seeds are subsequently dried back to the original moisture level before sowing.

Various priming techniques have been employed to increase the speed and synchrony of seed germination in many crop species such as lettuce (Cantliffe *et al.*, 1984), wheat (Giri and Schillinger, 2003; Rajpar *et al.*, 2006), soybean (Sadeghi *et al.*, 2011), sunflower (El-Saidy *et al.*, 2011) and the tree crop *Cordia millenaria* (Adebisi *et al.*, 2011). In upland rice, Harris *et al.* (1999) demonstrated that on-farm seed priming markedly improved establishment and early vigor of seedlings, resulting in faster development, earlier flowering and maturity and higher yields, while Farooq *et al.* (2006) observed improved emergence, yield and quality of direct-seeded rice. These authors as well as Mondal *et al.* (2011) attributed the positive effect of rice seed priming to an increase in endospermic amylase activity resulting from the increase in soluble sugar content of the primed seed. Invariably, the best priming method would depend on the type of stress the seed is exposed to (Yadav *et al.*, 2011), as well as the genotype (Frimpong *et al.*, 2004; Berchie *et al.*, 2010).

This study aimed to evaluate the effect of a number of priming techniques on agronomic performance of NERICA rice as well as quantify their potential benefit with a view to recommending the most cost-effective one(s) to farmers.

MATERIALS AND METHODS

The field study was conducted at the University of Calabar, Southeastern Nigeria during the early cropping season of 2009 and 2010. A 25×13 m piece of land was cleared with machete and spade, the debris burnt and minimum tillage operation consisting of opening up the spot to dibble in the seeds using a hand hoe, adopted. The field was divided into 3 blocks, each with 6 plots of 3×3 m and separated from each other by boundary of 1.0 m. NERICA 1 seeds at the rate of 60 kg ha⁻¹ was used for the study. Four seeds were sown per hole at a spacing of 30×30 cm and thinned to 2 seedlings per hill, 3 Weeks after Planting (WAP). Carbofuran (Furadan) at the rate of 2.5 kg a.i. per ha was incorporated into the planting rows. Each plot received 60 kg N, 13 kg P and 25 kg K ha⁻¹ with basal application of P and K at sowing and top dressing with one-third Urea at beginning of tillering and the remaining two-thirds at about panicle initiation. Treatments laid out in randomized complete block design were as follows:

- **Nonprimed (control):** Sowing of dry seeds
- **On-farm priming:** Seeds were soaked overnight in water before sowing (Harris *et al.*, 1999)
- **Hardening:** Alternate soaking of seeds in tap water for 24 h and drying (one cycle) before sowing (Basra *et al.*, 2003)

- **Hydropriming:** Seeds were soaked in aerated distilled water for 48 h and thereafter dried under shade before sowing in the field
- **Osmohardening:** Similar to hardening but in the presence of NaCl (with osmotic potential of -1.5 MPa, one cycle)
- **Osmopriming (osmoconditioning):** Seeds were pre-treated with Polyethylene glycol 6000 at a concentration of 235 g kg⁻¹ water, giving an osmotic potential of -0.8 MPa (Michel and Kaufmann, 1973) for 12 h. The seeds were subsequently rinsed in distilled water and sundried to the initial moisture content, before sowing (Bray, 1995)
- **Vitamin(Ascorbate) priming:** Seeds were soaked in aerated solution of Ascorbic acid at a concentration of 10 ppm for 48 h, rinsed in running water and dried under shade for 24 h before sowing (Basra *et al.*, 2006)

Primed seeds were given three washings with water and re-dried under shade to the initial moisture level.

Weeding was by hand pulling and hoeing, twice at 3 and 10 WAP, while birds were controlled by the use of 'scare crows' and screening with fishing nets. The crop was harvested when about 90% of the grains had turned to straw colour. The time to 50% germination (T50) was calculated according to the formula of Coolbear *et al.* (1984) modified by Farooq *et al.* (2005), while number of days to 50% emergence was computed as described by Farooq *et al.* (2006). Analysis of variance (ANOVA) was carried out using SAS software (SAS Institute, 2001). Excel software was used to draw figures, while means were compared by applying Least Significant Difference (LSD) at 5% probability. The cost of priming was computed based on the following: one liter of tap and distilled water cost No. 0.40 and 150.00, respectively; one gram each of ascorbic acid, sodium chloride and polyethylene glycol cost No. 25.00, 0.30 and 40.00, respectively and a kilo of unmilled rice was estimated at No. 32.00. It was estimated that it took one-man day at a cost of No. 1000.00 per man-day to prime seeds for 1 ha.

RESULTS AND DISCUSSION

Effect of seed priming on germination and seedling emergence: The effect of seed priming on germination was significant ($p = 0.05$). Figure 1 compares the germination time for various

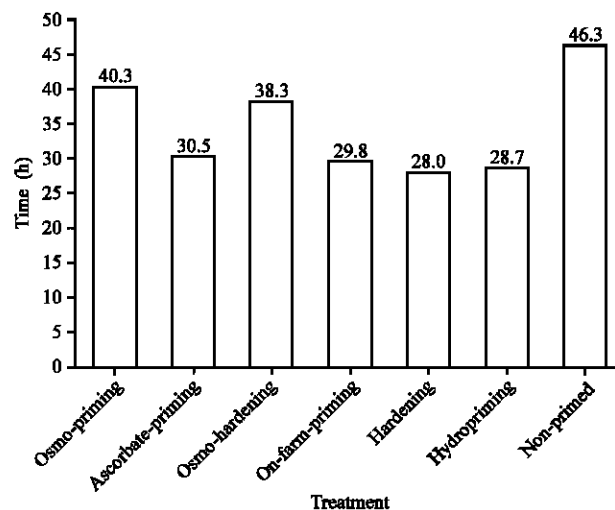


Fig. 1: Pooled effect of seed priming method on time of 50% germination of NERICA 1

primed seeds to non primed ones. The mean time for 50% germination of non-primed seeds was 46 h which was reduced to approximately 40, 38 and 30 h, respectively for Osmopriming, osmohardening, Ascorbate and on-farm priming. Hardening gave the earliest germination at 28 h, a reduction of about 18 h relative to the unprimed seeds, followed closely by hydropriming. Although, osmopriming was superior to no priming, it was statistically inferior to all other priming techniques evaluated in this study. The fastest germination was obtained with hydropriming and hardening probably because of faster water uptake and re-drying which might have led to earlier initiation of metabolism process that determines radicle protrusion. The regulation of water uptake during rice seed imbibition has been reported to play an important role in germination ability of rice seed (El-Hendawy *et al.*, 2011). On-farm priming might have been inferior to these because the seeds were not re-dried after soaking, while soaking seeds in limited water imposed by osmotic solutions was slower and resulted in less advanced metabolic processes and slower germination. Basra *et al.* (2005) similarly reported that primed seeds exhibit an increased germination rate which Bray *et al.* (1989) attributed to metabolic repair during imbibition, build-up of germination-enhancing metabolites (Basra *et al.*, 2005) and osmotic adjustment (Bradford, 1986). Mavi *et al.* (2006) who worked with tomato concluded that seed priming is rather effective through the reduction of germination time than subsequent relative growth of the plant.

At 3 days after planting, only 39% of unprimed seeds emerged, compared with 92, 86, 78, 74, 63 and 60% for hardened, hydro primed, on-farm primed, Ascorbate primed, osmohardened, osmoprimered, respectively (Fig. 2), representing 53, 47, 39, 35, 24 and 21% higher seedling emergence compared with the control. Seedling emergence percentage for seeds primed with water was higher than that with osmotic solutions. Good seedling emergence is the key to controlling stand establishment. In wheat, barley and oats, Kibite and Harker (1991) showed that seed hydration improved the uniformity of seedling emergence, while Harris *et al.* (1999) found that priming enhanced seedling establishment and early vigor of upland rice, maize and chickpea. Primed seeds emerge from the soil faster and often more uniformly than non-primed seeds because of limited adverse environmental exposure. This is accomplished by shortening the lag metabolic phase (i.e., phase II in the triphasic water uptake pattern, Bewley and Black (1978) in the germination process. The metabolic phase occurs just after seeds are fully imbibed and just prior

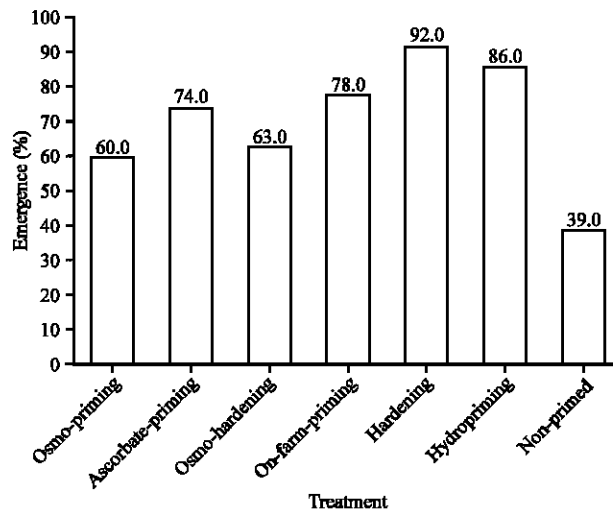


Fig. 2: Pooled effect of seed priming method on seedling emergence at 3 days after plantation of NERICA 1

to radicle emergence. Since seeds have already gone through this phase during priming, germination time in the field can be greatly reduced upon subsequent rehydration.

Effect of seed priming on growth and yield characters: Seed priming did not significantly influence plant height at maturity and weight of 1000 grains which might have been a varietal characteristic (Table 1). However, tiller number per plant, duration to 50% heading and duration to plant maturity, as well as grain yield were all significantly affected by priming NERICA 1 seeds prior to sowing.

The number of days to 50% heading and duration to plant maturity followed a consistent pattern, being least with on-farm priming, hardening and hydropriming but although Osmopriming, osmohardening and Ascorbate priming, gave plants that matured significantly earlier than the unprimed seeds, they did not differ significantly from each other ($p = 0.05$). Early plant maturity may be advantageous to the farmer in that the crop might escape potentially unfavorable environmental conditions such as drought. Tiller number per plant and number of fertile panicles per plant was highest in hardening, on-farm priming and hydro priming (Table 2), followed by Ascorbate priming, osmopriming and osmohardening. Hardened seeds and on-farm primed seeds gave 36.6 and 31.7% more tillers per plant and a corresponding increase of 30.3 and 26.4% more fertile panicles per plant.

Grain yield ranged from about 3.3 t ha⁻¹ for unprimed seeds to 5.3 t ha⁻¹ for hardened seeds, a difference of about 37.7%. Significantly higher yield was obtained from hardened seeds, hydroprimed seeds or on-farm primed seeds followed by osmoprime, ascorbate primed and

Table 1: Effect of seed priming method on days to heading, duration to maturity and plant height of NERICA 1

Priming method	Days to 50% heading		Days to maturity		Plant height (cm)	
	2009	2010	2009	2010	2009	2010
Non-primed	78.12	77.64	110.32	101.14	91.02	104.30
Osmopriming	70.62	79.10	98.10	108.08	101.54	98.84
Osmohardening	70.49	76.71	101.64	102.86	92.74	103.24
Ascorbate Priming	80.84	68.02	105.7	100.33	112.37	104.19
On-farm priming	70.06	70.16	100.08	91.04	99.55	100.67
Hydropriming	76.88	66.10	106.20	91.94	109.75	100.33
Hardening	67.02	74.24	100.48	90.02	102.90	106.04
LSD (0.05)	0.97	1.47	1.92	2.16	ns	ns

ns: Not significant

Table 2: Effect of seed priming method on grain yield and yield characters of NERICA rice

Priming method	No. of tiller/plant		No. of fertile panicles/plant		1000 grain wt. (g)		Grain yield (kg ha ⁻¹)	
	2009	2010	2009	2010	2009	2010	2009	2010
Non-primed	7.95	2.63	18.23	22.75	28.68	29.16	3272.93	3304.11
Osmopriming	16.11	10.99	26.37	22.29	29.69	28.43	4709.70	4616.40
Hydropriming	11.19	14.67	19.79	30.49	27.32	30.76	5289.46	4918.94
Ascorbate priming	10.88	16.10	20.43	30.83	30.70	27.48	4625.36	4475.20
On-farm priming	16.99	13.23	30.14	25.56	28.71	29.39	4944.05	5106.33
Osmohardening	14.58	14.16	28.61	21.55	28.37	29.41	4659.00	4137.80
Hardening	17.24	15.24	31.44	27.38	28.46	29.48	5654.17	5009.17
LSD (0.05)	2.68	2.52	1.28	3.06	ns	ns	530.14	594.08

ns: Not significant

Table 3: Cost and return estimates of priming NERICA 1 rice seeds

Priming method	Cost of application (ha ⁻¹)	Grain yield (kg ha ⁻¹)	Gross returns (ha ⁻¹)	Net returns (ha ⁻¹)
Non-primed	-	3288.52	105,232.60	105,232.60
Osmopriming	6875.00	4663.05	149,217.60	142,342.60
Hydropriming	4000.00	5104.20	163,334.40	159,334.40
Ascorbate priming	6500.00	4550.28	145,608.96	139,108.96
On-farm priming	1008.00	5025.19	160,806.08	159,798.08
Osmohardening	2038.00	4398.40	140,748.80	138,710.80
Hardening	2008.00	5331.67	170,613.44	168,605.44

osmohardened all of which did not differ significantly from each other. Hardening of the rice variety Swarna (MTU 7029) also reportedly gave satisfactory results (Mondal *et al.*, 2011). Better performance resulting from priming is attributed to early seedling emergence and vigorous growth as indicated in percent emergence, days to 50% heading and number of tillers and fertile panicles per plant. However, based on benefit/cost ratio, Okonkwo and Vanderlip (1985) and Carter *et al.* (1992) also reported that better yields are associated with stand establishment and vigorous early growth.

Both gross and net returns (Table 3) indicated the superiority of hardening, closely followed by on-farm- and hydropriming methods, over unprimed and other priming methods studied. Compared with unprimed seeds, these methods respectively gave 37.6, 34.1 and 34.0% higher net returns. These priming methods are known to be cheap and easy technology to adopt (Berchie *et al.*, 2010).

CONCLUSION

Although, transplanting remains the preferred method of rice establishment in West Africa, the increasing cost of labour, scarcity of water and release and rapid adoption of high yielding upland rice varieties such as NERICA suggest that direct seeding in dry unpuddled soil could be an alternative. However, poor germination, uneven crop stand and high weed infestation all of which combine to reduce yield, are constraints that discourage its adoption. Selective (even if expensive) herbicides are now available for effective weed control but poor germination and poor crop establishment are still concerns. Results from this study suggest that seed priming has the potential to overcome this problem.

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