EFFECTS OF OSMO-PRIMING DURATION ON RICE (*ORYZA SATIVA* L.) SEED GERMINATION AND SEEDLING PARAMETERS

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ABSTRACT

The study was conducted to determine the effects of osmo-priming duration on the germination and seedling parameters of rice seeds. Two rice varieties FARO 44 and FARO 59 were used for the study. Three osmo-priming chemicals (Calcium chloride CaCl, Potassium nitrate KNO_3 and Polyethylene glycol PEG6000) and four priming duration's (Control, 12, 24 and 36 hours in the above chemical solutions) as treatments in the study. Data were collected on the following parameters; final germination percentage, germination rate index, mean germination time, coefficient of velocity of germination, seedling height, seedling fresh weight and seedling dry weight. For most of the parameters, osmo-priming duration was statistically significant. The results showed that chemical priming treatments had significant effect on final germination percentage, mean germination time, germination rate index, coefficient of velocity of germination, seedling height and seedling weight of rice seeds. Primed with KNO_3, PEG6000 and CaCl solution for a period of 24 - 36 hours is a remarkable technique for improving seed germination and seedling growth of rice. The no priming treatment showed the lowest final germination percentage, mean germination time, germination rate index, coefficient of velocity of germination, seedling height and seedling weight of rice seeds. Therefore, the present study concludes that improvement of germination capacity and rapidity of germination of rice seed could be possible by employing osmo-priming duration treatments.
Keywords: Rice; Osmo-priming; Duration; Seed; Germination; Seedling and Parameters.

Introduction

Rice (*Oryza sativa* L.) is a widely grown cereal crop and a staple meal for over half of the world's population, particularly in tropical Latin America and East, South, and Southeast Asia. It is cultivated in a variety of locales, covering around 11 % of the world's arable land (Seck *et al*. 2012). Paddy rice output in the globe totals 178 million tonnes, with Asia leading the way with 90.6 percent, followed by America with 5.2 percent, and Africa with 3.5 percent (FAOSTAT, 2020). Rice output in Nigeria increased from 3.7 million metric tons in 2017 to 4.0 million metric tons in 2018. According to Kamai *et al*. (2020) the primary rice-producing states in Northern Nigeria are Kebbi, Borno, Kano, and Kaduna. Rice requires a lot of water for maximum germination, development, and output, drought is a severe barrier to rice production in Northern Nigeria (Kamai et al. 2020).

Direct seeded rice is an essential production strategy for resource-poor farmers in Sub-Saharan African (SSA) nations (Ampong, 1996), and it is predicted to expand in importance with the

Received 27 March 2019; Revised 4 September 2023; Accepted 31 October 2023; Published Online 31 October 2023; Published

introduction and widespread acceptance of New Rice varieties with high yield potential and a short growth cycle (WARDA, 2008). Direct seeding of rice in aerobic cultures has evolved as a resource-saving approach that eliminates the need for puddling in transplanted rice cultures, saving water, labor, and fuel (Liu, 2014). Broadcasting without dibbling on wet soil has been a standard seeding strategy for rice sowing in West Africa, particularly Nigeria (Ampong, 1996). Poor germination, on the other hand, has been one of the barriers to its acceptance in the field (Liu, 2014). Uniformity, poor germination, and variable seedling emergence capabilities have a significant influence on eventual yield, quality, and, ultimately, revenues (Tzortzakis, 2009). Priming is the process of immersing seeds in enough water to initiate pre-germinative metabolic activity while inhibiting radicle emergence. These seeds may be dried, and when imbibed, they will typically show faster radicle emergence and good seedling establishment (Heydecker *et al*. 1997). Rice uses a variety of seed priming strategies such as hydro-priming, osmo-priming, hormone priming, nutritional priming, and chemical priming (Farooq *et al*. 2009). Priming a rice crop gives it a strong head start, resulting in faster and more uniform emergence, greater stand establishment, and higher rice output (Farooq *et al*. 2009). These characteristics have significant agronomic significance, particularly in difficult germination settings (McDonald, 2000). Osmo- and hydro-priming of seed considerably increased germination and early seedling properties of caraway, according to (Iman *et al*. 2020). Although various investigations have been carried out to examine the effects of pretreatment on the germination performance of commercially cultivated rice seeds, less attention has been paid to the use of seed osmo-priming in rice agriculture. The purpose of this study was to determine how osmo-priming time affected seed germination metrics and early seedling traits in rice.

MATERIALS AND METHODS

Experimental Site and Materials Used

The experiment was conducted in the Plant Breeding and Seed Science Laboratory, of Joseph Sarwuan Tarka University, Makurdi in the year 2021. Two untreated rice varieties (FARO 44 and FARO 59) obtained from Kemol Agro Nig LTD was used for the study. Also sharp sand, plastic containers and measuring instrument were used for the experiment.

Treatment and Experimental Design

The experiment was a 2 x 3 factorial combination laid out in a Completely Randomized Design (CRD) with four replications. The various treatments assigned were 2 rice varieties (FARO 44 Lowland and FARO59 Upland), 3 priming chemicals (Calcium chloride CaCl, Potassium nitrate $KNO_3$and Polyethylene glycol PEG6000) and 4 priming durations (Control, 12, 24 and 36 hours in chemical solutions)

Seed Priming

500g of untreated rice seeds were soaked in 1 liter of osmo-priming solutions for a period as prescribed by the treatments and re-dried under room temperature for a period of 24 hours before use in the germination test.

Germination Test

Germination test was set up on 400 seeds per treatment according to ISTA, (2015). Seeds were tested using sand method in plastic containers. The sand was washed and heat sterilized to kill soil microbes and foreign seeds before use. One hundred (100) seeds were broadcasted in each container to represent a replicate. Broadcasted seeds were constantly moistened with clean and uniform quantity of water at 8 am and 5 pm daily until 14 days that the experiment was terminated. Germinated seeds were counted daily until the number of days for a treatment to attain a recommendable germination percentage was attained.

Data Collection

Data was recorded on the following parameters;

Final Germination Percentage (FGP): FGP = $\frac{Ng}{Nt}$ x 100 where Ng = Total number of seeds germinated and Nt = Total number of seeds evaluated according to Scott *et al*., (1984)
Mean Germination Time (MGT): MGT = $\frac{\Sigma NiTi}{\Sigma Ni} = 100 / CVG$ where Ni = Number of seeds germinated per day and Ti = Number of days from the starting the experiment as described by Orchard, (1977)
Coefficient of Velocity of Germination (CVG): 100 × $\frac{\Sigma Ni}{\Sigma NiTi}$ where Ni = Number of germinated seeds per day and Ti = Number of days from the start of the experiment Jones and Sanders, (1987)
Germination Rate Index (GRI): G1 / 1 + G2 / 2 + …. + Gx /X where G1 = Germination percentage at first day and G1 = Germination percentage at the second day and so on Esechie (1994) after modification.
Seedling Height (SH): The seedlings or shoot height was determined in the standard germination test after the final count. Ten (10) normal seedlings were randomly selected from each replicate on the 8th day of broadcasting. The shoot height was measured from the point of attachment to the embryo (endosperm), to the tip of the seedling and the average shoot height was computed. The average shoot length was computed according to (ISTA, (2015).)
Root Length (RL): Ten (10) normal seedlings were randomly selected from each replicate on the 8th day of broadcasting. The root length was measured from the point of attachment to the embryo (endosperm), down to the tip of the growing root and the average root length was computed the average shoot length was computed according to (ISTA, (2015).
Seedling Fresh Weight (SFW): Ten (10) normal seedlings were randomly selected from each replicate on the 8th day of broadcasting. The seedling fresh weight was measured by weighing the sampled seedlings in grams and finding the average. The average shoot length was computed according to (ISTA, (2015).
Seedling Dry Weight (SDW): Ten (10) normal seedlings were randomly selected from each replicate on the 8th day of broadcasting and oven dried to a constant weight. The seedling dry weight was measured by weighing the sampled seedlings in grams and finding the average. The average shoot length was computed according to (ISTA, (2015).

Data Analysis

The data collected from germination test was subjected to analysis of variance (ANOVA). Treatment means were separated and ranked at 0.05% level of probability using Tukey Pairwise Comparisons (TPC). All data analysis was carried out using Minitab, version 2017.

Results and Discussion

Variety x Chemical x Priming Duration Interaction for FGP

The interaction effects of variety, chemical and priming duration in rice showed that, at control, FARO 59 had the highest FGP (26.31) while the least (22.89) was recorded in FARO 44, this difference however is not significant. FARO 44 when soaked in KNO_3 for 12 hrs; though not significant, gave the highest FGP (92.00) while FARO 44 and 59 soaked in PEG6000 had the least FGP (49.11). At 24 hrs priming duration, FARO 59 soaked in PEG6000 showed the highest FGP (96.66) and is significant different to the least FGP (79.33) recorded from FARO 59 soaked in KNO_3. Duration of soaking for 36 hrs showed no difference in FGP. The results of the present study clearly showed that more germination advantages of rice seed could be achieved by priming with different chemicals. Rice seeds soaked for a duration of less than 24 hours gave the least final germination percentage below 50% as compared to the seeds soaked for a duration of 24 and 36 hours that gave above 75% germination percentage. The higher FGP observed in primed seeds over the non-primed seeds could be due to the several changes in the enzymes activities associated with the germination process as a result of seed priming. These activities include increase in the acid phosphatase and esterase as reported in lettuce according to (Khan *et al*. 1978), increase in α-amylase as reported by (Farooq *et al*., 2006). In the case of rice and increase in antioxidant enzymes as reported in the case of wheat (Afzal *et al*., 2006). According to Sivritepe *et al*. (2003), priming with KNO_3 increased also germination percentage and seedling growth under salt stressed conditions. These positive effects could probably due to the stimulatory effects of priming at the early stages of the germination process by mediation of cell division in germinating seeds.

Variety x Chemical x Priming Duration Interaction for GRI (%)

It is found that priming treatments had significant effect on mean germination index of rice varieties for different chemical treatments (Table 1). FARO 59 and FARO 44 in the control showed no significant difference. A similar trend was observed when the seeds were primed for 12 hrs respectively across all the chemical. At 24 hrs however, FARO 59 soaked in PEG6000 gave the highest GRI (92.77) and is significantly different from the lowest GRI (51.18) recorded when the same variety was soaked in KNO_3 for the same duration of 24 hrs. At 36 hrs soaking duration, FARO 59 showed highest result for GRI (93.77) and is significantly different from all interaction except FARO 59 in KNO_3 (70.55). At the same duration of 36 hrs, there was no significant difference when FARO 44 and FARO 59 was soaked in KNO_3, with means of (70.55) and (69.55), respectively. The results revealed that priming enhanced rapid germination of seed compared with non-primed seed. The significant speed of germination might have been caused due to increased amylase activity that is positively correlated with the reserve mobilization and mean germination rate in rice according to (Lee and Kim, 2000).

Variety x Chemical x Priming Duration Interaction for CVG

Generally, there was consistency in CVG result although higher CVG was observed in the primed seeds over the control (Table 1). According to the result, the only significance difference recorded was in PEG6000 and CaCl soaked for the duration of 36 hrs s for FARO 59 and FARO 44 and 12 hr for FARO 44, respectively.

Table 1. Effects of Variety x Chemical x Priming Duration Interaction

Variety	Chemical	Duration	FGP	GRI	CVG	MGT
FARO 59	Unprimed	0 hrs	26.31fghi	26.31fghi	67.98abcdef	4.16bcd
FARO 44	Unprimed	0 hrs	22.89hi	22.89hi	66.61cdef	4.79ab
FARO 59	PEG6000	12 hrs	49.11def	49.11degf	81.00abcd	2.26fghi
FARO 44	PEG6000	12 hrs	49.11defg	49.11degf	90.89abc	3.01cdef
FARO 59	CaCl	12 hrs	56.56cde	56.56cde	87.25ab	2.11fghi
FARO 44	CaCl	12 hrs	46.58defgh	46.58de	97.36a	2.66fgh
FARO 59	KNO_3	12 hrs	54.86cde	54.86cde	87.14abcd	2.19fghi
FARO 44	KNO_3	12 hrs	52.00cde	47.00def	84.66abcdef	2.43fgh
FARO 59	PEG6000	24 hrs	96.66ab	92.77a	93.85ab	1.12i
FARO 44	PEG6000	24 hrs	95.33abc	83.15ab	90.94abc	1.47ghi
FARO 59	CaCl	24 hrs	92.00abcde	79.22abc	84.64abc	1.48ghi
FARO 44	CaCl	24 hrs	94.00abcd	57.71cde	88.44abc	2.17fghi
FARO 59	KNO_3	24 hrs	79.33de	51.18def	64.01def	3.10cdef
FARO 44	KNO_3	24 hrs	92.66abcde	55.17cd	85.93abc	2.43fgh
FARO 59	PEG6000	36 hrs	100.00a	93.77a	100.00a	1.15hi
FARO 44	PEG6000	36 hrs	98.66ab	62.04bcde	97.36a	2.02fghi
FARO 59	CaCl	36 hrs	92.66abcde	66.14bcde	86.94abc	2.29fghi
FARO 44	CaCl	36 hrs	98.00ab	69.80abcde	96.06ab	1.95fghi

FARO 44	KNO_3	36 hrs	88.00abcde	70.55abcd	77.76abcd	2.11fghi
FARO 59	KNO_3	36 hrs	86.00abcde	69.55abcd	76.56abcd	2.10fghi
Standard Error			0.91	2.64	1.61	0.14
Coefficient of Variation			8.62	42.47	16.53	43.77
Level of Significant			*	**	*	**

** = Significant at 1 % level of probability and * = Significant at 5 % level of probability

The value recorded as 64.01 is the least CVG at 24 hrs priming duration. The CVG increase in the primed seeds over the non-primed seeds indicate higher vigour which might be related to reduction of imbibition of lag time for priming treatment (Bradford, 1986). Priming also causes physiological and bio-chemical changes in seed during the seed treatments and metabolic activities increases a-amylase activity therefore, indicating higher vigour as reported by (Lee and Kim, 2000).

Variety x Chemical x Priming Duration Interaction for MGT (days)

MGT decreases with increase in priming duration of up to 24 hrs. However, beyond 24 hrs soaking duration, the MGT begins to increase but was not significantly different from that of 24 hrs. At control, FARO 44 showed significant difference and also holds the highest MGT (5.33). Priming for 12 hrs was not significantly different for all the chemicals. FARO 59 soaked in PEG6000 for 24 hrs which had the least MGT (1.12), differed significantly from FARO 59 and FARO 44 soaked in KNO3 for the same priming duration, with FARO 59 having the highest MGT (3.10). Significant difference was recorded at 36 hrs priming duration between the highest MGT (2.29) for FARO 49 in CaCl and the lowest MGT (1.15) from FARO 59 in PEG6000. The results revealed that priming enhanced rapid germination thereby, reducing the mean germination time of seed compared with non-primed seed. The significant enhancement in germination could due to increased amylase activity that is positively correlated with the reserve mobilization and mean germination rate in rice as reported by (Lee and Kim, 2000). Similar results were also found by Harris *et al*. (2002).

Variety x Chemical x Priming Duration Interaction for SH (cm)

The result showed an increase in seedling height with respect to increase in priming duration (Table 2). At control, varieties (FARO 59 and FARO 44) showed significant difference from each other. The highest SH (8.93) was observed in FARO 59 which is significantly different from the lowest SH (3.91) observed in FARO 44. When duration of priming was increased to 12 hrs FARO59 in KNO_3 gave the highest SH (10.89) and was significantly different from the lowest SH (8.06) recorded when FARO 44 is soaked in PEG6000 for the same duration of 12 hrs. FARO 59 soaked in CaCl for 24 hrs gave the highest SH (12.68) and was significant to the lowest SH (8.56) observed when FARO 44 was soaked in PEG6000 for 24 hrs. when priming duration was increased to 36 hrs, FARO 59 gave the highest values for SH (12.96) and this showed significance to the least SH value at same duration (12.96) which was of observed with FARO 44 in CaCl. The results of the present study clearly showed that osmopriming enhanced seedling height of rice varieties. This is linked to what was observed in MGT where primed seeds germinate faster giving rise to more vigorous seedling establishment than in the non-primed rice. This result is in agreement with that of Farooq *et al.* (2006).

Variety x Chemical x Priming Duration Interaction for RL (cm)

Control, 12 hrs and 24 hrs showed no significance for any interactions suggesting the same effects or no difference in effect of chemical, variety and priming duration on RL. However, the RL was increasing with the increase in priming duration. At a priming duration of 36 hrs, FARO 44 soaked in PEG6000 gave the highest RL (11.14) and was significantly different to the least RL (6.08) when FARO 59 is soaked in CaCl for the same duration. The results of the present study showed that root length of rice seedling increased by priming treatments. This results is connected to what was observed the MGT where primed seeds germinate faster giving rise to more vigorous seedling establishment than in the non-primed rice. Similar result was reported by Ruan *et al.* (2002).

Variety x Chemical x Priming Duration Interaction for SFW (g)

FARO 59 in the control gave the highest SFW (0.76) and is significantly different to the lowest SFW (0.07) observed in FARO 44. At 12 hrs priming duration, no significant difference is observed among all interactions for SFW. At 24 hrs priming duration, FARO 59 in CaCl had the highest SFW (1.14) which is significant to FARO 44 in KNO3 which recorded the lowest SFW (0.35). At 36 hrs of priming, FARO 59 soaked in CaCl had the highest SFW (2.50) and it is significantly different to the lowest SFW (0.50) recorded when FARO 44 is soaked in PEG6000. Seed priming duration increased seedling fresh weight probably by enhancing K+ condition in both seeds and seedlings as reported by (Faurooq *et al.*, 2007). The results clearly exhibited that seed priming had effect on seedling growth. The result of the present study is in agreement with that of Farooq *et al.* (2006, 2007 and 2008) and Tongma *et al.* (2001).

Table 2. Effects of Variety x Chemical x Priming Duration Interaction

Variety	Chemical	Duration	SH	RL	SFW	SDW
FARO 59	Unprimed	0 hrs	8.88defg	6.53bcd	0.64cdef	0.54abcde
FARO 44	Unprimed	0 hrs	4.46i	7.18bcd	0.40ef	0.033de
FARO 59	PEG6000	12 hrs	10.04bcd	6.42cd	0.66cdef	0.56abcde
FARO 44	PEG6000	12 hrs	8.06g	6.02cd	0.42ef	0.36de
FARO 59	CaCl	12 hrs	9.17cdef	7.27bcd	0.58cdef	0.47bcde
FARO 44	CaCl	12 hrs	8.31efg	7.02bcd	0.73bcde	0.63bcd
FARO 59	KNO3	12 hrs	10.89abc	6.48cd	0.78bcde	0.65bcd
FARO 44	KNO3	12 hrs	8.60defg	8.16abcd	0.32ef	0.24de
FARO 59	PEG6000	24 hrs	11.18abcd	6.27cd	0.88bcde	0.71bcd
FARO 44	PEG6000	24 hrs	8.56defg	8.91abc	0.49ef	0.39cde
FARO 59	CaCl	24 hrs	12.68ab	6.48cd	1.14bcd	0.97b
FARO 44	CaCl	24 hrs	11.02abc	8.25abcd	0.39ef	0.26de
FARO 59	KNO3	24 hrs	10.82abc	6.56bcd	0.81bcde	0.71bcd
FARO 44	KNO3	24 hrs	9.58cdefg	8.31abcd	0.35ef	0.20de
FARO 59	PEG6000	36 hrs	12.96a	6.84bcd	1.32b	0.95bc
FARO 44	PEG6000	36 hrs	8.41efg	11.14a	0.50ef	0.40cde
FARO 59	CaCl	36 hrs	11.64abc	6.08cd	1.18bc	1.02b
FARO 44	CaCl	36 hrs	7.67gh	9.94ab	0.52def	0.48bcde
FARO 59	KNO3	36 hrs	10.80abcd	7.12bcd	2.50a	1.84a
FARO 44	KNO3	36 hrs	8.22fg	7.18bcd	0.65cdef	0.48bcde
Standard Error			0.28	0.19	0.05	0.04
Coefficient of Variation			26.18	22.22	47.78	46.28
Level of Significant			*	**	**	**

** = Significant at 1 % level of probability and * = Significant at 5 % level of probability

Variety x Chemical x Priming Duration Interaction for SDW (g)

It is found that priming treatments had significant effect on seedling dry weight of rice varieties for different chemical treatments (Table 2). At control, FARO 59 gave the highest SDW (0.66) while FARO 44 had the lowest SDW (0.04) and both show significant difference. An increase in priming duration to 12 hrs showed that FARO 59 soaked in KNO3 gave the highest SDW

(0.65) significantly different from FARO 44 soaked in KNO3 with the lowest SDW (0.24). FARO 59 soaked in CaCl for 24 hrs gave the highest value (0.97) of SDW which is significantly different from FARO 44 soaked in KNO3 which has the lowest value for SDW (0.20) at the same duration. At 36 hrs of priming, FARO 59 soaked in KNO_3 had the highest SDW (1.84) significantly different from the lowest SDW (0.40) recorded when FARO 44 is soaked in PEG6000 for the same duration. Seed priming duration increased seedling dry weight probably by enhancing K+ condition in both seeds and seedlings, leading to improve a-amylase activity and the concentration of reducing sugars with amylase activity as reported by (Faurooq *et al.*, 2007). The results clearly showed that seed priming had effect on seedling growth. The result of the present study is in agreement with that of Farooq et al. (2006, 2007 and 2008) and Tongma *et al.*, (2001).

CONCLUSION

From the results of the present study, it may be stated that osmo-priming treatments enhanced rapid seed germination while lessening the mean germination time and enhancing seedling growth by different priming duration's. The results showed that chemical priming treatments had significant effect on final germination percentage, mean germination time, germination rate index, coefficient of velocity of germination, seedling height and seedling weight of rice seeds. Primed with KNO_3, PEG6000 and CaCl solution for a period of 24 - 36 hours is a remarkable technique for improving seed germination and seedling growth of rice. The no priming treatment showed the lowest final germination percentage, mean germination time, germination rate index, coefficient of velocity of germination, seedling height and seedling weight of rice seeds. Therefore, the present study concludes that improvement of germination capacity and rapidity of germination of rice seed could be possible by employing osmo-priming treatment.

REFERENCES

Afzal IS, Basra MA, Hameed A, Farooq M. 2006. Physiological enhancements for alleviation of salt stress in wheat. Pak. J. Bot., 38(5): 1649-1659.

Ampong-Nyarko, K., 1996. Weed management in rice in Africa. In: Auld, B.A., Kim, K.U. (Eds.), Weed Management in Rice. FAO, Rome, Plant Production and Protection Paper 139, pp. 183–191.

Esechie, H., 1994. Interaction of salinity and temperature on the germination of sorghum. Journal of Agronomy and Crop Science, 172, 194–199.

FAOSTAT. 2020. http://www.fao.org/faostat/en/#data/QC/visualize.

Farooq M, Basar SMA, Ahmad N. 2007. Improving the performance of transplanted rice by seed priming. Plant Growth Reg. 51(2): 129-137.

Farooq M, Basar SMA, Rehman H and Hussain M. 2008. Seed priming with polyamines on the germination and early seedling growth in fine rice. J. New Seeds. 9(2): 145-155.

Farooq M, Basra SMA and Rehman HU. 2006. Seed priming enhances emergence, yields and quality of direct-seeded rice. IRRN, 31: 42-44.

Farooq M, Basra SMA, Wahid A, Khaliq A and Kobayashi N. 2009. Organic farming, pest control and remediation of soil pollutants. *Lichtfouse, E.* [Rice seed invigoration: a review]. Springer, the Netherlands, 137–175.

Harris D, Tripathi RS and Joshi A. 2002. On-farm seed priming to improve estab lishment and yield in dry direct seeded rice. In: Pandey S, Mortimer M, Wade L, Tuong TP, Lopes K and Hardy B. (Eds.), Direct Seeding: Research Strategies and Opportunities. International Rice Research Institute Los Banos, Philippines, pp. 231–240.

Heydecker W and Coolbear P. 1977. Seed treatment for improved performance survey and attempted prognosis. Seed Sci. Technol., 13, 299–335.

Iman M, Attila K, Éva E, Márta L, Éva ZN and Péter R. 2020. The Effeect of Osmopriming on Seed Germination and Early Seedling Characteristics of *Carum carvi* L. Agriculture, 10, 94; doi:10.3390/agriculture10040094 www.mdpi.com/journal/agriculture

International Seed Testing Association. 2015. International rules for seed testing. Basserdorf, Switzerland: International Seed Testing Association.

Jones K and Sanders D. 1987. The influence of soaking pepper seed in water or potassium salt solutions on germination at three temperatures. Journal of Seed Technology, 11: 97–102.

Kamai N, Omoigui LO, Kamara AY and Ekeleme F. 2020. Guide to rice production in Northern Nigeria, Pages: 35.

Khan AA, Tao KL, Knypl JS, Borkowska B, Powell LE (1978). Osmotic conditioning of seeds: physiological and biochemical changes. Acta Hortic., 83: 267–282.

Lee SS and Kim JH. 2000. Total sugars, a-amylase activity and germination after priming of normal and aged rice seeds. Korean J. Crop Sci. 43: 157-160.

Liu H. 2014. Dry direct-seeded rice as an alternative to transplanted-flooded rice in Central China. Agron. Sustain. Dev. 10.1007/s13593-014-0239-0.

McDonald MB. 2000. Seed Priming-Seed technology and its biological basis. Black, M. and Bewley, J.D. (ed.). Sheffield Academic Press, Sheffield, UK, 287–325.

Orchard T. 1977. Estimating the parameters of plant seedling emergence. Seed Science and Technology, 5: 61–69.

Ruan S, Zue Q and Thylokowska K. 2002. Effects of seed priming on germination and health of rice (*Oryza sativa L.)* seeds. Seeds Sci. Technol. 30: 451-458.

Scott S, Jones R and Williams W. 1984. Review of data analysis methods for seed germination. Crop Science, 24: 1192–1199.

Seck PA, Diagne A, Mohanty S and Wopereis MC 2012. Crops that feed the world 7: Rice. Food Sec. 4, 7–24.

Sivritepe N, Sivritepe HO and Eris A. 2003. The effects of NaCl priming on salt tolerance in melon seedlings grown under saline conditions, Sci. Hortic., 97, 229–237

Tongma S, Kobayashi K and Usui K. 2001. Allelopathic activity of Mexican sunflower [*Tithonia diversifolia* (Hemsl.) A. Gray] in soil under natural field conditions and different moisture conditions. Wed Biol. Management 1(2): 115-119.

Tzortzakis NG. 2009. Effect of pre-sowing treatment on seed germination and seedling vigour in endive and chicory. Horti. Sci., 36, 117–125.

WARDA. 2008. NERICA: The New Rice for Africa-a compendium. In: Cotonou, Benin: Africa Rice Center (WARDA), Cotonou, Benin: Africa Rice Center (WARDA), Rome, Italy: FAO; Tokyo, Japan: Sasakawa Africa Assoc., Pages: 210.