Pre-sowing Treatment for Improving Seed Quality in West African Rice Varieties: I. Seed Germination and Seedling Vigor

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Abstract

Ten diverse modern West African rice varieties were exposed to six dry heat temperatures (40⁰C, 45⁰C, 50⁰C, 55⁰C, 60⁰C and control (32⁰C) for 24 hours and thereafter seed germination, speed of germination and seedling vigor were investigated. Dry heat temperatures significantly stimulated seed germination above the control. Temperatures of 40⁰C, 45⁰C and 50⁰C significantly promoted seed germination, seedling vigor and speed of germination of the rice varieties. Although heat intensities at 55⁰C and 60⁰C had no adverse effects on both seed germination and speed of germination, 60⁰C heat treatment specifically failed to increase seedling vigor. Dry heat temperatures generally promoted seed germination of TOx 4004 43-1-2-1 and WITA 12; speed of germination of ITA 230 and seedling vigor of BW348-1, ITA230, SIPI1692033, TOx 4004-43-1-2-1 and WITA 12. There was enhanced seed germination of WITA 12 at all the heat intensities except at 60⁰C. High dry heat temperatures (50⁰C, 55⁰C and 60⁰C) for 24 hours was sufficient to break seed dormancy that promoted seed germinatation in BW 348-1, WITA 1, CISADANE and WAB 189-B-B-B-H1. Seed dormancy in ITA 230, WITA 12 and TOx 4004-43-1-2-1 was almost completely broken under natural conditions. Beneficial carry-over effects beyond seed germination and vigor stages would need further investigations.

Key words: *Heat intensity, seed dormancy, seed quality, seedling vigor index*

Introduction

To the seeds man, the most essential role a seed has is its generative function, the capacity to produce that from which it came. Sadly, this biological function ignores other uses to which seeds are put. A high germination percentage is an essential characteristic of high quality seed. Imperfect, but the best routine test available for assessing the field sowing value. Dormancy, when in place, prevents seed from germinating, even when all conditions for germination are provided.

Quality of seed for sowing is an important factor, which affects rice production. Seed is a biological input which determines the effectiveness of other inputs in crop production. Seed dormancy is a survival mechanism by which seeds maintain their viability in unfavorable conditions. In order

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that a species is not obliterated during harsh weather, natural dormancy measures developed by species and cultivars must be deliberately confronted for good stand establishment (Ajala, 2003). In rice, it creates a problem in seed analysis (Nugraha and Soejadi, 1991). Rice seeds exhibit dormancy which, given time, could be completely broken under natural conditions or accomplished through application of certain chemicals or heat treatments (Lee *et al.*, 2002).

Dry heat is a convenient and effective method for large-scale treatment in many seed crops. The dry heat treatment of seeds is used mainly for two purposes. One is to control the external and internal seed borne pathogens including fungi, bacteria, viruses and nematodes (Nakagawa and Yamaguchi, 1989; Fourest *et al.*, 1990; Grondeau *et al.*, 1992; Detry, 1993; Lee *et al.*, 2002). The other is to break the dormancy of seed (Zhang, 1990; Seshu and Dadlani, 1991; Lee *et al.*, 2002).

Moreover, there exists contradictory results in literature concerning the improvement of seed quality by means of pre-sowing treatment. The range of dry heat temperature differs from one researcher to the other, and varies according to crops and purpose of treatment. Lee *et al.* (2002) reported that at higher temperatures (29.4°C and 32.2°C), percentage germination was significantly reduced in Korean rice varieties compared to the control, whereas treatment at relatively lower temperatures (21.1°C to 18.3°C) had no adverse effects. An earlier study by Dadlani and Seshu (1990) showed that in rice, dry heat treatment at 18°C for 7 days considerably lowered fungal incidence and had no adverse effect on seed germination and seedling vigor before or after storage. However, Rast and Stijger (1987) observed that dry heat application (21.1°C, 3 days) eliminated *Capsicum* mosaic virus, but adversely affected seed germination.

In general, the use of high temperatures in dry heat treatment of crop seeds (as in high temperature seed drying) invariably reduces seed viability and seedling vigor, but optimum temperature for breaking dormancy promotes seed germination and vigor in cereal crops (Lee *et al.*, 2002). This study views vigor as a measurable physiological trait of seed expressed as rapid, uniform and high germination or emergence even under unfavorable conditions. Among soybean seed lots, vigor differences of a given cultivar are expressed as differences in emergence, total growth and uniformity among individuals of the plant population (Abdul-Baki, 1980). Herranz *et al.* (1998) reported that the degree of seed germination by dry heat treatments showed a wide intraspecific variation. Most publications on heat treatment deal with foreign rice variety studies and there is a dearth of information on the efficacy of a pre-sowing treatment under laboratory conditions in West African rice varieties.

Therefore, since the modern West African rice varieties were developed from different genetic sources, it is necessary to determine the effect of dry heat treatment on seed germination and vigor and to evaluate whether or not the methods recommended by ISTA and AOSA are still fully effective in overcoming seed dormancy in West African rice varieties.

Materials and Methods

Seed preparation

Seeds of 10 rice varieties were collected, soon after harvest, from the West African Rice Development Association (WARDA), International Institute of Tropical Agriculture (IITA) branch in 2003 early season. The list of the rice varieties, status, region, year and genotype utilized. For the study is shown in Table 1.The seeds were stored at room-temperature for five months to break seed dormancy. The 10 rice varieties were prepared for various dry heat treatments.

Table 1: A list of rice varieties, status, origin, year and type utilized for study

S/N	DESIGNATION	Status	Origin	Year	Type
1	BW348-1	not released	Srilanka	---	
2	CISADANE (FARO 51)	released	Indonesia	1995	lowland
3	FARO 11 (056)	released	Nigeria	---	upland
4	ITA 230 (FARO 50)	released	IITA	91/92	lowland
5	SIPI 692033 (FARO 44)	released	Taiwan (China)	87/88	lowland
6	Tox 4004-43-1-2-1	not released	IITA	---	lowland
7	WAB 99-1-1	not released	WARDA	---	upland
8	WAB 189-B-B-B-HB	released	WARDA	---	upland
9	WITA 1	not released	WARDA	---	lowland
10	WITA 12	released	WARDA	---	lowland

Dry heat treatment

Seeds were pre-treated to reduce moisture content at 40°C for 48 hours in paper bag before treatment. Water content of seed was about 10% after predrying. Seeds of the 10 rice varieties were subjected to different dry heat temperatures of 40°C, 45°C, 50°C, 55°C and 60°C for 24 hours and repeated twice between January 5 and February 6, 2004 using ventilated oven at the Seed Laboratory, University of Agriculture, Abeokuta, Nigeria.

Control treatment was included at ambient room temperature (32°C). After treatment, seeds were kept at room temperature for 5 days and thereafter subjected to the following seed tests:

Seed Germination: One hundred seeds were placed on filter paper, moistened with 10ml distilled water and put inside incubator at 30°C for germination test. All treatments were tested in a completely randomized design with three replications. Germinated seeds were defined as those with a radicle at least 2mm long.

Percentage germination was recorded at 8 days after sowing.

Speed of Germination Index (SGI): This was calculated as described in the handbook of the Association of Official Seed Analysts (AOSA) (1983), using the following formula:

$$\text{Speed of Germination Index (SGI)} = \frac{\text{No. of germinated seed 1}^{st}\text{ Count}}{\text{Days to 1}^{st}\text{ Count}} + \frac{\text{No. of germinated seed 2}^{nd}\text{ Count}}{\text{Days to 2}^{nd}\text{ Count}} \ldots \frac{\text{No. seed germ final count}}{\text{Days to fanal Count}}$$

Seedling Vigour Index: Seedling vigor level of each genotype was calculated by multiplying percent normal germination by the average of seedling length of each genotype after 8 days of germination and divided by 100 (Adebisi and Ajala, 2000).

Statistical Analysis

Data analyses were performed using the SAS statistical (Version 8) software. Data for each trait were analyzed for statistical significance using ANOVA and differences among treatment means were determined using Duncan's Multiple Range Tests at 5% probability level.

Results

Data in Table 2 show that heat and variety effects as well as interaction effects of heat x variety were highly significant for the three seed quality traits examined.

Table 2: Summary of analysis of variance (ANOVA) of seed germination, speed of germination and seedling vigor of rice varieties evaluated

Sources of variation	Df	Mean squares Seed germination (%)	Speed of germination	Seedling vigor index
Heat	5	2331.180**	2135.046**	8.926**
Variety	9	10174.096**	9223.781**	37.273**
Heat x Genotype	45	125.150**	635.606**	4.102**
Error	120	40.967	43.450	0.537
Total	180			

** Significant at P = 0.01

The results in Table 3 indicate that the percentage seed germination, speed of germination and seedling vigor index under different heat intensities considerably differed. Seed germination values of heat-treated samples ranged from 51% to 70%. Seed germination under control was lowest with 51%, whereas seed germination and speed of germination were significantly highest at 50°C with 70% and 11.3 respectively.

Table 3: Effect of dry heat treatment on seed germination and speed of germination

Temperature (°C)	Seed germination (%)	Speed of germination index	Seedling vigor index
Control (32°C)	51_{d}	7.3^{cd}	3.2^{c}
40	56_{c}	8.0^{cd}	3.7^{b}
45	55_{c}	8.2^{c}	4.1^{a}
50	70^{a}	11.3^{a}	3.9^{ab}
55	66^{b}	10.2^{b}	3.5^{bc}
60	62^{b}	10.1^{b}	3.0^{c}
Mean	59	9.2	3.6

Values within a column followed by a common letter are not significantly different according to Duncan's multiple range test at P = 0.05.

There were significant differences in the three seed quality traits evaluated among the varieties regardless of temperatures as shown in Table 4. Mean seed germination was ranked highest with WITA 12 (88%) and TOx 4004-43-1-2-1 (85%), followed by ITA 230 with (80%) and SIPI 692033 with 79%. Conversely, BW348-1, CISADANE, WAB 189-B-B-B-HB and WITA 1 recorded seed germination of less than 50%.

Speed of germination of ITA 230 was ranked highest with 14.2 value, closely followed by WITA 12 with 13.3 value. Seedling vigor was significantly highest with TOx 404-43-1-2-1 (5.2) ITA 230 (5.0) and in FARO 56 (3.2) whereas CISADANE, WAB 189-B-B-B-HB and WITA 1 recorded lowest seedling vigor indices of less than 2.0 value, corresponding to their low germination values.

Table 4: Effect of variety on seed germination and seedling vigor of rice seed

Genotype	Seed germination (%)	Speed of germination index	Seedling vigor index
BW 348-1	40^{e}	6.0^{e}	4.6^{a}
CISADANE (FARO 51)	25^{g}	3.8^{f}	1.3^{c}
FARO 11 (056)	63^{d}	8.9^{d}	3.2^{b}
ITA 230 (FARO 50)	80^{b}	14.2^{a}	5.0^{a}
SIPI 692033 (FAR0 44)	79^{b}	12.2^{c}	4.7^{a}
TOX 4004-43-1-2-1	85^{a}	12.7^{c}	5.2^{a}
WAB 99-1-1	70^{c}	10.1^{d}	3.8^{b}
WAB 189-B-B-B-HB	31^{f}	4.8e^{f}	1.4^{c}
WITA 1	32^{f}	5.7^{e}	1.9^{c}
WITA 12	88^{a}	13.3^{b}	4.6^{a}
Mean	59	9.2	3.6

Values within a column followed by a common letter are not significantly different according to Duncan's multiple range test at P = 0.05.

Results in Table 5 show that the percentages of seed germination for the 10 rice varieties were different according to dry heat intensities. Seed germination of WITA 12 was significantly highest at 40°C to 55°C and control. However, ITA 230 had significantly highest seed germination of 94% and 95% under control treatment and 40°C heat intensities respectively. Variety ITA 230 recorded 91% germination at 45°C which was significantly above 89%, 88%, 73% and 64% recorded by SIPI692033, TOx 4004-1-2-1, WAB 99-1-1 and FARO 11 respectively. Five varieties (BW 348-1, CISADANE, WAB 189-B-B-B-11 and WITA 1) had low seed germination of less than 30% at 40°C, 45°C and control heat intensities. Germination of TOx 4004-43-1-2-1 was 87% at 50°C, which was significantly higher than 83%, 80%, 73% and 68% recorded for SIPI692033, CISADANE, ITA 230, BW 348-1 and WAB 99-1-1 respectively. Variety TOx 4004-43-1-2-1 recorded 86% germination at 55°C and was significantly above 74% and 70% obtained for BW 348-1 and ITA 230 respectively. When the dry heat treatment was increased to 60°C, TOx 4004-43-1-2-1 and BW 348-1 had significant highest germination values of between 78% and 77% respectively. Variety CISADANE had the lowest germination of 15% at 60°C.

Table 5: Effect of dry heat treatment on percentage seed germination of 10 rice varieties

	Temprature (°C)						
Variety	32(Control)	40	45	50	55	60	Mean
BW 348-1	4^{g}	4^{g}	13^{g}	69^{f}	74^{c}	77^{a}	40
CISADANE (FARO 51)	8^{g}	11^{f}	11^{g}	80^{d}	22^{h}	15^{e}	25
FARO 11(056)	58^{e}	71^{d}	64^{e}	62^{g}	61^{f}	60^{c}	63
ITA 230(FARO 50)	94^{a}	95^{a}	91^{b}	73^{e}	70^{d}	58^{d}	80
SIPI 692033 (FAR0 44)	77^{c}	95^{a}	89^{c}	83^{c}	65^{e}	64^{b}	79
TOX 4004 – 43-1-2-1	86^{b}	86_{b}	88^{c}	87^{b}	86^{b}	78^{a}	85
WAB 99-1-1	68^{d}	81^{c}	73^{d}	68^{f}	65^{e}	65^{b}	70
WAB 189 -B-B-B-HB	23^{f}	24e	26^{f}	29^{h}	31^{g}	54^{d}	31
WITA 1	2^{h}	2^{h}	4^{h}	58^{g}	62^{f}	64^{b}	32
WITA 12	92^{a}	93^{a}	94^{a}	95^{a}	93^{a}	61^{c}	88
Mean	51	56	55	70	63	60	

Values within a column followed by a common letter are not significantly different according to Duncan's multiple range test at P = 0.05.

Speed of germination of ITA 230 was consistently and significantly ranked highest at all the heat intensities including control with speed of germination of 12.7 (for 60°C) to 15.9 (for 55°C)(Table 6). However, WITA 12 and SIPI 692033 had comparable speed of germination with ITA 230 at low treatments (40 and 45°C) while BW 348-1, CIDADANE, WAB 189-B-B-B-H and WITA 1 recorded significantly low speed of germination under low heat intensities of 40°C, 45°C and control.

Table 6: Effect of dry-heat treatment on speed of germination of 10 rice varieties

Variety	Temperature (°C)						
	Control	40	45	50	55	60	Mean
BW 348-1	0.3h	0.5g	0.5g	11.0d	11.1d	12.8a	6.0
CISADANE (FARO 51)	1.1g	1.5f	1.7f	12.5c	3.3i	2.6e	3.8
FARO 11 (056)	7.7e	8.1d	8.3d	8.9f	9.6g	10.7b	8.9
ITA 230 (FARO 50)	13.6a	13.8a	13.9a	15.4a	15.9a	12.7a	14.2
SIPI 692033 (FARO 44)	11.6c	13.5a	14.2a	12.7c	10.8f	10.2a	12.2
TOX 4004-43-1-2-1	12.1b	12.6b	12.6b	12.7c	12.9c	13.0a	12.7
WAB 99-1-1	9.2d	11.1c	10.8c	10.5e	9.8f	9.2d	10.1
WAB 189-B-B-B-HB	2.7f	3.8e	4.3e	4.5g	4.8h	9.0d	4.8
WITA 1	1.0g	1.4f	1.8f	10.0f	10.3e	10.7b	5.7
WITA 12	13.8a	13.9a	13.9a	14.6b	13.6b	10.1c	13.3
Mean	7.3		8.0	8.2	11.3	10.2	10.1

Values within a column followed by a common letter are not significantly different according to Duncan's multiple range test at P = 0.05.

In Table 7, seedling vigor index of ITA 230 was significantly highest under control heat treatment with (5.4), followed by TOX 4004-43-1-2-1 with 5.0. Variety SIPI 692033 recorded the highest seedling vigor index (6.5) at 40°C and maintained it at 45°C (6.4) together with ITA 230 (5.6) and TOx 4004-43-1-2-1 (5.3). At 50°C, ITA 230 was significantly outstanding in seedling vigor with 6.2, followed by BW 348-1. However, when the heat intensity was increased to 55°C and 60°C, TOx 4004-43-1-2-1 was ranked highest in seedling vigor with 5.5 and 4.9 respectively compared to other varieties. Three varieties (WAB 189-B-B-B-HB CISADANE and WITA 1) consistently recorded significantly low seedling vigor under all the heat intensities including control.

Table 7: Effect of dry-heat treatment on seedling vigor index of 10 rice varieties

Variety	Temperature (°C)							
	Control	40	45	50	55	60	Mean	
BW 348-1	4.3c	4.7c	4.7b	5.8b	4.3d	3.8b	4.6	
CISADANE (FARO 51)	0.3g		0.5f	5.3a	1.0g	0.5i	0.3g	1.3
FARO 11 (056)	2.5e	3.3d	3.5d	3.8e	3.4f	2.5f	3.2	
ITA 230 (FARO 50)	5.4a	5.4b	5.6a	6.2a	4.6c	2.8e	5.0	
SIPI 692033 (FAR0 44)	4.5c	6.5a	5.4a	4.9d	3.4f	3.3c	4.7	
TOX 4004-43-1-2-1	5.0b	5.3b	5.3a	5.4c	5.5a	4.9a	5.2	
WAB 99-1-1	3.6d	4.5c	3.9c	3.9e	3.9e	3.1c	3.8	
WAB 189-B-B-B-HB	0.7e	0.9e	1.1e	1.2g	1.5h	2.9d	1.4	
WITA 1	1.0f	1.0e	1.2e	1.7f	2.6g	2.6e	1.9	
WITA 12	4.6c	4.7c	4.8b	4.8d	5.0b	3.7b	4.6	
Mean	3.2	3.7	4.1	3.9	3.5	3.0		

Values within a column followed by a common letter are not significantly different according to Duncan's multiple range test at P = 0.05.

Discussion

There were significant differences in variety and dry heat treatment for seed germination, speed of germination and seedling vigor index. Variation in dry heat intensities influenced the seed quality attributes of the different genotypes examined.

The study vividly revealed that the dry heat treatment remarkably stimulated seed germination when compared with control. Dry heat treatment at 50°C enhanced seed germination and speed of germination above other heat intensities. However, high heat treatment (55°C and 60°C) had no adverse effects on seed germination and speed of germination. Low temperatures (40°Cand 45°C) enhanced seed germination above the control. Numerous cracks in the hull may have been initiated by dry heat, and this probably enhanced permeability, which promoted seed germination and resulted in increased seedling vigor (Hayashi, 1980). Similar finding was observed by Dandlahi and Seshu (1990) in rice, and by Zaglaer *et al.* (1987), Nakagawa and Yamaguchi (1989), Forest *et al.* (1990) and Meng *et al.* (1999) in other crops. Our study revealed that low temperatures (40°C, 45°C and 50°C) enhanced seedling vigor above the control while high heat intensity (60°C) failed to increase seedling vigor.

Specifically, dry heat treatment remarkably promoted seed germination of TOx 4004-43-1-2-1 and WITA 12, closely followed by ITA 230, SIPI 692033 and WAB 99-1-1 with correspondingly high speed of germination and seedling vigor indices. It is noteworthy that speed of germination of ITA 230 and WITA 12 was stimulated only after heat treatment. In like manner, five varieties (BW 348-1, ITA 230, SIPI 692033, TOx 4004-1-2-1 and WITA 12) had highest seedling vigor after dry heat treatment. An earlier study by Lee *et al.* (2002) reported significant varietal differences in seed germination and seedling vigor index in five Korean rice varieties after heat treatment.

The study showed that seed germination, speed of germination and seedling vigor among the 10 West African rice varieties invariably depended on dry heat intensity. There were distinct varietal differences at each of the dry heat intensities suggesting differences in the genetic constitution of the varieties. WITA 12 had distinct seed germination at all the heat intensities including control except at 60°C. Seed dormancy was observed in BW 348-1, WITA 1, CISADANE and WAB 189-B-B-B-HB and this was broken at high temperatures of 50°C, 55°C and 60°C for 24 hours. However, germination of CISADANE seeds was remarkably stimulated at 50°C. Seed dormancy in ITA 230, WITA 12 and TOx 4004-43-1-2-1 was almost completely broken under natural conditions while low heat temperatures of 40 to 50°C slightly promoted germination of WITA 12 and TOx 4004-43-1-2-1. High temperature (60°C) recorded significant adverse effect on seed germination of WITA 12, WAB 99-1, TOx 4004 -43-1-2-1, SIPI 692033 and ITA 230 but remarkably stimulated germination in BW 348-1. This observation on responses based on varietal differences was also observed by Herranz *et al.* (1998) who initially pointed out that the enhancement of seed germination by dry heat treatment showed a wide intraspecific variation.

Speed of germination of BW 348-1, CISADANE, WAB 189-B-B-B-HB and WITA 1 varieties was enhanced at 50°C and 60°C temperatures. Variety ITA 230 consistently showed superior speed of germination under all the dry heat intensities including control. Speed of germination of ITA 230, SIPI 692033 and WITA 12 was considerably reduced at the highest temperature (60°C). Seedling vigor of ITA 230 was strongly stimulated at 45 and 50°C while that of SIPI 692933 was equally promoted even at low temperature (40°C). Surprisingly, dry heat temperatures (40-60°C) failed to increase seedling vigor in CISADANE, WAB 189-B-B-B-HB and WITA 1, an indication that some varieties could be heat-specific. This is a testimony to the fact that varieties may react differently to treatments and stresses, thus reflecting differences in standards of excellence commonly referred to as seed quality (Hampton, 2002).

Metabolic events in living organisms, including seeds, are temperature dependent. Even though, optimum temperature for seed germination is usually a species characteristic, the above findings confirm that it is also cultivar dependent. Optimum temperature for germination may shift close to the maximum in some or in others, to the minimum temperature, depending on the cumulative prevailing environment during seed development and maturation for many years. In general, while low temperatures (40-50^oC) appear to have no effect on the speed of germination, medium temperatures were generally found stimulating germination and seedling vigor of others. In a few instances, those varieties with improved germination at high temperatures have both their speed of germination and seedling vigor equally enhanced. High temperatures of 55-60^oC were generally stimulatory with respect to germination and overall seedling vigor, a feature that cannot be compromised for good stand establishment under poor field situations.

Conclusion

The result of this investigation suggests that dry heat temperatures for improving seed germination and vigor depended on heat intensity and duration of exposure and has proved effective in overcoming dormancy in some modern West African rice varieties. Also dry-heat treatment for improving seed germination and vigor varied with rice varieties, implying that it is a varietal attribute. As a consequence, further investigation is necessary to classify rice varieties according to seed quality and to determine the critical temperatures of dry heat treatment with resultant modification of seedling growth behavior of new West African rice seeds.

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