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INFLUENCE OF STORAGE CONDITIONS AND PACKAGING MATERIALS ON GERMINATION AND GROWTH OF SORGHUM SEEDS

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ABSTRACT
The effect of different storage conditions and packaging materials on the germination of sorghum (accession number: NGB/08/0270) seed was investigated in this study. The seeds were stored at three different storage conditions: short term gene bank (stored at 18 ^{0}C and relative humidity [R.H.] of 40%), long term gene bank (stored at -20 ^{0}C and R.H. of 10%) and freezer (stored at -21 ^{0}C and R.H. of 10%); while the packaging materials were in an aluminum foil, plastic container and envelope. The result showed that sorghum seeds stored under freezer condition and packaged with aluminum foil recorded the highest germination percentage, seedling vigour, shoot and root lengths (86.0%, 2373.6, 8.21 and 19.39 cm) respectively. Sorghum seeds stored under short-term gene bank packaged with plastic container had low germination percentage (67.33%). Seeds stored under long term gene bank and inside plastic container recorded the highest electrical conductivity of seed leachate and total chlorophyll content (69.53 µScm^{-1} and 0.617 µgml^{-1}) respectively. This investigation also revealed that low temperature condition associated with lower moisture content is very suitable for sorghum seed storage.
KEY WORDS: *gene bank, factor, packaging, Sorghum, aluminum foil.*

INTRODUCTION

Storage environment and packaging materials into which a seed is placed can have a dramatic effect on the long-term usefulness of the seed. Storability of the seed is a function of initial seed quality and the storage conditions (Heatherly & Elmore, 2004). Most seeds have been reported to be hygroscopic in nature, possessing ability to absorb environmental moisture during storage (Copeland & McDonald, 2001). The success of packaging can be influenced by packaging materials and storing techniques. Good and appropriate packaging materials help to maintain the quality and viability of seed for a long period of time.

There are many factors that can narrow down the gap between potential and farm level yield. Among them, use of quality seed is the most important one, as quality seeds ensure better germination as well as better yield (Ahmad, 2001). But

if the seed is inferior, poor quality and crop failure are unavoidable. Although seed quality is governed by genetic make-up, however, commonly the quality of seeds is deteriorated during storage period.

Poor storage conditions greatly affect seed vigour; vigour of seed at the time of storage is an important factor that affects storage live. Seed are usually stored for varying lengths of time after harvest. Viability at the end of any storage period is often influenced by the initial viability at harvest, as determined by factors of production, methods of handling and rate at which deterioration takes place.

This rate of physiological change varies with the kind of seed and the environmental condition of storage-primarily temperature and humidity. During storage, seed quality is determined by several factors like environmental conditions during seed production, pests, diseases, seed oil content, seed moisture content, mechanical damages of seed in processing, storage longevity, packaging materials, pesticides, air temperature and relative air humidity in storage and biochemical injury of seed tissue (Reuzeau & Cavalie, 1995; Anfinrud, 1997; Al-Yahya, 2001; Guberac *et al.,* 2003; Heatherly & Elmore, 2004; Alexan & Ianovici, 2018; Ciobanu & Ianovici, 2018). Longevity of seed in storage is influenced by the stored seed quality as well as storage conditions.

Irrespective of initial seed quality, unfavourable storage conditions, particularly air temperature and air relative humidity contribute to accelerating seed deterioration in storage. Seed longevity has been reported to be influenced by several factors such as temperature, oxygen, relative air humidity and seed moisture content (Wang *et al*., 2018). Hence, it is difficult to assess the effective storage period because the storability of the seed is a function of initial seed quality and the storage conditions (Anfinrud, 1997; Heatherly & Elmore, 2004). Hussain *et al*. (2015) reported that no significant decrease in germination percentage was found when primed seeds were store at −4◦C.

The cereals wheat, maize, rice, barley, and sorghum are grown on almost 700 million hectares, and collectively they provide approximately 40% of the energy and protein components of the human diet (Domin *et al*., 2020; Datcu *et al,* 2020). Sorghum, like many grains, has a diversity of uses, including human consumption and animal feed. Seed are usually stored for varying lengths of time after harvest. Viability at the end of any storage period and the rate of deterioration are influenced by temperature and packaging material (Owolade *et al*., 2011). Understanding the influences of different storage conditions on the seeds of sorghum. The aims of this study were to evaluate the effects of temperature and relative humidity, and different packaging materials on germination and seedling attributes of sorghum.

MATERIALS AND METHODS

The experiment was conducted in the seed testing laboratory of the National Centre for Genetic Resources and Biotechnology (NACGRAB), Moor Plantation, Ibadan, Oyo State, Nigeria. Sorghum seed samples with accession number, NGB/08/0270 were obtained from the seed gene bank of NACGRAB. Moisture content of seed samples was adjusted to the required level (12%).

Seed storage and collection: Seed samples were stored in three types of packets: envelope (P_1), plastic container (P_2), aluminum foil (P_3) as shown in Plate 1. Each package was filled with 500g of sorghum seeds and stored for 12 months under three storage environments: (i.) short term gene bank at temperature of 18˚C and relative humidity of 40% (S_1), (ii.) long term gene bank at temperature of -20˚C and relative humidity 10% (S_2), and (iii.) freezer condition at temperature of -21˚C and relative humidity of 8% (S_3). Random seed samples were taken from each package material (P_1, P_2 and P_3) to determine seed viability and seedling vigour.

A B C

PLATE 1: Containers used for storage of sorghum seeds (A: paper envelope, B: plastic container, and C: aluminium foil)

Seed quality evaluation

Determination of Seed Germination Percentage (SGP): Seed germination was tested on 50 seeds, with four replicates for all treatments. Seeds of each replicate were set to germinate at 25 ± 2 °C on non-toxic paper towel, moistened and placed in a plastic seed box. Germination, adjudged by the appearance of the radicle, was counted daily up to day 8. At the final count, the numbers of normal and dead seedlings were assessed. The seed germination percentage (SGP) was calculated as follows:

$$\text{SGP (\%)} = \frac{\text{number of germinated seeds}}{\text{Total seed number}} \times 100$$

Electrical conductivity: The electrical conductivity of seed leachate was determined according to the procedures described by ISTA (1993).Three sub-samples of 50 seeds of each treatments were weighed and placed into glassware with 100 ml of distilled water, and held at 25°C for 24h along with blank, the electrical conductivity of the leachates was determined using EC meter. The mean values were expressed in μScm^{-1}.

Seed vigour index: Seed vigour was calculated using the following formula of Copeland (1976):

$$Seed\ Vigour\ Index = \frac{Number\ of\ seed\ germinated\ (1st\ count)}{Number\ of\ days\ to\ first\ count} \times \frac{Number\ of\ seed\ germinated\ (last\ count)}{Number\ of\ days\ to\ last\ count}$$

Root and shoot length: From the germination test, twenty-five (25) healthy seedlings were selected randomly from each treatment and the shoot length and root length was measured after 8 days of germination test. The root length of each seedling was measured from collar region to the tip of primary root while the shoot length was measured from the base of primary leaf to collar region. The mean shoot length was expressed in centimeter.

Chlorophyll analysis (chlorophyll a and b): Chlorophyll a, b, and total chlorophyll (a+b), were analysed according to the procedures of (Lichtenthaler, 1987). Leaf samples (25 mg fresh weight) was clipped and placed in 7 ml of 100% acetone. The homogenate was soaked in acetone for three days. The supernatant absorbance at 661.6, 644.8 and 470 nm were measured using a Bio Mate 3 spectrophotometer (Thermo Spectronic Rochester, N.Y.) Concentration of chlorophyll was calculated by the equations of (Lichtenthaler, 1987).

Seedling vigour index: This was calculated as follows: Seedling vigour index = Seedling length (cm) X Germination percentage.

Seed index (100 seed weight g): This was measured by absolute displacement methods (Kramer and Twig, 1962)

Seedling dry weight (mg): The same twenty-five healthy seedlings used for shoot and root length measurement were put in butter paper packet and kept in an oven maintained at 70 °C for 72 hours. After drying, the seedlings were kept for cooling in desiccators and the seedling dry weight was recorded and was expressed in milligrams (Anon, 2007).

Experiment design: Data obtained was subjected to Analysis of variance (ANOVA), using Statistical Package for Social Sciences (SPSS version 17). Differences between treatment mean values were separated using Duncan's Multiple Range Test ($P<0.05$).

RESULTS AND DISCUSSIONS

The seeds stored in storage environment freezer and packaged with aluminum foil (S_3P_3) recorded significantly highest germination percentage (86.00%), followed by S_2P_3 (84.00%) and S_3P_2 (81.33%), while, seed stored in short term gene bank and packaged with plastic, recorded the lowest germination S_1P_2 (67.33%) as shown in Table 1.

The effect of storage condition and packing material on electrical conductivity was found to be significant only in S_2P_2. Seed stored in the long-term gene bank (S_2) with packaging material plastic (P_2) recorded significant maximum conductivity value of 69.53 μScm^{-1}, while seeds stored in other storage environments and packing materials, do not differ significantly ($P<0.05$) as shown in Table 1.

TABLE 1: Influence of storage condition and packaging material on germination percentage and electrical conductivity of sorghum seeds (NGB/08/0270)

Storage condition and packaging materials	Germination percentage (%)	Electrical conductivity (μScm^{-1})
S_1P_1	70.67^{d}	29.07^{b}
S_1P_2	67.33^{d}	43.30^{b}
S_1P_3	75.33^{bcd}	29.13^{b}
S_2P_1	69.33^{d}	26.43^{b}
S_2P_2	76.67^{abcd}	69.53^{a}
S_2P_3	84.00^{ab}	35.20^{b}
S_3P_1	72.67^{cd}	32.87^{b}
S_3P_2	81.33^{abc}	26.00^{b}
S_3P_3	86.00^{a}	25.33^{b}

S_1: Short-term gene bank; S_2: Long-term gene bank; S_3: Freezer; P_1: Envelop; P_2: Plastic; P_3: Aluminum foil. Values bearing the same letter(s) along the same column are not significantly different at ($P< 0.05$).

The shoot length due to interaction of storage environment and packaging materials (S×P) differ significantly ($P<0.05$) during the entire period of storage. However, the shoot length recorded in seed stored in the freezer and packaged with aluminum foil (S_3P_3) was highest (8.21 cm), followed by S_2P_3 (8.28 cm), and was less (4.51cm) in S_3P_2 as shown in Table 2.

TABLE 2: Shoot and root length as influenced by storage condition and packaging material during storage of sorghum (NGB/08/0270)

Storage condition and packaging material	Shoot Length (cm)	Root Length (cm)
S_1P_1	4.98^{e}	14.29^{bc}
S_1P_2	5.61^{d}	11.94^{d}
S_1P_3	6.60^{c}	12.76^{cd}
S_2P_1	6.61^{c}	13.52^{bcd}
S_2P_2	5.84^{d}	15.10^{b}
S_2P_3	8.28^{a}	12.23^{d}
S_3P_1	7.44^{b}	18.00^{a}
S_3P_2	4.52^{e}	14.18^{bc}
S_3P_3	8.21^{a}	19.39^{a}

Highest shoot length was recorded in S_2P_3, though it was not significantly different from with treatment S_3P_3 at $P<0.05$. Similarly, in the root length, S_3P_3 treatment recorded the highest value (19.39 cm), followed by S_3P_1 (18.00 cm) and S_2P_2 (15.10 cm). Comparatively, lower values of root lengths were observed throughout the storage period in seeds stored in short-term gene bank and packaged with plastic (S_1P_2) (11.94 cm) as shown in Table 2.

TABLE 3: Root and shoot dried weight of sorghum seedling as influenced by storage environments and packaging materials

Storage condition and packaging material	Fresh weight of shoot (g)	Dry weight of shoot (g)	Fresh weight of root (g)	Dry weight of root (g)
S_1P_1	0.5240^{bc}	0.1493^{c}	0.3443^{cde}	0.1583^{c}
S_1P_2	0.2450^{d}	0.0785^{d}	0.2657^{e}	0.0870^{c}
S_1P_3	0.4637^{c}	0.1593^{bc}	0.4120^{bcd}	0.1580^{c}
S_2P_1	0.3260^{d}	0.0853^{d}	0.5023^{b}	0.0843^{d}
S_2P_2	0.3000^{d}	0.0810^{d}	0.2770^{cd}	0.1030^{d}
S_2P_3	0.6060^{ab}	0.1713	0.4783^{bc}	0.2017^{bc}
S_3P_1	0.5357^{bc}	0.1357^{c}	0.7840^{a}	0.2287^{ab}
S_3P_2	0.6360^{a}	0.2020^{b}	0.2533^{e}	0.2257^{ab}
S_3P_3	0.6880^{a}	0.2527^{a}	0.6710^{a}	0.2700^{a}

The highest fresh weight of shoot was recorded by seed stored in freezer and packaged with aluminum foil (S_3P_3), though it was not significantly different from treatments S_3P_2 and S_2P_3 (0.6360 g and 0.6060 g) respectively at $P<0.05$. The minimum seedling fresh weight (0.2450 g) was recorded in S_1P_2 at the end of the storage period. Similarly, the seedling dry weight recorded from seeds stored in freezer and packaged in aluminum foil was the highest, and significantly different from all other treatments as shown in Table 3.

Highest fresh and dry weight of root of the seedlings were highest in seeds with treatment S_3P_3 (0.671 and 0.270 g) respectively. However, lowest values of seedling fresh and dry weights were recorded by treatments S_3P_2 and S_2P_1 (0.253 and 0.084 g) respectively (Table 3).

TABLE 4: Influence of storage environment and packaging material during storage of sorghum (NGB/08/0270) on chlorophyll a, chlorophyll b and total chlorophyll (a + b) content of the seedling

Storage area and packaging materials	Chlorophyll a (µg/ml)	Chlorophyll b (µg/ml)	Total Chlorophyll (a+b) (µg/ml)
S_1P_1	0.1400^{e}	0.1133^{g}	0.2533^{h}
S_1P_2	0.1700^{d}	0.1162^{g}	0.2867^{g}
S_1P_3	0.1133^{f}	0.1267^{f}	0.2400^{h}
S_2P_1	0.3167^{b}	0.2733^{a}	0.5900^{b}
S_2P_2	0.3600^{a}	0.2567^{b}	0.6167^{a}
S_2P_3	0.2333^{c}	0.2367^{c}	0.4700^{c}
S_3P_1	0.1667^{d}	0.1533^{d}	0.3233^{e}
S_3P_2	0.1767^{d}	0.1300^{e}	0.3067^{f}
S_3P_3	0.2267^{c}	0.1633^{d}	0.3900^{d}

Highest chlorophyll a and b contents were recorded in treatments S_2P_2 and S_2P_1 (0.360 and 0.273 µg/ml) respectively, and were significantly different from those of all other treatments at $P<0.05$. Total chlorophyll content recorded was highest and lowest at treatments S_2P_2 and S_1P_3 (Table 4).

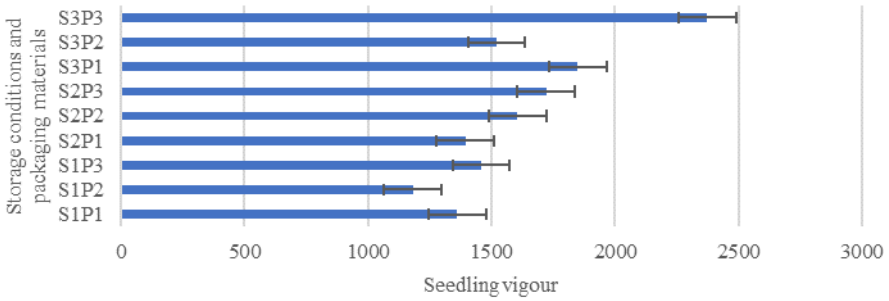

FIG. 1: Effect of storage co nditions and packing materials on seedling vigour of sorghum

The seed treatment that resulted in highest seedling vigour was recorded in S_3P_3 (2373.6), followed by S_3P_1, S_2P_3 and S_2P_2 (1848.73, 1722.84 and 1605.47) respectively. However, the lowest seedling vigour was recorded from S_1P_2 (1181.64) as shown in Figure 1.

Influence of storage period

Results of the present study revealed that there was gradual decline in seed quality traits such as germination percentage, root length, shoot length, vigour index, seedling dry weight, moisture content and marked increase in electrical conductivity of seed leachate during entire storage period from initial to 12 months period. This observation is in consonance with earlier report by Domin *et* al. (2020) who investigated the germination energy and capacity of maize seeds following low-temperature short storage. They reported that deterioration in stored moist seed is a product of the high rate of respiration, which culminated in the breakdown of the food reserve, mainly starch, accompanied by the release of heat. Similar findings were also reported in maize (Hanegave, 2009), in rice (Yogalakshmi *et al*., 1996), in pearl millet (Gaur *et al.*, 2000), in sorghum (Sunilkumar *et al*., 2005; Navi *et al*., 2006 and Balekai, 2009), and in Bengal gram (Merwade, 2000; Kulkarni *et al*., 2008).

Influence of packaging materials and storage conditions

Among seed containers and storage conditions, the seeds stored in storage environment freezer and packaged with aluminum foil (S_3P_3) recorded significantly highest (86.00%) germination percentage respectively and was lower in seed stored in short term gene bank and packaged with plastic, S_1P_2 (67.33%) at the end of 12

months of storage. Higher emergence recorded with aluminum foil package. The results of the present study corroborate with findings of Channakeshava *et al.* (2001) in maize, and Sastry *et al.* (2007) in groundnut.

The seedling vigour parameters such as root length, shoot length, chlorophyll analysis, vigour index and seedling dry matter accumulation were significantly higher in seed stored in freezer and packaged with aluminum foil packaging material followed by those stored in plastic and envelop at the end of 12 months of storage. The seed stored in freezer and packaged with aluminum foil showed their superiority in maintaining seedling vigor parameters. The higher seedling vigour parameters observed with seed stored in freezer and packaged with aluminum foil packaging material may be due to lesser seed deterioration on account of lesser autoxidation of lipids, lesser moisture content, lesser free radicals and lesser activity of pests and diseases. The findings are in agreement with the reports of Chiu *et al.* (2003), Bailly (2004) and Ellis & Hong (2007).

Higher Electrical Conductivity (EC) values recorded in seeds stored in the long-term gene bank (S_2) with packaging material plastic may be due to higher level of seed deterioration on account of age induced membrane damage of various cell and cell organelles (Yeh *et al.*, 2007; Sastry *et al.*, 2007). Further, higher leachates in stored seeds obtained may be on account of pest and disease in wheat and rice (Raikar *et al.*, 2011). On the contrary, lower EC values recorded in seeds stored in vacuum and polythene bag packaging is mainly due to lesser seed deterioration on account of lesser biotic and abiotic factors (Mbata *et al*., 2004).

CONCLUSIONS

Seed quality deterioration is an inexorable and an irreversible process. It has been found that the life span of seeds depends on moisture content of the seeds, relative humidity, temperature, light and oxygen content under which the seeds are stored. The result of this experiment showed that adequate handling of sorghum seeds in gene bank and freezing conditions can retain the viability and seedling vigour of the seeds. It was indicated that sorghum seeds can be stored in gene bank and freezer with any of the packaging materials (aluminum foil, plastic container and envelop) without loss of viability of the seed in both when electricity was available for at least 8 h each day. It further indicates that aluminum foil is suitable seed storage materials for sorghum compared to envelop and plastic packages. The storage material significantly affected the quality of seed in terms of percentage vigour and germination. However, seeds stored under the ambient condition (28 to 32 °C) with an air-tight aluminum foil package could be the storage option for farmers living in the rural areas where there are no modern storage facilities. This investigation also recorded that low temperature condition associated with lower moisture content is very suitable for sorghum seed storage. Finally, sorghum seeds

meant for storage should be properly dried to safe moisture content before storage in an air-tight aluminum foil in any of the storage environment.

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