Seed Res., Vol. 42(2): 152-158 December 2014

Effect of seed moisture content and storage conditions on physiological and bio-chemical characteristics of sorghum seeds

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ABSTRACT The present study was undertaken to determine the optimum moisture content to which the seeds of sorghum can be dried without affecting their seed quality as well as storage potential. Moisture content of the seeds was brought to 11±0.2%, 7±0.2%, 5±0.2% and 3±0.2% in a desiccator with silica gel and stored at Medium Term Storage (MTS 8±10C) and ambient conditions for six months. The observation from six months of storage showed that optimum seed moisture content of sorghum for storage was 5-7 %. Activity of dehydrogenase, sod, pox which are positively correlated, was found highest in seeds stored with 5-7 % moisture content and values for EC was negatively correlated with seed quality, which was minimum in seeds stored with 5-7 % moisture content. Least survival was found in control having moisture content around 11±0.2% and ultradried (3±0.2%) seed lot, irrespective of the genotype studied.

Keywords: Sorghum, moisture content, storage temperature, germination, vigour index, antioxidant enzyme activities

Seed moisture content and storage temperature are the major factors affecting seed longevity during storage. In general, lower the seed moisture content, longer the longevity [1]. However, the seed storage behaviour varies from species to species. Some species produce seeds that tolerate drying to low moisture content and are not sensitive to low temperature and are known as orthodox species and can be stored in genebanks. Sorghum produces orthodox seeds and belongs to this category. There is, however, a limit to which orthodox seeds can be dried, beyond which there is no benefit for further drying. This limit has been termed as the critical moisture content [2]. Medium to long-term seed conservation in gene banks as well as the delivery of high quality commercial seed lots under the humid tropical climates are practically impossible without cooling facilities, because seed deteriorates rapidly under the prevailing conditions of high temperature and relative humidity (RH) that causes high equilibrium Seed Moisture Content (SMC) [3]. But, investment in cooling facilities and energy is too cost-intensive for economical operation of seed gene banks and for operating sustainable commercial seed industry in the humid tropics. Ultra-dry seed storage is a technique for decreasing the seed moisture content to less than 5% and storage at ambient temperatures; it can reduce the cost of construction and maintenance of the gene bank and has brought worldwide attention because of its potential economic benefits and promising applications in germplasm conservation. But, there is lack of information on statistical evaluation of potential seed longevity in low input seed storage systems at ambient humid tropical conditions [4].

Over-drying of seed beyond critical moisture can be detrimental. Thus, there is a need to determine the critical seed moisture content suitable for long term storage of seed of different species. Therefore, the present study was carried out to determine the optimum and critical moisture content to which sorghum seed can be dried and also to investigate at what extent the seed quality parameters are affected by different moisture content among different genotypes of sorghum.

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Received: March 2014 Revised: October 2014 Accepted: November 2014

MATERIALS AND METHODS

Sorghum (CSH16 and CSV 18) genotypes were subjected to silica gel drying to bring down moisture content to 7±0.2%, 5±0.2% and 3±0.2% moisture levels from initial 11±0.2%. The moisture content was confirmed by high constant temperature method as per ISTA, 2011. When the moisture content reached the respective target, the seed lots of each moisture categories were divided into two equal parts and packed in laminated aluminium foil packets, hermetically sealed and stored at ambient and Medium Term Storage (MTS:8±10C) conditions and quality parameters was observed at 3 months interval.

Physiological parameters: Germination %

Germination test was conducted as per ISTA [5] and percent germination was determined by number of normal seedlings. Ten normal seedlings were picked randomly from germination test; root-shoot length and fresh weight were measured and dried at 80^{0}C for 24 hours to measure the dry weight. Vigour Index (VI) was determined [6] as

Vigour Index I= Germination % X Seedling length (cm)

Vigour Index II= Germination % X Seedling dry weight (g)

Biochemical parameters: Electrolyte leakage

Electrical conductivity and changes in enzymes activity *i.e.* dehydrogenase, peroxidase and superoxide dismutase were measured following the methods [7-9] respectively.

RESULTS AND DISCUSSION

In general, lower the seed moisture content, longer the seed longevity. However, the seed storage behaviour varies from species to species. Seed deterioration leading to loss of germination progresses rapidly at higher humidity and at higher temperature [1].

Germination (%)

Over-drying of seeds may expose macro-molecular surfaces to free radical attack and reduce the longevity of seeds, viability and germination [2]. In the present study, the fresh seeds showed the maximum germination and decreased with increasing the storage duration, irrespective of the storage regimes and genotype studied. At ambient and MTS, the seeds stored at 7 percent and 5 percent seed Moisture Content maintained the seed viability of 91.32 and 93.31 percent and 90.33 and 89.34 percent, respectively after six months of storage in the CSH 16 whereas the corresponding values were 90.06 and 94.02 at 7 percent SMC and91.05 anf 92.04 at 5 percent SMC in CSV 18, respectively (Table 1.).

Seedling length and seed vigour

The consequences of seed aging and deterioration during storage is most conspicuously manifested through changes in seed viability. The decrease in seedling root and shoot length was concomitant with loss in seed germinability. In the present study, seedling length showed significant differences among the genotypes studied and stored at different moisture content under ambient conditions. The seed lot with 7 percent moisture content showed minimum decline for seedling length after six months of storage in CSH 16 (28.59 cm) and CSV 18 (30.88 cm), while maximum reduction in length was observed in ultra-dried seeds stored at ambient temperature (Table 2). Similar observation was observed in dry weight. The nature and characteristics of seedling vigour emphasized that seedling vigour is ultimately the most relevant expression of the seed quality [1]. In the present study, seeds stored for six months with high SMC (>10%) and low SMC (3%) recorded maximum reduction in vigour index and seedling dry weight in both genotypes. After 6 months of storage, a decrease in vigour index I and II was observed in control (high moisture) and ultra-dried seeds (e”3% mc) of both genotypes, irrespective of storage conditions. However, the decline was

Table 1. Effects of seed moisture content and storage condition on germination (%) of sorghum genotypes

Genotype	Seed storage regimes		Storage duration in months		
	Seed mc (%)	Temperature (⁰C)	0	3	6
CSH 16	control	ambient	92.93(74.96)	88.94(70.75)	84.94(67.27)
	7	ambient	95.29(77.53)	93.31(75.05)	91.32(72.91)
		8±1	95.29(77.53)	94.30(76.24)	93.31(75.05)
	5	ambient	92.31(73.95)	91.32(72.91)	90.33(71.92)
		8±1	90.33(73.95)	90.33(71.92)	89.34(70.98)
	3	ambient	90.33(71.92)	87.35(69.20)	85.37(67.54)
		8±1	94.02(91.92)	88.34(70.08)	86.36(68.36)
CSV 18	control	ambient	94.02(75.91)	91.05(72.64)	87.09(68.98)
	7	ambient	96.98(80.14)	95.007(77.17)	90.06(71.67)
		8±1	96.98(80.14)	95.99(78.56)	94.02(75.91)
	5	ambient	93.03(74.75)	95.99(74.75)	91.05(72.64)
		8±1	93.03(74.75)	93.03(74.75)	92.04(73.67)
	3	ambient	96.98(80.14)	90.06(71.67)	86.10(68.15)
		8±1	96.98(80.14)	90.06(71.67)	87.09(68.98)
Source				CD (p=0.05)	
Genotype (G)				0.46	
Seed storage regimes (S)				0.86	
Storage duration in months (D)				0.56	
G X S				1.22	
G X D				0.79	
S X D				1.49	
G X S X D				2.11	

* Control sample maintained moisture content in between 10-11.5 % during storage period

significantly low under the MTS conditions. Similar decrease in seedling vigour index with ageing has been reported in naturally aged seeds of sunflower [10].

Electrical conductivity of seed leachates

Physiological events occur during seed aging long before the loss of actual viability. It starts with the degradation of membranes, leading to an increase in the amount of cell leachates, followed by a decline in the activity in enzymes and synthesis of macromolecules. In the present study, the minimum decline in seed leachate value was observed when seeds dried to 5 percent moisture content (Table 3). The maximum decline was observed in ultra-dried seeds of CSH 16 (258.1msi/ cm/ gfw) and CSV 18 (277.1msi/ cm/ gfw), followed

Table 2. Effects of seed moisture content and storage condition on seed vigor parameters of sorghum genotypes

Genotype	Seed Storage regimes: Seed mc (%)	Seed Storage regimes: Temperature (°C)	Seedling Length (cm), Storage duration in months: 0	3	6	Seedling Dry Weight (g), Storage duration in months: 0	3	6	Vigour index I, Storage duration in months: 0	3	6	Vigour index II, Storage duration in months: 0	3	6
	control	Ambient	40.47	30.68	25.48	0.172	0.1584	0.1366	3763.99	2730.45	2166.05	15.99	14.1	11.61
	7	Ambient	38.72	33.01	28.59	0.1683	0.1606	0.1414	3717.02	3103.05	2631.08	16.15	15.09	13.02
		8±1	38.72	35.9	31.91	0.1683	0.165	0.1598	3717.02	3410.95	2999.937	16.15	15.68	15.02
CSH 16	5	Ambient	40.7	35.73	29.08	0.176	0.156	0.1405	3785.04	3287.71	2646.747	16.37	14.35	12.78
		8±1	40.78	33.87	32.4	0.176	0.1633	0.1434	3792.89	3082.15	2916.057	16.37	14.86	12.91
	3	Ambient	39.22	30.93	26.09	0.1983	0.154	0.147	3569.05	2721.97	2244.36	18.05	13.55	12.64
		8±1	39.22	33.38	29.86	0.1983	0.1698	0.1477	3569.047	2971.12	2597.77	18.05	15.12	12.85
	control	Ambient	41.17	32.56	26.32	0.205	0.1778	0.1528	3911.16	2995.52	2316.61	19.47	16.36	13.45
	7	Ambient	42.85	34.8	30.88	0.2057	0.1901	0.1772	4199.06	3340.95	2810.76	20.15	18.25	16.12
		8±1	42.85	37.41	33.52	0.1925	0.181	0.1676	4199.06	3629.23	3184.87	20.15	18.64	16.24
CSV 18	5	Ambient	45.52	37.21	33.25	0.1925	0.1546	0.1478	4279.32	3497.88	3059.26	18.09	14.53	13.6
		8±1	45.55	40.37	36.62	0.2057	0.1922	0.1709	4281.65	3795.57	3405.9	18.09	17.01	15.59
	3	Ambient	39.38	30.44	26.7	0.1804	0.1624	0.1326	3859.61	2770.23	2323.01	17.68	14.77	11.54
		8±1	39.38	34.67	27.93	0.1804	0.1791	0.1628	3859.61	3155.69	2457.7	17.68	16.3	14.33

Source	Seedling Length CD (p=0.05)	Seedling Dry Weight CD (p=0.05)	Vigour index I CD (p=0.05)	Vigour index II CD (p=0.05)
Genotype (G)	0.15	0.001	14.54	0.069
Seed Storage regimes (S)	0.29	0.001	27.2	0.13
Storage duration in months (D)	0.19	0.001	17.806	0.085
G X S	0.41	0.002	38.466	0.184
G X D	0.27	NS	25.182	0.12
S X D	0.51	0.003	47.111	0.225
G X S X D	0.72	0.004	66.625	0.318

* Control sample had moisture content around 11 + 0.2%

Table 3. Effects of seed moisture content and storage condition on EC and Enzyme activities of sorghum genotypes

Genotype	Seed Storage regimes: Seed mc (%)	Seed Storage regimes: Temperature (°C)	EC (μ siemens/cm/g seed), Storage duration in months: 0	3	6	Dehydrogenase activity (OD at 480 nm/20 seed), Storage duration in months: 0	3	6	Peroxidase enzyme activity (μmolar/min/g fwt), Storage duration in months: 0	3	6	Super Oxide Dismutase enzyme activity (units/g seed/min), Storage duration in months: 0	3	6
	control	Ambient	40.47	30.68	25.48	0.172	0.1584	0.1366	3763.99	2730.45	2166.05	15.99	14.1	11.61
	7	Ambient	38.72	33.01	28.59	0.1683	0.1606	0.1414	3717.02	3103.05	2631.08	16.15	15.09	13.02
		8±1	38.72	35.9	31.91	0.1683	0.165	0.1598	3717.02	3410.95	2999.937	16.15	15.68	15.02
CSH 16	5	Ambient	40.7	35.73	29.08	0.176	0.156	0.1405	3785.04	3287.71	2646.747	16.37	14.35	12.78
		8±1	40.78	33.87	32.4	0.176	0.1633	0.1434	3792.89	3082.15	2916.057	16.37	14.86	12.91
	3	Ambient	39.22	30.93	26.09	0.1983	0.154	0.147	3569.05	2721.97	2244.36	18.05	13.55	12.64
		8±1	39.22	33.38	29.86	0.1983	0.1698	0.1477	3569.047	2971.12	2597.77	18.05	15.12	12.85
	control	Ambient	41.17	32.56	26.32	0.205	0.1778	0.1528	3911.16	2995.52	2316.61	19.47	16.36	13.45
	7	Ambient	42.85	34.8	30.88	0.2057	0.1901	0.1772	4199.06	3340.95	2810.76	20.15	18.25	16.12
		8±1	42.85	37.41	33.52	0.1925	0.181	0.1676	4199.06	3629.23	3184.87	20.15	18.64	16.24
CSV 18	5	Ambient	45.52	37.21	33.25	0.1925	0.1546	0.1478	4279.32	3497.88	3059.26	18.09	14.53	13.6
		8±1	45.55	40.37	36.62	0.2057	0.1922	0.1709	4281.65	3795.57	3405.9	18.09	17.01	15.59
	3	Ambient	39.38	30.44	26.7	0.1804	0.1624	0.1326	3859.61	2770.23	2323.01	17.68	14.77	11.54
		8±1	39.38	34.67	27.93	0.1804	0.1791	0.1628	3859.61	3155.69	2457.7	17.68	16.3	14.33

Source	EC CD (p=0.05)	Dehydrogenase CD (p=0.05)	Peroxidase CD (p=0.05)	SOD CD (p=0.05)
Genotype (G)	0.15	0.001	14.54	0.069
Seed Storage regimes (S)	0.29	0.001	27.2	0.13
Storage duration in months (D)	0.19	0.001	17.806	0.085
G X S	0.41	0.002	38.466	0.184
G X D	0.27	NS	25.182	0.12
S X D	0.51	0.003	47.111	0.225
G X S X D	0.72	0.004	66.625	0.318

* Control sample had moisture content around 11 + 0.2%

by control stored under ambient conditions after six months of storage (Table 3). This indicates that seed membrane degradation increased with the increase in seed moisture content and storage temperature.

Enzyme activities

Antioxidant enzymes (expressed in %)

Peroxidase and SOD are directly related to the removal of free radicals or damaging molecules, which in turn participate in oxidative toxicity. In the present study, the maximum peroxidase enzyme activity was observed in the fresh seeds (control) of both genotypes and significant reduction was observed in seeds dried to 5 and 7 percent moisture content with a maximum decline in ultra-dried seeds (45% and 23% in CSH 16 and CSV 18, respectively) followed by control (40% in CSH 16 and 37% in CSV 18) stored at ambient conditions. Similar results were found in MTS but the reduction in enzyme activity was less significant than the ambient storage. The increase in peroxidise activity during the initial period of storage might be due to the conversion of tetrameric molecules of catalase activity to monomeric molecules of peroxidise activity. The subsequent decline in peroxidise activity after six months of storage might be attributed to severe loss of catalase activity. These results are in corroboration with the findings of in pigeon pea [12]. A decrease in the level of soluble proteins is an expression of the loss of activities of the membrane-associated superoxide dismutase. In the present experiment, the activity of SOD showed a significant decline with increase in the duration of storage period and moisture level. Minimum decline was observed in seeds dried to 7 and 5 percent moisture content of CSH 16 (41-45%) and CSV 18 (19%) and maximum decline was observed in ultra-dried seeds followed by control stored at ambient conditions (Table 3).

Dehydrogenase

Dehydrogenase enzyme activity is generally used as reliable indices for the evaluation of seed viability [11]. In the present study, dehydrogenase activity of fresh seeds brought to different moisture level was found to be the maximum and showed higher germination percent at ambient and MTS condition. The activity was lowered within 3 months of storage and further decreased with increase in storage duration in both genotypes. However, minimum decline was observed in 5 percent moisture content seed lots in CSH 16, while CSV 18 showed similar results in 7 percent moisture content seed lots (Table 3).

CONCLUSION

The optimum moisture content of sorghum was found to be about 7 percent, which resulted in maximum germination and other seed quality parameters, followed by 5% moisture content. Below 5% moisture content, all the seed quality parameters were affected adversely. Therefore, it can be suggested that the optimum seed moisture content for sorghum to ensure maximum viability is between 5-7%, whereas below 5% SMC, the seed quality is adversely affected.

ACKNOWLEDGEMENT

This work was supported by NBPGR National Bureau of Plant Genetic Resources and IARI Indian Agricultural Research Institute, New Delhi. The first author is thankful to ICAR Indian Council of agricultural research for providing Fellowship for his post-graduation.

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