References

Elangovan, M. and Prabhakar, B. 2001. Rabi sorghum germplasm collection from Karnataka and Maharashtra. Report submitted to National Agricultural Technology Project (Mission Mode Plant Biodiversity). New Delhi, India: National Bureau of Plant Genetic Resources (NBPGR). 9 pp.

Gopal Reddy, V., Mathur, P.N., Prasada Rao, K.E., and Mengesha, M.H. 1993. Rabi sorghum germplasm collection in Northern Karnataka and adjoining areas of Andhra Pradesh. Genetic Resources Progress Report 74. Patancheru, Andhra Pradesh: International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). 13 pp.

Gopal Reddy, V. and Verma, V.D. 1996. Rabi sorghum germplasm collection in Maharashtra and adjoining areas of Karnataka. Genetic Resources Progress Report 85. Patancheru, Andhra Pradesh: International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). 19 pp.

Planning Commission. 1989. Working group report on agricultural research and education for the formulation of the Eighth Five-Year Plan. New Delhi, India: Government of India. 134 pp.

Vacuum Storage and Seed Survival in Pearl Millet and Sorghum

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Introduction

Seed longevity is controlled by three major factors-moisture content, temperature and oxygen concentration in the storage environment (Roberts 1972). The effects of moisture content and temperature on seed longevity have been extensively studied. Ellis and Roberts (1981) quantified the relationships and developed equations to estimate seed viability after storage in any environment. Many researchers have also investigated the effect of air (oxygen), vacuum and other inert gases on seed survival, however, the reported results were variable and sometimes contradictory. Tao (1989) reviewed the literature and concluded that the benefit from vacuum storage is limited and variable, hence it should not be used for conservation by multi-crop genebanks. Nevertheless, much of the confusion on the effect of various gases and vacuum in previous reports appears to have resulted from lack of appreciation of the role of seed moisture content (MC). Ibrahim and Roberts (1983), investigating seed viability in lettuce, found evidence for an interaction between MC and the partial pressure of oxygen—at MCs below a critical value (15%), oxygen was found to be deleterious to seed survival, but above this MC the response changed and oxygen increased longevity. Ibrahim and Roberts (1983) also found that the lower the MC below 15%, the greater the relative beneficial effect of excluding oxygen. Eliminating oxygen from storage, therefore, is expected to improve the longevity of seeds, especially at the low MCs (5 ± 2%) used for long-term conservation. We studied the effect of vacuum on the longevity of pearl millet [*Pennisetum glaucum* (L.) R.Br.] and sorghum [*Sorghum bicolor* (L.) Moench] seeds by storing them under a range of conditions that accelerated their deterioration and the results are presented here.

Materials and methods

Sorghum (cv. Maldandi) seeds with 8.4% initial MC and 98% germination and pearl millet (cv. Sadore local) seeds with 9.2% initial MC and 94% germination were used for the study. The effect of vacuum on seed longevity was studied at three MCs: 6%, 10% and 14%. The MCs were adjusted by holding the seeds on saturated salt solutions of LiCl (13% RH), $MgCl_2$ (33% RH), and NaCl (75% RH) for about a week at 25°C. Each seed lot was then sub-divided into aliquots of 5 g and hermitieally sealed in small aluminum foil envelopes in air or with vacuum using an Audionvac VM101H® vacuum-sealer programmed to a pressure of -0.95 bar. Seeds were held at 50°C to accelerate ageing and sampled at regular intervals to study seed deterioration. The sampling intervals ranged from once every day (50°C and 14% mc) to once in 8 weeks (50°C and 6% mc), depending on the storage treatment. In addition to 50°C, pearl millet seeds were also stored to 35°C. The initial viability of seeds was estimated at the beginning of storage and subsequently at each sampling time by conducting germination tests using four replicates each of 50 seeds. Germination was expressed as the percentage of normal seedlings produced after 7 days of incubation at 20°C.

Results and discussion

There was gradual loss in germinability of the seeds under all storage conditions. Seeds stored at the high temperature (50°C) and/or high MC (14%) deteriorated faster compared with other treatments. Under similar conditions of storage, pearl millet seeds survived longer than those of sorghum. Within each crop, differences were observed in rate of seed deterioration between vacuum and air-storage treatments, especially at the low MC. Since there was gradual loss in viability in all seed lots, the data on seed survival were subjected to probit analysis and seed longevity was expressed as half-viability period (P_{50}), i.e., time taken for viability to decrease to 50%. Analysis of variance of the estimates of P_{50} showed significant effects of MC, vacuum and their interaction on seed survival at 50°C ($P < 0.001$). Decreasing seed MC from 14% to 6% increased longevity in both air and vacuum (Table 1). However, the increase in seed longevity with the decrease in seed MC was more in seeds stored under vacuum than those stored in air. Thus, in pearl millet seeds stored at 50°C, decreasing seed MC from 14% to 6% increased seed longevity by a factor of 189 under vacuum storage, but a similar reduction in seed MC increased longevity by a factor of 145 in air storage. In sorghum, decreasing seed MC from 14% to 6% increased seed longevity by a factor of 80 under vacuum, compared with the 52-fold increase when sealed in air.

Table 1. Longevity (estimated as half-viability period, P_{50}) of pearl millet and sorghum seeds stored under different conditions

	Storage condition		P_{50} (days)	
Crop	Temperature (°C)	Moisture content (%)	Vacuum	Air
Pearl millet	50	14	3.7	3.7
		10	44.8	42
		6	697.8	538.8
Pearl millet	35	14	30.5	33.9
		10	422.4	392.1
		6	3060.7	2931.7
Sorghum	50	14	2.7	2.5
		10	25.6	24.7
		6	218.2	130.2

A comparison of the effect of vacuum within each MC at 50°C showed that in both pearl millet and sorghum, while survival of seeds in vacuum and air was similar at 14% MC, and marginally higher in vacuum at 10% MC, longevity was substantially higher under vacuum at 6% MC (Figure 1). At 35°C in pearl millet, seeds stored in air with 14% mc survived longer than those in vacuum, and those stored with 10% and 6% MCs survived better in vacuum than in air, although the differences were statistically insignificant. At the low MC (6%), germination remained very high in both air (89%) and vacuum (85%) at the end of this study after 216 weeks,

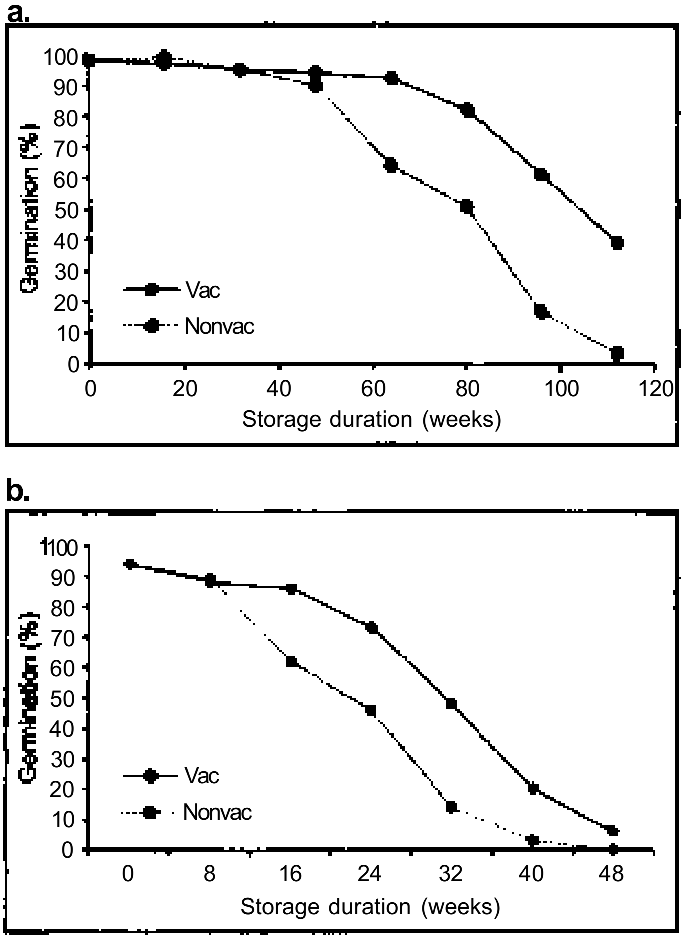

Figure 1. Survival of a. pearl millet and b. sorghum seeds hermetically stored with 6% moisture content at 50°C

hence the values of P_{50} derived through extrapolation could have underestimated the potential differences and therefore the benefit of the vacuum. The results presented here also demonstrate the potential benefit of storing seeds with very low MCs, irrespective of vacuum. Thus, pearl millet seeds stored with 6% MC at temperatures as high as 50°C retained good germination (>85%) even after one year.

Conclusions

- Seeds dried to 6% MC retain viability for considerably long periods, and replacing air with vacuum further enhanced seed longevity
- Vacuum packing had no significant effect on longevity of sorghum and pearl millet seeds stored at 14% and 10% MCs
- Pearl millet seeds survived longer than sorghum under similar conditions of storage.

References

Ellis, R.H. and Roberts, E.H. 1981. The quantification of ageing and survival in orthodox seeds. Seed Science and Technology 9: 373--W9.

Ibrahim A.E. and Roberts, E.H. 1983. Viability of lettuce seeds. I. Survival in hermetic storage. Journal of Experimental Botany 34: 620-630.

Roberts, E.H. 1972. Storage environment and control of viability. Pages 14-58 *in* Viability of seeds (Roberts, E.H., ed.). Chapman and Hall Ltd., London.

Tao, K.L. 1989. Should vacuum packing be used for seed storage in genebanks? Plant Genetic Resources Newsletter (88-89): 27-30.

Genetics and Breeding

Cross-Linked Sorghum-Rice Physical Maps: Update on Research

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Substantial new genomic resources for sorghum research have been produced under a National Science Foundation (NSF) project entitled 'Cross-Linked Sorghum-Rice Physi-cal Maps', led by A Paterson and including 8 co-Principal Investigators located at the University of Georgia (USA; Bhandarkar, M-M Cordonnier-Pratt; A Gingle; J Kececio-glu, L Pratt); Clemson University (R Dean, R Wing), and Cornell University (S Kresovich). This project greatly advanced the quantity and characterization of genomic resources for sorghum and its relatives. A partial summary of selected results was published (Draye et al. 2001). A few examples of research tools generated include an approximately 2,600 locus molecular map of sorghum (Bowers et al. 2002) including 1048 (40.3%) heterologous loci as links to most public maps for maize (*Zea mays* L.), rice [*Oryza saliva* L.), sugarcane [*Saccorum officinalis* L.), Buffelgrass (*Cenchrus ciliaris* L.), Bermudagrass [Cynodon dactylon (L.) Pers.]; and the small grains; two BAC libraries, a 17x coverage BAC library of *Sorghum bicolor* (L.) Moench (available from R Wing; www.genome. clemson.edu) and 13x (73,728 clones of average 132 kb inserts) of *Sorghum propinquum* (Kunth) Hitchc. (available from A Paterson; www.plantgenome.uga.edu); finger-prints for 10x coverage of the *S. bicolor* (SB) and *S. propinquum* (SP) BAC libraries (on line at http://www.genome. clemson.edu/projects/sorghum/fpc); RFLP-to-BAC hybridization data for most of the mapped probes; 10 cDNA libraries, 184,320 arrayed clones, and 50,000 cDNA clones sequenced from each end (see Genbank for sequences, and request clones from L Pratt); 5,000 from each library; sequencing of all sorghum RFLP probes on the high-density map and their exploration for SSRs and homologues (see Schloss et al. 2002); study of the allelic richness of coding sequences and genomic DNA sequences in 57 diverse sorghum accessions (in progress; see www.igd.cornell.edu); and a Web-accessible database (cggc.agtec.uga.edu/cggc). Many additional publications are in progress. The grant was recently renewed for September 20001-September 2005.

References

Bowers, E.J., Bethell, C.M., Lemke, C., Masters, S.L., Marler, B.S., Scoggins, S.L., Blackmon, B., Soderlund, C., Wing, R.A., and Paterson, A.H. 2002. High throughput placement of DNA markers on BAC libraries of sorghum, rice, sugarcane and maize. http://www.intl-pag.org/pag/10/abstracts/PAGX_P434.html

Draye, X., Lin, Y., Qian, X., Bowers, J.E., Burow, G., Morrell, P., Peterson, D., Presting, G.G., Ren, S., Wing, R.A., and Paterson, A.H. 2001. Toward integration of comparative genetic, physical, diversity, and cytomolecular maps for grasses and grains, using the Sorghum genome as a foundation. Plant Physiology 125: 1325-1334.

Schloss, S.J., Mitchell, S.E., White, G.M., Kukatla, R., Bowers, J.E., Paterson, A.H., and Kresovich, S. Characteriza-tion of RFLP probe sequences for gene discovery and SSR development in *Sorghum bicolor* (L.) Moench. Theoretical and Applied Genetics 105: 912-920.

Use of Male Sterility for Isolating Apomictic Sorghum Lines

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Isolation and investigation of lines with elements of apomixes is an area within modern plant genetics closely related to both fundamental problems of sexual reproduc-tion and applied tasks of plant breeding. Sorghum [*Sorghum bicolor* (L.) Moench] is a useful species for investigating apomixis in that: 1. there is a great variety of