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Genetic variability for seed ageing and longevity among the forage sorghum cultivars

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Abstract
Nine popular forage sorghum cultivars released in India were evaluated for seed vigour and longevity traits under accelerated ageing and natural storage conditions, aimed to examine the genetic variation, heritability and relationships among seedling vigour traits. The results on variability for fungus free seed (%) revealed the association with seed ageing. The traits seed germination, field emergence and seedling vigour were much affected due to accelerated ageing and natural storage for three years, compared to the seeds stored for one year and two years. The study revealed that most forage sorghum cultivars [except PC 6 (69%)] had the seed germination ranging from 75 to 90% with a mean of 80% after two years of storage indicating that the revalidation may not be required at least for 18 months in these cultivars as per seed certification standards of sorghum (75% seed germination) in India. Seedling dry weight and seedling vigour index showed all high values of phenotypic and genotypic coefficients of variation (PCV and GCV), heritability (h^2-bs) and genetic advance over mean (GAM) for all categories of fresh, accelerated aged, one year old, two years old and three years old seeds. The field emergence had moderate positive genetic and phenotypic correlations with seed hardness (0.49, 0.44), and high correlation (0.78, 0.67) with seed germination of fresh seeds. Field emergence showed moderate to high positive association with all traits studied in case of accelerated aged and three years old seed categories.

Keywords: Accelerated ageing, Forage sorghum, Genetic variability, Longevity, Seed vigour

Abbreviations: g: Gram, **mg**: Milligram, **cm**: Centimeter, **Sec**: Seconds, **ISTA**: International seed testing association, **AICSIP**: All India coordinated sorghum improvement program

Introduction
Forage sorghum can be used in various forms and situations encompassing: single cut types for rainfed farming, multi-cut types for irrigated agriculture and stover and silage type for storage and extended use in India. About 20-60% of dry fodder supply in semi-arid area is consisted of sorghum. In view of its importance as fodder crop, number of forage cultivars suitable for different forage sorghum growing regions have been developed and released at the national and state levels in India (Table 1). Production of seeds of the forage sorghum is a great problem in north India due to higher seed rate and price coupled with seed longevity and storability. The farmer is concerned with the phenomenon of seed longevity because he wants good germination and vigorous emergence and stand establishment from the seeds. The seed industry is also concerned with the longevity of seeds because if germination drops below a certain limit, seeds are unsalable and suffers from financial losses. The potential storage life of seed varies among and within the species and is governed by various factors such as genetic make-up, differences in physiological maturity, handling and processing practices and storage conditions.

Further, research on sorghum seed vigour and longevity in general received less attention than maize. Genetic influence on seedling vigour appears to be a potential area for breeders to screen cultivars as well as for laboratory applications to predict seedling vigour. Factors such as seed size, membrane integrity and response to seed maturation temperature influence the resultant seed vigour in sorghum (Burris, 2005). The research on longevity or storage life of forage sorghum seed is scanty and it is necessary to identify the variability for seed vigour and longevity among the existing forage sorghum cultivars in order to overcome the problems related to seed germination and vigour by incorporating the features of seed quality in forage sorghum improvement programs. With this background, nine popular forage sorghum cultivars were evaluated for seed ageing and longevity traits with respect to genetic variation, heritability and relationships among seedling vigour traits.

Table 1. Details of forage sorghum cultivars used in the study

Cultivar name	Pedigree	Year of release	Central/ state release	Source/centre
UPC 2 (UP Chari 2)	Vidisha 60-1 × IS 6953	1984	Central	GBPUA&T, Pantnagar, Uttarakhand
PC 3 (Pant Chari 3)	Visarada 61-1 × IS 6953	1990	State	GBPUA&T, Pantnagar, Uttarakhand
PC 4 (Pant Chari 4)	IS 4776 × RIO	1995	State	GBPUA&T, Pantnagar, Uttarakhand
PC 5 (Pant Chari 5)	CS 3541 × IS 6935	1999	Central	GBPUA&T, Pantnagar, Uttarakhand
PC 6 (Pant Chari 6)	SDSL 92140-MCT-36-93, Selection from Zimbabwe germplasm line	2006	Central	GBPUA&T, Pantnagar, Uttarakhand
CSH 20MF	2219A x UPMC 503	2007	Central	GBPUA&T, Pantnagar, Uttarakhand
HC 136	IS 3214 (bicolor) × PC 7R	1982	Central	CCSHAU, Hisar, Haryana
HC 171	SPV 8 × IS 4776	1987	Central	CCSHAU, Hisar, Haryana
SSG 59-3	Non-sweet Sudan grass × JS 263	1977	Central	CCSHAU, Hisar, Haryana

Source: Tonapi *et al.* (2009)

Materials and Methods

The seeds of nine popular forage sorghum cultivars (Table 1) were multiplied during the post rainy season of 2006. Fresh seeds with initial moisture content of 10% and germination of around 95% were used for the experiment. The seeds were treated with Thiram @ 2 g/ kg and sealed in moisture proof rigid plastic bottles and stored at ambient conditions for 3 years (2007-2010) to study the seed longevity. Sampling of seed was done at 12, 24 and 36 months after storage for analysis of seed longevity. The sampled seeds at each interval were tested for seed germination, root length, shoot length, seedling dry weight, seedling vigour index and field emergence. The germination test was conducted in paper towels as per International Seed Testing Association (ISTA, 2004) rules. The vigour index was calculated by multiplying mean germination percentage by dry weight of single seedling and expressed to the nearest whole number. At each interval of seed storage study, 50 seeds/replication from each of the treatments were sown in cement pot (45 cm diameter) filled with potting mixture. After 10 days, the seedlings with leaves above the soil surface were considered as emerged.

The viability or storage potential of the seeds was tested by subjecting the fresh seeds to accelerated ageing (Delouche and Baskin, 1973). These accelerated aged seeds were tested for seed physiological traits, and fungal contamination, especially *Fusarium* and *Aspergillus* spp. Two hundred seed from each sample were tested for fungal colonization and germination using blotter method under laboratory conditions. Initially, fresh seed samples were tested for hundred seed weight, seed hardness, germ size and size of corneous endosperm with four replications in each cultivar. For measuring the seed hardness, seeds were equilibrated to a moisture content of 6.5 +/- 1.0% by keeping the samples in the oven at 37° for 3 days, before hardness determinations. The seed hardness was tested by measuring resistance to grinding by the Stenvert hardness tester. The grinding resistance offered by 18g of sorghum grains in a micro hammer-cutter mill to obtain a fixed volume of flour was measured in seconds (Pomeranz *et al.* 1985). The size of mark of germ on seed and corneous endosperm percentage were rated as per the prescribed guidelines on sorghum DUS testing (Kannababu *et al.* 2006).

The data was transformed to arc sine values, wherever necessary and ANOVA was performed in randomized complete block design using a statistical software package (Statistrix, version 8.1). Variance components, genetic parameters, correlation analysis and pair wise Euclidean distances based on the mean values of the quantitative traits were estimated using SAS mixed procedure (SAS 9.2).

Results and Discussion

***Mean performance for seed ageing and longevity traits*:** Among the nine cultivars, seed quality values of fresh seeds ranged from 1.2 (SSG 59-3) to 3.9 g (HC 136) for hundred seed weight, 32 (PC 6) to 55 sec. (CSH 20MF) for seed hardness, 86 (PC 6) to 99% (SSG 59-3) for seed germination, 20 (HC 171) to 29cm (PC 4) for shoot length, 8.5 (PC 4) to 13.5cm (HC 136) for root length, 11.4 (PC 6) to 20.1mg (PC 3) for seedling dry weight, 982 (PC 6) to 1910 (PC 3) for seedling vigour index, and 81 (PC 6) to 95% (HC 171) for field emergence traits (Tables 2 and 5; Fig. 1). Similar results in sorghum, with highly significant differences for visual seedling vigour, seed germination, field emergence, seedling height, shoot dry weight were reported by Cisse and Ejeta (2003). The percentage of corneous endosperm ranged from the grade 25 (UPC 2, PC 3, PC 4, HC 136, HC 171) to 75% (CSH 20 MF). The cultivars PC 5, PC 6 and SSG 59-3 showed 50% of corneous endosperm texture (Table 5). Two grades of germ size were identified among the nine cultivars studied, *viz*., medium size (PC 4, PC 5, PC 6, HC 171 and SSG 59-3) and large size (UPC 2, PC 3, CSH 20MF and HC 136) (Table 5). After accelerated ageing reduction in seed quality traits was noticed (Table 2, and Fig. 1). Similar to these results, Chauhan and Deswal (2013) reported the decreased seed vigour due to accelerated ageing of six wheat varieties based on seedling length and seedling dry weight. In the present study, the fungal contamination (%) on accelerated aged seed samples of forage sorghum cultivars varied with different fungal spp (Table 4). The *Fusarium spp* ranged from 4 (SSG 59-3) to 51% (PC 6), *Aspergillus flavus* from 0 (SSG 59-3 and CSH 20MF) to 8% (PC 6), *Aspergillus niger* from 0 (SSG 59-3 and UPC 2) to 4% (PC 3 and HC 171), and the other fungi from 11 (SSG 59-3) to 60% (HC 136). The results on variability for fungus free seed (%) revealed that the accelerated aged seed with less fungus free seed exhibited the lowest values of seed germination, than that with high percentage of fungus free seed indicating the association with seed vigour, viability potential and longevity. These findings are in agreement with the report of Das *et al.* (2012). Also, the present results corroborate with the findings of Mane *et al*. (2011) that there was a significant increase in mycoflora from 5 to 31% and reduction in seed germination from 89 to 57%.

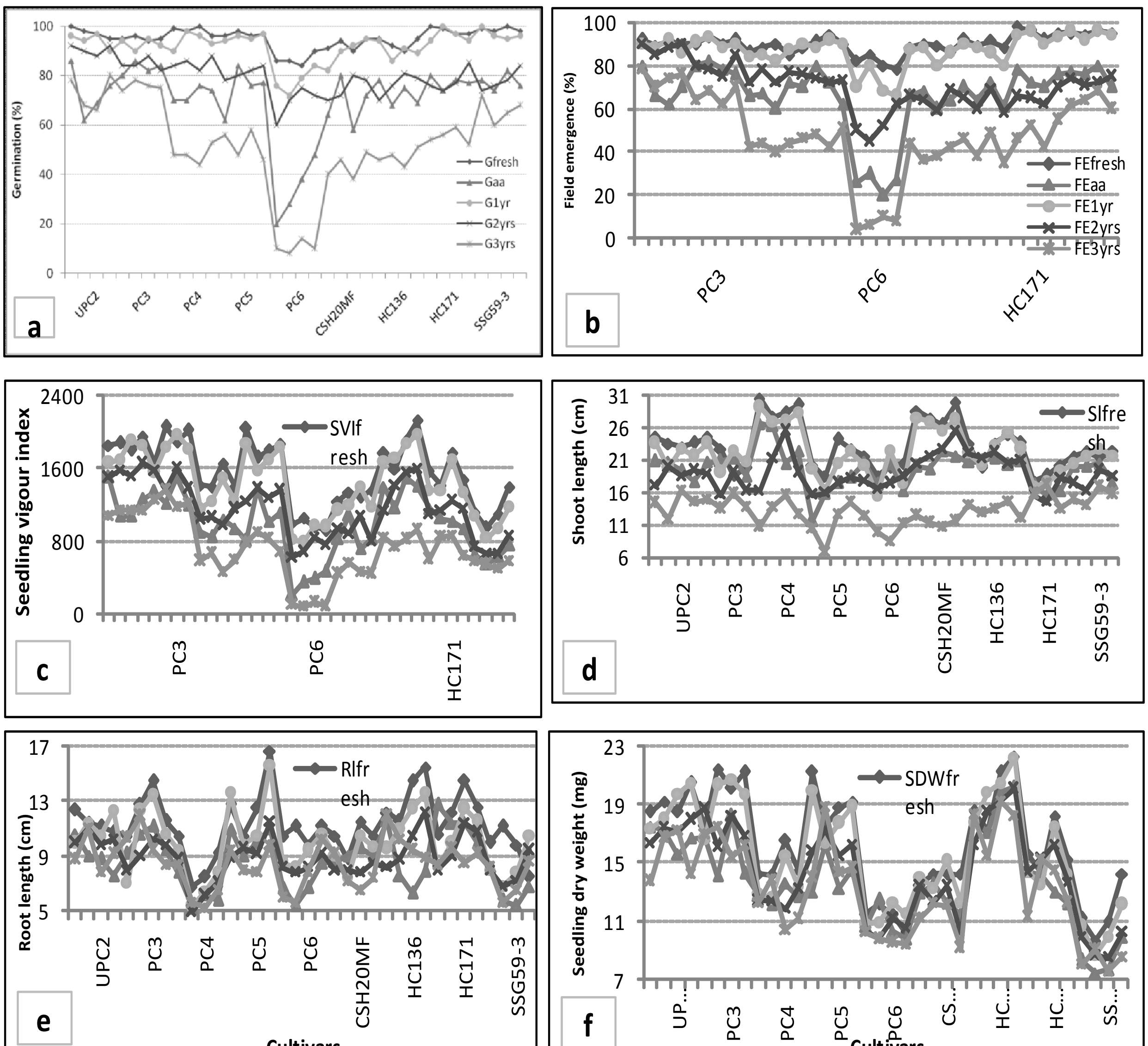

Fig. 1. Variations in seed traits of forage sorghum cultivars. **(a)** Germination, **(b)** field emergence, **(c)** seedling vigour, **(d)** shoot length, **(e)** root length and **(f)** seedling dry weight of fresh, accelerated aged (aa) and stored (1yr, 2yrs, 3yrs) seeds.

Table 2. Components of variation in forage sorghum cultivars for seed ageing and longevity related traits

Traits / Estimates	100-Seed weight (g)	Seed hardness (Sec.)	Seed germi-nation (%)*	Shoot length (cm)	Root length (cm)	Dry weight (mg)	Seedling vigour index	Field emergence (%)*
Fresh seeds								
Minimum	1.2	32.0	86 (68.5)*	20.0	8.5	11.4	982	81 (64.4)*
Maximum	3.9	54.5	99 (84.5)	29.0	13.5	20.1	1910	95 (77.7)
Mean	2.5	43.0	96 (78.7)	23.1	11.3	16.2	1547	90 (71.9)
CV	4.2	1.0	4.6	7.2	14.2	9.0	9.1	2.8
CD ($P \le 0.05$)	0.2	0.6	5.3	2.4	2.4	2.1	205.8	3.0
CVg(%)	34.0	23.3	7.5	15.8	15.0	24.4	25.6	6.3
CVp(%)	34.3	23.3	8.8	17.3	20.6	26.0	27.1	6.9
h^2(bs)	98.5	99.8	72.9	82.8	52.6	88.1	88.7	83.2
GAM	69.5	48.0	13.2	29.6	22.3	47.2	49.6	11.8
Accelerated aged seeds								
Minimum	-	-	33 (35.1)	15.8	6.3	8.3	357	25 (30.4)
Maximum	-	-	83 (65.7)	23.9	11.4	18.82	1365	79 (62.8)
Mean	-	-	71 (57.4)	19.6	8.7	13.8	981	66 (54.5)
CV	-	-	8.6	10.2	13.2	9.7	15.9	5.7
CD ($P \le 0.05$)	-	-	7.2	2.9	1.7	1.9	227	4.5
CVg(%)	-	-	17.0	12.0	22.9	25.9	37.3	19.9
CVp(%)	-	-	19.0	15.7	26.5	27.6	40.6	20.7
h^2(bs)	-	-	79.7	58.4	75.2	87.7	84.7	92.4
GAM	-	-	31.2	18.9	41.0	49.9	70.8	39.4
One year old seeds								
Minimum	-	-	78 (62)	18.83	7.2	10.4	887	71 (57.5)
Maximum	-	-	97 (80.8)	27.8	12.4	20.1	1805	94 (76.6)
Mean	-	-	93 (74.7)	22.2	10.1	15.6	1440	88 (69.9)
CV	-	-	6.2	7.5	16.4	8.4	7.8	4.7
CD ($P \le 0.05$)	-	-	6.7	2.4	2.4	1.9	164	4.8
CVg(%)	-	-	8.2	15.9	16.8	26.4	28.5	8.8
CVp(%)	-	-	10.3	17.6	23.4	27.7	29.5	9.9
h^2(bs)	-	-	63.8	81.7	51.3	90.8	93.0	77.8
GAM	-	-	13.5	29.7	24.8	51.8	56.5	15.9
Two years old seeds								
Minimum	-	-	69 (56.4)	16.8	6.8	9.3	726	52 (46.3)
Maximum	-	-	90 (72.1)	22.5	10.3	18.6	1563	88 (70.0)
Mean	-	-	80 (63.6)	18.9	8.9	14.4	1155	71 (57.5)
CV	-	-	3.6	10.8	11.5	7.8	9.2	3.9
CD ($P \le 0.05$)	-	-	3.3	3.0	1.5	1.6	156	3.3
CVg(%)	-	-	8.2	10.9	13.8	26.2	31.1	13.6
CVp(%)	-	-	8.9	15.3	18.0	27.4	32.4	14.1
h^2(bs)	-	-	83.8	50.4	59.1	91.9	91.9	92.3
GAM	-	-	15.4	15.9	21.9	51.8	61.4	26.9

Traits / Estimates	100-Seed weight (g)	Seed hardness (Sec.)	Seed germi-nation (%)*	Shoot length (cm)	Root length (cm)	Dry weight (mg)	Seedling vigour index	Field emergence (%)*
Three years old seeds								
Minimum	-	-	10 (18.8)	10.5	6.4	8.3	103	6 (15.1)
Maximum	-	-	75 (60.5)	15.4	10.2	17.8	1253	74 (59.7)
Mean	-	-	52 (46.1)	13.2	8.4	13.3	719	47 (43.3)
CV	-	-	6.1	13.2	15.8	10.2	10.4	6.2
CD (Pdȍ0.05)	-	-	4.1	2.5	1.9	2.0	109.5	3.9
CVg(%)	-	-	30.8	13.3	15.5	27.4	55.2	33.9
CVp(%)	-	-	31.4	18.7	22.2	29.2	56.2	34.5
h^2(bs)	-	-	96.3	50.6	49.0	87.8	96.5	96.8
GAM	-	-	62.2	19.5	22.4	52.8	64.3	68.7

*Values in parenthesis are arcsine transformed values

The cultivars stored for one year recorded the seed quality values ranging from 78 (PC 6) to 97 % (SSG 59-3) for seed germination, 18.83 (PC 6) to 27.80cm (C 4) for shoot length, 7.25 (PC 4) to 12.38cm (PC 5) for root length, 10.38 (SSG 59-3) to 20.09mg (HC 136) for seedling dry weight, 887 (PC 6) to 1805 (HC 136) for seedling vigour index, and 71 (PC 6) to 94% (SSG 59-3) for field emergence traits among the nine cultivars (Table 2 and Fig. 1). Similar results were found in second and third years. The results revealed that the influence of seed physical traits (corneous endosperm and embryo size) on seed ageing and longevity traits is very less (Table 5 and Fig. 1) in forage sorghum cultivars. Rajkumari Parwani and Archana Mankad (2010) reported that seed germination, seedling length and vigour were significantly affected during third year in *Cenchrus ciliaris* seeds stored for three years. The present results are in agreement with the report of Chauhan and Deswal (2013) that natural ageing of wheat seeds showed significant deleterious effects on germination, seedling length, seedling dry weight and vigour index.

In the present study, the loss in seed germination, field emergence, seedling vigour, shoot length and root length traits were more due to accelerated ageing compared to natural ageing irrespective of genotypes. Whereas, the differences due to accelerated and natural ageing were not much with the trait seedling dry weight concerned. These trends indicated that the traits seed germination; field emergence and seedling vigour were much affected due to accelerated ageing and natural storage for three years, compared to the seeds stored for one year and two years. Also, the study revealed that most forage sorghum cultivars had mean seed germination of 80% after two years of storage indicating that the revalidation may not be required at least for 18 months in these culti-vars as per seed certification standards of sorghum (75% seed germination) in India. Kannababu *et al.* (2010) reported that the seeds of forage sorghum (SSG 59ï 3) could be stored safely at 8% moisture up to two years under ambient conditions, without significant loss in seed vigour and viability.

Genetic variability, heritability and genetic advance for seed ageing and longevity: Effectiveness of selection depends on the magnitude of genetic variability in a particular trait. The trait hundred seed weight showed high phenotypic coefficient of variation (PCV) (34.3%), genotypic coefficient of variation (GCV) (34%), high heritability (h^2) (98.5%), and high genetic advance over mean (GAM) (69.5%) (Table 2). Seed hardness showed high values of PCV (23.3%), GCV (23.3), h^2-bs (99.8%) and GAM (48%). Seed germination percentage showed low values of PCV (7.5%) and GCV (8.8%), high h^2-bs (72.9%) and moderate GAM (13.2%) for fresh seeds; moderate values of PCV (19%) and GCV (17%), high values of h^2-bs (79.7%) and GAM (31.2%) for accelerated aged seeds; moderate PCV (10.3%), low GCV (8.2%), high h^2-bs (63.8%) and moderate GAM (13.5%) for naturally aged (one year old) seeds; low values of PCV (8.2%) and GCV (8.9%), high h^2-bs (83.8%) and moderate GAM (15.4%) for two years old seeds; high PCV (31.4%), GCV (30.8%), h^2-bs (96.3%) and high GAM (62.2%). Seedling field emergence recorded low values of PCV, GCV high h^2-bs and GAM in fresh seeds and one year old seeds; high values of PCV, GCV, h^2-bs and GAM for accelerated aged seeds; moderate values of PCV and GCV, high h^2-bs and GAM for two year old seeds; and high values of PCV, GCV, h^2-bs and GAM for three year old seeds (Table 2). In the present study, the traits seedling dry weight and seedling vigour index showed all high values of PCV, GCV, h^2-bs and GAM for all categories of aged seeds (Table 2). Whereas, the traits

Table 3. Broad sense genotypic (above diagonal) and phenotypic (below diagonal) correlations for seed ageing and longevity related traits in forage sorghum

Traits / Estimates	100-Seed weight	Seed hardness	Seed germi-nation	Shoot length	Root length	Dry weight	Seedling vigour index	Field emergence
Fresh seeds								
100-Seed weight		-0.29	-0.28	0	0.87	0.84	0.78	-0.04
Seed hardness	-0.28		0.43	0.31	-0.27	-0.34	-0.27	0.49
Seed germination	-0.22	0.35		0.13	-0.23	0.12	0.26	0.78
Shoot length	0	0.28	0.15		-0.72	-0.09	-0.07	-0.32
Root length	0.59	-0.17	-0.16	-0.41		0.84	0.78	0.35
Dry weight	0.77	-0.31	0.08	-0.07	0.55		0.99	0.21
Vigour index	0.72	-0.25	0.23	-0.05	0.51	0.99		0.31
Field emergence	-0.04	0.44	0.67	-0.19	0.09	0.18	0.27	
Accelerated aged seeds								
100-Seed weight		-0.29	0.24	-0.02	0.56	0.97	0.82	0.19
Seed hardness	-0.28		0.36	-0.12	0.08	-0.48	-0.18	0.39
Seed germination	0.23	0.31		0.08	0.46	0.33	0.73	1.02
Shoot length	-0.04	-0.09	0.06		-0.69	0.08	0.08	0.03
Root length	0.46	0.06	0.41	-0.37		0.51	0.6	0.49
Dry weight	0.87	-0.44	0.28	0.05	0.36		0.89	0.27
Vigour index	0.73	-0.16	0.73	0.07	0.49	0.86		0.7
Field emergence	0.19	0.38	0.93	0.02	0.35	0.25	0.66	
One year old seeds								
100-Seed weight		-0.29	-0.14	0.02	0.85	0.89	0.82	-0.02
Seed hardness	-0.28		0.59	0.3	-0.28	-0.41	-0.28	0.6
Seed germination	-0.1	0.44		0.09	0.09	0.14	0.32	1.06
Shoot length	0.02	0.26	0.01		-0.64	-0.09	-0.06	0
Root length	0.55	-0.19	-0.02	-0.41		0.88	0.86	0.24
Dry weight	0.83	-0.38	0.05	-0.1	0.71		0.98	0.18
Vigour index	0.78	-0.27	0.26	-0.09	0.68	0.97		0.36
Field emergence	-0.03	0.51	0.63	-0.02	0.08	0.13	0.26	
Two years old seeds								
100-Seed weight		-0.29	0.16	0.38	0.74	0.91	0.79	0.04
Seed hardness	-0.28		-0.24	0.26	-0.34	-0.4	-0.42	-0.13
Seed germination	0.12	-0.21		-0.11	0.24	0.51	0.7	1.01
Shoot length	0.24	0.17	-0.07		-0.28	0.04	-0.02	-0.2
Root length	0.52	-0.24	0.2	-0.39		0.85	0.78	0.3
Dry weight	0.84	-0.38	0.45	-0.05	0.66		0.97	0.44
Vigour index	0.73	-0.4	0.67	-0.08	0.62	0.96		0.65
Field emergence	0.06	-0.13	0.85	-0.1	0.12	0.37	0.56	
Three years old seeds								
100-Seed weight		-0.29	0.13	-0.07	0.93	0.93	0.53	0.11
Seed hardness	-0.28		0.11	0.03	-0.48	-0.42	-0.27	0.14
Seed germination	0.12	0.11		0.9	0.49	0.42	0.87	1
Shoot length	-0.04	0.03	0.57		0.4	0.17	0.65	0.89
Root length	0.57	-0.32	0.32	0.14		1.02	0.87	0.44
Dry weight	0.85	-0.38	0.35	0.09	0.63		0.79	0.38
Vigour index	0.51	-0.26	0.85	0.42	0.58	0.77		0.84
Field emergence	0.11	0.13	0.95	0.55	0.31	0.35	0.8	

shoot length and root length showed mostly moderate to high values of PCV, GCV, h^2-bs and GAM for different aged seeds. The results indicated that there is genetic potential to improve seed quality in terms of seedling vigour and longevity. The results on genetic variability corroborate with the report of Pedersen and Toy (2001) in grain sorghum. Cisse and Ejeta (2003) reported a significant additive variance for seedling vigour which could be utilized to improve field vigour, emergence and seedling growth in sorghum. The present results on heritability corroborate with the findings of Cisse and Ejeta (2003) in sorghum that the heritability estimates for percentage germination, emergence, and seedling height were high at I and II week, while those for seedling height at III week and seedling dry weight were low to medium. Further, Revilla *et al*. (2006) concluded that there was heritable genetic variability for longevity within maize inbred lines, which allowed natural selection for viability and vigour during storage.

Character association for seed ageing and longevity: Hundred seed weight showed high positive genetic and phenotypic correlation with seedling root length, dry weight and seedling vigour index of fresh seeds and one, two and three year old stored seeds (Table 3).Seed hardness showed moderate positive genetic and phenotypic correlations with seed germination (0.43, 0.35), shoot length (0.31, 0.28) and field emergence (0.49, 0.44) of fresh seeds. Also, seed hardness showed positive association with seed germination and field emergence in all categories except in one year old seeds (Table 3). Seed germination had moderate to high positive genetic and phenotypic correlations with seedling dry weight, vigour index and field emergence in all categories of seeds. Seedling dry weight had moderate to high positive association with most of the seed quality traits in all categories of seeds studied. The field emergence had moderate positive genetic and phenotypic correlations with seed hardness (0.49, 0.44), and high correlation (0.78, 0.67) with seed germination of fresh seeds. Field emergence showed moderate to high positive association with all other traits studied in case of accelerated aged and three years old seed categories indicating the importance of all traits studied for seed viability and longevity in practically realizing the seedling stand establishment in field of forage sorghums. These

Table 4. Fungal contamination on accelerated aged seed samples of forage sorghum cultivars

Cultivar name	Fugal contamination (%)				Fungus free seed (%)
	***Fusarium* spp**	***Aspergillus flavus***	***Aspergillus niger***	**Other fungi**	
UPC 2 (UP Chari 2)	8	4	0	48	40
PC 3 (Pant Chari 3)	32	3	4	43	18
PC 4 (Pant Chari 4)	16	2	2	56	24
PC 5 (Pant Chari 5)	14	4	2	41	39
PC 6 (Pant Chari 6)	51	8	2	35	4
CSH 20MF	39	0	1	57	3
HC 136	20	3	3	60	14
HC 171	12	4	4	48	32
SSG 59-3	4	0	0	11	85

Table 5. Variation in physical seed parameters among forage sorghum cultivars

Cultivar name	100-Seed weight (g)	Seed hardness (Sec.)	Corneous Endosperm (%)*	Germ size**
UPC 2 (UP Chari 2)	2.75	34.00	25	7
PC 3 (Pant Chari 3)	2.83	33.50	25	7
PC 4 (Pant Chari 4)	2.09	44.00	25	5
PC 5 (Pant Chari 5)	2.79	49.00	50	5
PC 6 (Pant Chari 6)	1.92	32.00	50	5
CSH 20MF	2.61	54.50	75	7
HC 136	3.89	39.00	25	7
HC 171	2.58	48.13	25	5
SSG 59-3	1.19	53.00	50	5
Mean	2.52	43.01	-	-
CD ($P \leq 0.05$)	0.15	0.62	-	-
CV (%)	4.16	0.99	-	-

*States of the endosperm texture as per DUS test guidelines of sorghum, **Note of trait as per DUS test guidelines of sorghum (5 = medium; 7 = Large) results are in agreement with the report of Brar and Stewart (1994) that the laboratory evaluations have been shown to be useful in establishing significant positive correlations between laboratory germination and field emergence as well as with seedling vigour in the field. However, in sorghum Cisse and Ejeta (2003) reported that kernel weight was not significantly associated with most seedling vigour traits except for percentage emergence. Adam (2010) also reported that the field emergence was positively correlated with the speed of germination, seedling length and seedling dry weight suggesting that these vigour attributes could be used to estimate field emergence of sorghum seeds.

Conclusion

Seedling vigour in sorghum is important for improving stand establishment of the crop, particularly in arid regions and in areas where low soil temperatures prevail at planting time. In arid environments, crop varieties with early seedling vigour and good stand establishment tend to maximum use of available soil water, resulting in increased dry matter accumulation and improved grain yield. Good, uniform crop stands from genetically pure seeds of the selected varieties/genotypes are crucial for exploiting the full potential of improved genotypes. A reduction in seed viability may theoretically be compensated by increasing the seed rate, but it often leads to practical difficulties due to strong correlation between percentage seed viability and seed vigour parameters. Low vigour seeds when planted in field may lower crop performance due to a suboptimal plant population and/or plant growth. Such plants are more prone to stress, while poor growth is the consequence of a slower growth rate in the early stages of the seedlings derived from such seeds. The present study revealed the clear variability among the cultivars of forage sorghum for seed vigour and longevity.

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