Received : 15 Jun 2019 | Revised : 23 Jan 2020 | Accepted : 25 Jan 2020

Electronic Journal of Plant Breeding

Research Article

Identification of germplasm lines for diversification of dual-purpose sorghums

P. Sanjana Reddy[1*], B.R. Ranwah[2], Sushil Pandey[3]

[1]ICAR-Indian Institute of Millets Research, Hyderabad 500030, Telangana, India.
[2]Maharana Pratap University of Agriculture and Technology, Udaipur 313001, Rajasthan, India.
[3]ICAR-National Bureau of Plant Genetic Resources, New Delhi 110012, India.
***E-Mail:** sanjana@millets.res.in

Abstract
Characterization and evaluation of germplasm is a pre-requisite for diversifying the genetic base in breeding populations. Preliminary evaluation of 642 germplasm lines for 25 traits at MPUAT, Udaipur during 2014 rainy season led to the identification of promising germplasm lines for each of the traits. Looking into the climatic pattern of the region, early flowering, dual-purpose lines with terminal drought tolerance are preferred. The germplasm lines IC 484464, IC 484889 and IC 240866 were found promising. The principal components analysis clearly showed that the entire variation in the 642 sorghum germplasm lines cannot be explained on the basis of few characters though glume covering, plant height and the number of leaves explained the variation in PC I explaining 19.5% of the total variability. Trait association showed that the yield enhancement in Udaipur location representing zone III, can be brought about by breeding for early flowering, terminal drought tolerance (non-senescence), bold grain, medium height, and tan plant colour background, apart from other significantly associated traits.

Keywords
Sorghum, germplasm, principal component, association, early flowering

INTRODUCTION

Sorghum has immensely contributed to productive agriculture systems of many countries through its diverse uses in the form of flours, porridges, malted and distilled beverages, animal feed and speciality foods such as popped grain. Forage sorghum is used as animal feed while dual-purpose sorghum serves for both food and fodder needs. Landraces and wild relatives of cultivated sorghum from the centers of diversity have been rich sources of resistance to new pathogens, insect pests and other stresses, as well as sources of traits to improve food and fodder quality, animal feed and industrial products. The identification of variability among accessions is pivotal to the maintenance, utilization and acquisition of germplasm resources (Mwirigi *et al*., 2009). Incorporation of variability in the desirable agronomic background and suitable for the target location is the first step towards commercialization of sorghum crop as a whole and income generation to the poor farmers. As a prerequisite for efficient utilization of the germplasm, it must be systematically evaluated, characterized and documented with a workable retrieval system so that any group of entries carrying any desired characteristics could be easily pulled out and used in breeding programs (Gebrekidan, 1982). The current study was taken up with an objective of identifying promising germplasm lines suitable for the Udaipur region (zone III – dual purpose and forage sorghum growing zone) in early maturity background, identify the traits that contributed significantly towards variability and to study the association among the traits.

MATERIALS AND METHODS

The experiment: The experimental material consisted of 750 sorghum germplasm lines obtained from National Genebank (NGB), ICAR-National Bureau of Plant Genetic Resources (NBPGR), NewDelhi. These lines were characterized in 2014 *Kharif* season at MPUAT, Udaipur (24.34°N and 73.42° E, 582m altitude). The germplasm lines were grown in an augmented design along with four checks, namely, CSV 17, CSV 20, CSV 27, CSV 21F, randomized in each block and thereby the experiment consisted of 30 blocks with each block having 25 germplasm lines and four checks. Each accession was grown in a single row of two meters length and inter- and intra- row distance were kept at 45 cm and 15 cm, respectively.

Data recording: Due to the photosensitive nature of some of the germplasm lines, data could be recorded on 642 germplasm lines. Data was recorded for both qualitative and quantitative traits.

Quantitative traits: The days to flowering was calculated as the days required for 50% of the plants in a plot to have 50% anthesis. Plant height was recorded as the length from the base of the plant to the tip of the panicle. The total number of leaves was counted. The leaf length was measured as the length from the base of the ligule to the tip of the seventh leaf from the base of the plant. The leaf width was measured on the same plants by taking the width of the widest section of the leaf. Panicle length was measured from the base to the tip of the panicle at maturity. Panicle width was measured at the widest diameter of the panicle. These observations were recorded on five randomly selected plants and the mean was calculated. The yield was calculated as the total grain weight per plot (kg) after threshing and then converted into kilograms per hectare. Weight of 100 grains in grams was recorded.

Qualitative traits: Observations were recorded for early plant vigour (on a 1-3 scale where 1= poor, 2= good and 3= very good), leaf colour (on a 1-3 scale where 1= pale green, 2= light green and 3= dark green), leaf-sheath pigmentation (tan, non-tan), leaf midrib colour (white, yellow, green, dark green), panicle compactness (very loose, loose, semi compact, compact, broom corn), race (bicolor, guinea, caudatum, durra, kafir), panicle shape (broom corn, cylindrical, elliptical, ovate, round), glume colour (white, straw, light brown, brown, reddish brown, light red, red, dark red, purple, black, straw and brown, straw and purple), glume coverage (glume covering the grain upto quarter, half, three-fourths and full), grain colour (white, chalky white, creamy straw, light yellow, yellow, light brown, brown, reddish-brown, light red, red, white and red mixed), grain shape (compactly flat, round, sub lenticular round but flat from other side, oval, elliptical), grain size (small, medium, bold), presence of awn (present, absent), endosperm texture (compactly corneous, mostly corneous, intermediate, completely starchy), grain luster (non-lustrous, lustrous) and staygreenness (nonsenescent or staygreen, senescent).

Data analysis: Analysis of variance (ANOVA) for augmented RBD for all quantitative attributes was done. Descriptive statistics score summary was derived and statistics such as Mean, Standard Deviation (SD), Range, Coefficient of Variation (CV) was calculated. The adjusted data were subjected to Principal Component Analysis (PCA). Data from the PCA was used to generate Eigenvalues, the percentage of the variation accumulated by the PCA and the load coefficient values between the original characters and respective PCA. Those PCs with Eigenvalues greater than one were selected as proposed by Jeffers (1967). Correlations between the traits were calculated. All the statistical analysis was performed in Genstat 12thedn.

RESULTS AND DISCUSSION

The descriptive statistics were calculated for 9 quantitative traits. The CV, also known as Relative Standard Deviation (RSD), is a standardized measure of dispersion. It shows the extent of variability in relation to the mean of the population. It is used for comparison between data sets with different units or widely different means. The highest CV was found for the trait grain yield followed by plant height, panicle width and panicle length indicating more variability for these traits. Using an arbitrary selection criterion, promising germplasm lines for each of these traits is given in **Table 1**. Five germplasm lines (IC 253535, IC 484685, IC 485054, IC 309915, IC 285822) which flowered in less than 45 days were identified from the study. These lines can be utilized in the breeding programs for the development of early flowering, high yielding lines. Also, high yielding germplasm lines (IC 484464, IC 484889, IC 587905, IC 485180, IC 484860, IC 240831, IC 240866, IC 11255, IC 285880, IC 285926, IC 587909, IC 541857, IC 144589, IC 285836) with more than 65g/ panicle were identified in diverse agronomic backgrounds. The performance of these lines for all the 25 qualitative and quantitative traits is given in **Table 2**. The germplasm lines were scored for 16 qualitative traits. The percentage of germplasm lines occurring in each group in each of the 16 traits is given in **Table 3.** The germplasm lines were almost equally distributed among all the classes for early plant vigour. For leaf colour, the majority (88.6%) of the accessions were dark green. The pigmented leaf sheath is indicative of drought tolerance in sorghum and for this trait, about 60% of the germplasm lines showed non-tan or pigmented leaf sheath while 40% were tan types. Most of the lines showed a white midrib colour (51.6%) followed by a green midrib colour (36.3%). The panicles of 58% of the lines had loose to very loose panicles while 23% had semi-compact to compact panicles and the remaining19% representing broom corn types. About 67% of the lines had elliptical panicle shape. The glumes of the majority of accessions were straw coloured (48.2%) and with half (41%) to three-fourth (43%) covering the grain. The grains were mostly creamy straw (39.9%) followed by white (22.1%) colored. In shape, most of were oval (48.8%) and in size medium (44%) to bold

(37%). Awns were mostly absent (60%) and endosperm texture was of intermediate (50%) in nature. The grains were mostly non-lustrous (62%). However, germplasm lines represented almost all the classes in each of these traits(**Table3**).

Table 1. Descriptive statistics for quantitative traits in 642 germplasm lines evaluated at Udaipur, Rajasthan

Trait	Mean	Minimum	Maximum	SD±	CV(%)	Selection criteria	Desirable germplasm lines for the trait
Days to 50% flowering	77	41	124	15.71	20.35	≤45 days	IC 253535, IC 484685, IC 485054, IC 309915, IC 285822
Plant height (cm)	241	56	480	78.5	32.65	≥440 cm	IC 484684, IC 485226, IC 485229, IC 484364, IC 484397, IC 484949
Leaf length (cm)	74	9	100	12.82	17.41	>95 cm	IC 485132, IC 289225, IC 484656, IC 485074, IC 485125, IC 144836
Leaf width (cm)	8	3	13	1.69	21.01	>11 cm	IC 587868, IC 484860, IC 240848, IC 240851, IC 240856, IC 585142, IC 585143, IC 144879, IC 285828, IC 285850
No. of leaves	11	5	21	2.91	26.42	≥18	IC 587889, IC 426758, IC 285821, IC 285850
Panicle length (cm)	23.9	5	48	7.35	30.74	>40 cm	IC 484779, IC 587890, IC 484328, IC 484445, IC 484489, IC 484658, IC 588062, IC 585157, IC 585158
Panicle width (cm)	7.1	2.11	15.4	2.24	31.62	>13 cm	IC 587890, IC 426746, IC 285871, IC 285878, IC 285908, IC 285919, IC 285920, IC 285921, IC 285922
Grain yield (g/panicle)	25.3	0.02	80	18.86	74.43	≥ 65g	IC 484464, IC 484889, IC 587905, IC 485180, IC 484860, IC 240831, IC 240866, IC 11255, IC 285880, IC 285926, IC 587909, IC 541857, IC 144589, IC 285836
100-grain weight (g)	3.2	1.5	5.18	0.60	18.82	≥4.8 g	IC 587864, IC 240866, IC 484899, IC 484989, IC 144843, IC 144844, IC 285920

Table 2. Performance of high yielding germplasm lines for other agronomic traits

Traits	Germplasm line IC 484464	IC 484889	IC 587905	IC 587909	IC 485180	IC 484860	IC 240831	IC 240866	IC 541857	IC 144859	IC 11255	IC 285836	IC 285880	IC 285926
Early Plant Vigour	Very good	Very good	Very good	Good	Good	Very good	Very good	Good	Poor	Good	Poor	Very good	Good	Poor
Days to 50% flowering	62	61	74	82	73	67	55	63	101	70	70	75	72	74
Total Number of Leaves	11	11	10	10	9	10	8	10	14	8	8	14	11	9
Leaf Length (cm)	79	85	67	69	65	82	86	82	75	95	67	70	65	71
Leaf Width (cm)	9	11	8	8	7	12	9	8	8	11	8	11	9	9
Leaf Colour	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green
Leaf Sheath Pigmentation	Tan	Non-Tan	Non-Tan	Non-Tan	Tan	Non-Tan	Tan	Tan	Non-Tan	Tan	Tan	Non-Tan	Non-Tan	Non-Tan
Leaf Midrib Colour	Green	Yellow	White	White	Green	White	White	White	Green	Green	Green	White	Green	White
Panicle Compactness	Loose	Loose	Compact	Compact	Loose	Very loose	Very loose	Loose	Semi compact	Loose	Loose	Compact	Compact	Semi compact
Panicle Length (cm)	28	25	13	12	19	29	27	26	17	20	27	13	18	15
Panicle Width (cm)	8.2	10.6	6.4	7.1	2.5	4.2	5.2	4.2	10.1	3.7	5.4	9.8	9.1	9.3
Race	Kafir	Caudatum	Durra	Durra	Kafir	Kafir	Kafir	Kafir	Bicolor	Kafir	Kafir	Durra	Durra	Caudatum
Panicle Shape	Elliptical	Elliptical	Round	Cylindrical	Elliptical	Elliptical	Elliptical	Elliptical	Elliptical	Elliptical	Elliptical	Elliptical	Ovate	Ovate
Glume Colour	Straw	Red	Light red	Straw	Straw	Straw	Straw	Reddish-brown	Light red	Straw and brown	Straw	Red	Straw	Red
Glume Covering	0.5	0.25	0.5	0.75	0.5	0.5	0.5	0.25	0.5	0.25	0.25	0.75	0.5	0.5
Plant Height (cm)	165	175	320	300	120	185	240	176	295	183	132	270	227	200
Grain Weight (g)	66.2	67.9	72.3	65.3	68.2	70.3	69.0	67.9	64.8	65.4	66.3	65.0	80.0	65.5
Grain Colour	Creamy straw	Straw and brown	Creamy straw	Creamy straw	Creamy straw	Creamy straw	Creamy straw	Creamy straw	White	Creamy straw	Creamy straw	Straw and brown	Straw and brown	Creamy straw
Grain Shape	Round	Oval	Round	Round	Oval	Round	Oval	Round	Oval	Oval	Round	Elliptical	Oval	Round
Grain Size	Bold	Bold	Medium	Bold	Medium	Bold	Medium	Bold	Bold	Bold	Bold	Bold	Bold	Bold
Presence of Awn	Absent	Absent	Present	Absent	Absent	Present	Absent	Absent	Present	Absent	Absent	Absent	Present	Present
Endosperm Texture	Intermediate	Starchy	Starchy	Starchy	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Compactly corneous	Intermediate	Intermediate
Grain Lusture	Non-lustrous	Non-lustrous	Non-lustrous	Lustrous	Non-lustrous	Non-lustrous	Non-lustrous	Non-lustrous	Lustrous	Non-lustrous	Non-lustrous	Non-lustrous	Lustrous	Non-lustrous
100 Seed Weight (g)	4.3	3.8	3.6	3.5	3.4	3.8	3.3	4.9	3.9	3.0	4.0	2.0	4.0	3.7
Stay Green	Non-senescent	Non-senescent	Senescent	Senescent	Senescent	Senescent	Senescent	Non-senescent	Senescent	Senescent	Senescent	Senescent	Senescent	Senescent

Principal component (PC) analysis showed that out of the ten, the first 7 PCs having Eigenvalue >1 explained most of the variation. These seven PCs contributed 60.13% of the total variability amongst the sorghum germplasm lines assessed for different morpho-physiological traits (**Table 4**). The PC I contributed maximum towards the variability (19.46%) followed by PC II (10.18%), PC III (9.14%), PC IV (7.03%), PC V (5.13%), PC VI (4.7%) and PC VII (4.49%). The PC I was explained by the variations among the accessions mainly for the traits glume covering, plant height and the total number of leaves with positive factor loadings and race with negative factor loading on PC I. Similarly the PC II was related to diversity among sorghum genotypes due to early plant vigour, grain size, leaf length and leaf width and all these traits had positive loadings. The PC III was explained mainly by variation among genotypes resulted from panicle length, panicle shape, grain colour, leaf-sheath pigmentation and presence of awn. In this principal component, panicle length contributed negatively. The fourth (PC IV) was explained negatively by the variations resulting from days to 50% flowering and staygreenness, and positively by glume colour. The fifth (PC V) was explained positively by the variations resulting from early plant vigour and negatively by grain size, panicle width and 100-grain weight. The sixth (PC VI) was explained negatively by the variations resulting from endosperm texture and grain colour. The seventh (PC VII) was explained negatively by the variations resulting from leaf colour and positively from grain lustre (**Table 4**). The principal components analysis clearly showed that the entire variation in the 642 sorghum germplasm lines cannot be explained on the basis of few characters and thereby a number of traits were involved in explaining the gross variance among the genotypes though with different magnitudes.Similar results were discussed in earlier studies in sorghum (Ayana and Bekele, 1999; Tesfamichael *et al*., 2015).

Table 3.Percentage variation of germplasm lines for qualitative traits in 642 germplasm lines evaluated at Udaipur, Rajasthan

Trait	Descriptors for the trait				
Early plant vigour	Poor (36%)	Good (29%)	Very good (36%)		
Leaf colour	Pale green (0.5%)	Light green (10.9%)	Dark green (88.6%)		
Leaf-sheath pigmentation	Tan (40%)	Non-Tan (60%)			
Leaf midrib colour	White (51.6%)	Yellow (2.6%)	Green (36.3%)	Dark green (9.5%)	
Panicle Compactness	Very loose (27%)	Loose (31%)	Semi compact (12%)	Compact (11%)	Broom corn (19%)
Race	Bicolor (50%)	Caudatum (5%)	Durra (12%)	Guinea (3%)	Kafir (31%)
Panicle Shape	Broomcorn (8%)	Cylindrical (3%)	Elliptical (67%)	Ovate (18%)	Round (4%)
Glume colour	White (1.8%)	Straw (48.2%)	Light brown (0.5%)	Brown (1.3%)	Reddish brown (5.4%)	Light red (6.4%)
	Red (11.3%)	Dark red (4.8%)	Purple (1%)	Black (12.4%)	Straw and Brown (5.3%)	Straw and purple (1.8%)
Glume coverage	0.25 (16%)	0.5 (41%)	0.75 (43%)			
Grain colour	White (22.1%)	Chalky white (2%)	Creamy straw (39.9%)	Light yellow (2.3%)	Yellow (0.7%)	Light brown (5%)
	Brown (11.8%)	Reddish brown (1.4%)	Light red (2.9%)	Red (0.4%)	White and red mixed (11.6%)	
Grain shape	Compactly flat (0.5)	Round (18.2)	Sub lenticular round but flat from other side (3.4%)	Oval (48.8)	Elliptical (29.1)	
Grain size	Small (19%)	Medium (44%)	Bold (37%)			
Presence of awn	Absent (60%)	Present (40%)				
Endosperm Texture	Compactly comeous (4%)	Mostly comeous (8%)	Intermediate (50%)	Completely starchy/ fluoury (37%)		
Grain lustre	Nonlustrous (62%)	Lustrous (38%)				
Staygreen	Nonsenescent/ staygreen (40%)	Senescent (60%)				

Table 4. Eigenvalues, total variance, cumulative variance, and eigenvectors for 25 traits in sorghum germplasm

Character	PC1	PC2	PC3	PC4	PC5	PC6	PC7
100 Seed Weight (g)	-0.19	0.37	0.07	0.05	-0.34	0.10	0.16
Days to 50% flowering	0.26	-0.12	-0.07	-0.40	0.00	0.04	0.06
Panicle compactness	0.24	-0.02	-0.07	0.26	0.07	0.15	0.11
Panicle length (cm)	0.12	0.02	-0.45	0.14	-0.26	-0.05	-0.17
Panicle shape	-0.07	0.13	0.39	-0.18	0.15	-0.01	0.04
Panicle width (cm)	0.20	0.06	0.04	-0.11	-0.51	0.14	-0.20
Early Plant Vigour	0.09	0.36	-0.04	0.28	0.31	-0.12	-0.01
Endosperm texture	-0.05	0.03	0.01	-0.10	0.02	-0.74	0.01
Glume colour	0.17	0.02	0.08	0.36	0.05	-0.14	0.13
Glume covering	0.32	-0.12	0.06	0.09	0.03	0.04	-0.15
Grain colour	0.09	-0.04	0.30	0.12	-0.20	-0.39	0.15
Grain lusture	0.14	0.12	0.18	0.08	0.12	0.19	0.49
Grain shape	0.23	-0.23	-0.04	0.14	-0.17	-0.15	0.20
Grain size	-0.15	0.33	0.18	-0.04	-0.42	0.06	0.06
Grain yield	-0.22	0.28	-0.03	0.24	0.12	0.19	0.01
Leaf colour	0.04	0.14	0.15	0.20	0.01	-0.05	-0.67
Leaf length (cm)	0.18	0.37	-0.24	-0.16	0.04	-0.07	-0.01
Leaf midrib colour	-0.24	-0.05	-0.11	-0.19	0.14	-0.10	-0.05
Leaf sheath pigmentation	0.27	0.07	0.32	0.04	0.01	0.05	-0.19
Leaf width (cm)	0.04	0.41	-0.14	-0.28	0.02	-0.19	0.03
Plant height (cm)	0.35	0.20	-0.10	0.02	0.16	0.05	-0.06
Presence of awn	0.05	0.04	0.45	-0.12	0.16	-0.01	-0.16
Race	-0.31	0.01	-0.15	0.08	0.22	0.04	-0.10
Stay Green	0.02	-0.09	0.07	-0.34	0.12	0.19	-0.09
Total number of leaves	0.31	0.22	-0.12	-0.25	0.14	0.01	0.07
Eigen values	4.866	2.546	2.284	1.757	1.282	1.175	1.124
% of total variance	19.46	10.18	9.14	7.03	5.13	4.7	4.49
%cumulative variance	19.46	29.64	38.78	45.81	50.94	55.64	60.13

Table 5. Correlation coefficients between different traits recorded on 642 sorghum germplasm lines at Udaipur, Rajasthan

DF	-0.20**	1																					
TL	0.28**	0.59**	1																				
LL	0.29**	0.20**	0.52**	1																			
LW	0.23**	0.05	0.37**	0.56**	1																		
LC	0.15**	-0.10*	0.01	0.04	-0.01	1																	
PIG	0.12**	0.25**	0.29**	0.10*	0.01	0.23**	1																
MC	-0.15**	-0.18**	-0.26**	-0.15**	0.06	-0.08	-0.39**	1															
PC	0.16**	0.22**	0.30**	0.08	-0.07	0.02	0.24**	-0.25**	1														
PL	0.09*	0.04	0.12**	0.31**	0.13**	0.01	-0.11*	-0.06	0.14**	1													
PW	-0.04	0.23**	0.23**	0.17**	0.13**	0.06	0.27**	-0.22**	0.20**	0.21**	1												
PS	0.05	-0.09*	-0.05	-0.08	0.08	0.05	0.11*	0.06	-0.21**	-0.45**	-0.01	1											
GCLR	0.21**	-0.04	0.12**	0.06	-0.05	0.12**	0.23**	-0.19**	0.26**	0.08	0.02	-0.01	1										
GCOV	0.08	0.33**	0.34**	0.11*	-0.12**	0.07	0.43**	-0.38**	0.33**	0.15**	0.27**	-0.12**	0.27**	1									
PHT	0.41**	0.38**	0.68**	0.47**	0.21**	0.12**	0.41**	-0.40**	0.42**	0.25**	0.26**	-0.10*	0.29**	0.50**	1								
GRWT	0.21**	-0.42**	-0.24**	-0.01	0.10*	0.09	-0.21**	0.14**	-0.06	-0.07	-0.21**	0.06	-0.10*	-0.35**	-0.20**	1							
GRCL	0.02	0.02	0.01	-0.08	-0.03	0.09	0.21**	-0.20**	0.09*	-0.14**	0.14**	0.11*	0.18**	0.13**	-0.01	-0.12**	1						
GRS	-0.03	0.25**	0.14**	0.02	-0.16**	-0.06	0.16**	-0.21**	0.27**	0.20**	0.15**	-0.16**	0.25**	0.37**	0.21**	-0.35**	0.19**	1					
GRSZ	0.06	-0.23**	-0.08	0.01	0.17**	0.09*	-0.05	0.04	-0.21**	-0.18**	0.07	0.21**	-0.08	-0.26**	-0.16**	0.24**	0.02	-0.26**	1				
AWN	0.01	0.00	-0.04	-0.03	0.03	0.14**	0.39**	-0.03	-0.04	-0.35**	0.10*	0.29**	-0.02	0.16**	0.02	-0.06	0.19**	-0.06	0.05	1			
ENTEX	0.03	0.01	-0.03	-0.03	0.10*	-0.01	-0.06	0.09**	-0.10*	-0.034	-0.12**	0.01	-0.06	-0.10*	-0.06	-0.03	0.11*	-0.05	0.05	0.02	1		
LUS	0.13**	0.08	0.19**	0.13**	0.06	-0.04	0.24**	-0.22**	0.17**	-0.09*	0.05	0.04	0.16**	0.14**	0.22**	-0.01	0.13**	0.11*	-0.02	0.22**	-0.11*	1	
SDWT	0.11*	-0.31**	-0.15**	0.05	0.19**	0.05	-0.13**	0.11*	-0.18**	-0.09*	-0.04	0.15**	-0.09*	-0.40**	-0.17**	0.43**	-0.04	-0.30**	0.63**	-0.06	0.03	0.02	1
SG	-0.14**	0.18**	0.09*	-0.07	0.01	-0.02	0.00	0.07	-0.08	-0.08	0.01	0.10*	-0.06	0.01	0.05	-0.11*	-0.02	-0.03	-0.04	0.07	-0.06	-0.02	-0.11*
	VIG	DF	TL	LL	LW	LC	PIG	MC	PC	PL	PW	PS	GCLR	GCOV	PHT	GRWT	GRCL	GRS	GRSZ	AWN	ENTEX	LUS	SDWT

VIG: early plant vigour, DF: Days to 50% flowering, TL: Total number of leaves, LL: Leaf length, LW: Leaf width, LC: Leaf colour, PIG: Leaf-sheath pigmentation, MC: Leaf midrib colour, PC: Panicle compactness, PL: Panicle length, PW: Panicle width, PS: Panicle shape, GCLR: Glume colour, GCOV: Glume covering, PHT: Plant height, GRWT: Grain yield, GRCL: Grain colour, GRS: GRSZ: Grain size, AWN: Presence of awn, ENTEX: Endosperm texture, LUS: Grain lustre, SDWT: 100 Seed Weight, SG: Stay Green

Trait associations

The highest significant association was between plant height and total number of leaves (0.68**) followed by the associations between seed weight and grain size (0.63**), late-flowering with more number of leaves (0.59**), leaf length with leaf width (0.56**) and greater leaf length with more number of leaves (0.52**). Chase and Nanda (1967) found a significant correlation between the number of leaves and days to maturity in maize and also suggested it as a selection criterion for early maturity in maize. Greater plant height showed a significant association with more glume coverage (0.50**), more leaf length (0.47**), more early plant vigour (0.41**), non-tan leaf-sheath pigmentation (0.41**), late-flowering (0.38**) and white midrib colour (0.40**). Early flowering was associated with more grain yield (0.42**), grain size (0.31**) and non-senescence or staygreenness (0.18**). Apart from above, higher grain yield was associated with greater early plant vigour (0.21**), less number of leaves (-0.24**), greater leaf width (0.1*), tan pigmentation (-0.21**), dark green midrib (0.14**), narrow panicle width (-0.21**), white glume colour (0.1*), less glume coverage (-0.35**), less plant height (-0.2**), white grain colour (-0.12**), greater grain size (0.24**) and staygreenness (0.1*) (Table 3). It is clear from this study, that yield enhancement in this location can be brought about by breeding for early flowering, terminal drought tolerance (non-senescence), bold grain, medium height, and tan plant colour background apart from other significantly associated traits. Earlier studies also reported that improvement for early maturity and high yield coupled with staygreen character is possible (Shakoor and Qureshi, 1999).

Acknowledgements

This research has been carried out under the Indian Council of Agricultural Research (ICAR) funded project "Consortium Research Platform on Agrobiodiversity" being coordinated by the lead centre ICAR-NBPGR, which is duly acknowledged.

REFERENCES

Ayana, A. and Bekele, E. 1999. Multivariate Analysis of Sorghum (*Sorghum bicolor* (L.) Moench) Germplasm from Ethiopia and Eritrea. *Genet. Resour. Crop Ev.* **46:** 273-284 http://dx.doi.org/10.1023/A:1008657120946

Chase, S. and Nanda, D.K. 1967. Number of leaves and maturity classification in *Zea mays* L. *Crop Sci.* **7:** 431-432.

Gebrekidan, B. 1982. Utilization of germplasm in sorghum improvement. Pages 335–345 *in* Proceedings of the International Symposium on Sorghum, (House LR, Mughogho LK and Peacock JM, eds.). 2–7 November 1981, ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

Mwirigi, P.N., Kahangi, E.M., Nyende, A, B, and Mamati, E.G. 2009. Morphological variability within the Kenyan yam (*Dioscorea spp.). J. Appl. Biosciences*. **16:** 894–901.

Shakoor, A. and Qureshi, A. 1999. Correlation of early maturity and nonsenescence traits in sorghum. *Pakistan J. Biol. Sci.* **2(4):** 1543-1547.

Tesfamichael, A., Stephen, M.G., Remmy, K., Woldeamlak, A. and Aggrey, B.N. 2015. Genetic variation among sorghum (*Sorghum bicolor* L. Moench) landraces from Eritrea under post-flowering drought stress conditions. *Am. J. Plant Sci.* **6:** 1410-1424.