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Full Length Research Paper

Characterization of sorghum germplasm for various morphological and fodder yield parameters

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This study was performed to evaluate and characterize 24 sorghum accessions for various morphological and fodder yield parameters. The germplasm displayed considerable variability for leaf color, midrib color, panicle shape, days to 50% flowering, leaf area, flag leaf area, plant height and green fodder yield, while differences of smaller magnitude were observed for number of leaves and tillers plant^{-1}. Genotype Fsd -sorghum was mature early with minimum days to maturity (63) while maximum plant height (232 cm) was observed for Acc.1692. Moreover, Acc.1827 exhibited maximum leaf area (447 cm^2) and the highest green fodder yield at 50% maturity (58 t ha^{-1}) was recorded for Acc. 1763. The results of this study indicate that significant genetic diversity exists among the sorghum accessions. The genetic potential of Fsd-sorghum, accessions 1692, 1827 and 1763 can be exploited in future sorghum breeding programs. Further, these genotypes are recommended for commercial cultivation to meet the fodder needs of the country.

Key words: Fodder, *Sorghum bicolor,* accessions.

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] ranks fifth among cereals in both production and area planted worldwide (FAOSTAT, 2008). It is particularly important to food security in the semi-arid zones of Western and Central Africa (Andrew and Cox, 1993). Besides being a staple food crop in the semi-arid regions of the world, sorghum is also used for feed, traditional beverages, fuel, construction material, confection (sweet sorghums), brooms, as well as for making sugar, syrup and molasses (Doggett and Rao, 1995; Duncan, 1996). This crop is adapted to a wider range of ecological conditions. It is typically cultivated in the tropical, sub-tropical and temperate regions of the world generally in those dry areas with low soil moisture that are not suitable for maize cultivation (ICRISAT, 1996). It is planted in areas considered to be too dry and hot for other cereals, because of its tolerance to drought and heat stress (Poehlman, 1987).

Sorghum is the fourth important cereal of Pakistan after wheat, rice and maize. Area under cultivation of grain sorghum is 263 thousand hectares with production of 165 thousand tones (Economics Survey of Pakistan, 2009-10). It is the second major fodder crop of Pakistan after berseem (*Trifolium alexandrinum*). For fodder purposes, it is cultivated on an area of 221000 thousand hectares with a total production of 139000 thousand tones. However, the average yield of Pakistan for both grain and fodder sorghum is quite low as compared to other sorghum growing countries.

Fodder production is an important traditional part of the present cropping system for conserved feed in Pakistan. Lack of quality fodder, especially during winter is one of the major constraints to improve livestock production.

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Cattle are fed both on rangelands and in the sheds, however, many animals are underfed and weak in winter due to lack of quality feed. The problem could be solved through cultivation of the high yielding sorghum cultivars, but unfortunately in Pakistan there is lack of improved cultivars. Development of broad genetic base, high yielding and stable sorghum cultivars requires a continuous supply of new germplasm as a source of desirable genes and/or gene complexes in breeding programs. The primary sources of such genes are landraces, introductions, weedy, and wild relatives of crop plants (Rao et al., 1989; Harlan, 1992). The objectives of this study were to estimate the extent of morphological diversity among sorghum genotypes based on both qualitative and quantitative traits data and to identify the promising sorghum genotypes for future breeding programs.

MATERIALS AND METHODS

This study was performed on 24 accessions of sorghum at the Plant Breeding and Genetics (PBG) Research Farm, KPK Agricultural University, Peshawar, during July to October 2007 and 2008. Each accession was planted in a four row plot with row length of 3 m long and row-row distance of 30 cm apart. Standard crop production technology as needed for sorghum crop was used in the experiment. Data were recorded on six qualitative and 11 quantitative parameters. Qualitative traits taken into consideration were node type, leaf color, midrib color, panicle shape, the presence/absence of auricles and ligules. Quantitative traits studied were days to 50% flowering, plant height, peduncle length, number of tillers plant^{-1}, number of nodes plant^{-1}, internode length, leaf area, number of leaves plant^{-1}, flag leaf area, root lodging and green fodder yield at 50% maturity. Both qualitative and quantitative traits data were recorded on five randomly selected plants of each accession.

Days to 50% flowering for each accession were recorded from the date of sowing till 50% panicle emergence on plot basis. Number of nodes and tillers per plant were counted for each accession. Number of leaves plant^{-1} was counted when the crop became ready for fodder purpose. Leaf area was determined by the formula by Zaman et al. (2004):

Leaf area = Maximum leaf length (cm) × Maximum leaf breadth (cm) × 0.75 (correction factor)

Plant height was taken in centimeters from the base of the plant up to the flag leaf at 50% flowering. Internode length was measured using 6th internode or 30 cm above the ground level as standard in all the accessions (Ali et al., 2006), while peduncle length was the distance in centimeters between last node and panicle base on the culm. Data of root lodging was taken in percentage on plot basis visually. When the crop reached 50% maturity, two rows of each accession were harvested and yield was determined as follows:

$$\text{Yield (t ha}^{-1}\text{)} = \frac{\text{Green fresh weight row}^{-1}\text{(kg)} \times \text{Number of harvested rows} \times 10000\text{m}^2 \times \text{ton}}{3.6\text{m}^2 \times \text{ha} \times 1000\text{kg}}$$

Data analysis

Mean values were determined for all the studied quantitative traits. Pair-wise Euclidean distance of genotypes was computed on qualitative, quantitative and both qualitative and quantitative traits taken together, and the resulting matrices were used to synthesize dendrograms by unweighted pair-group method with arithmetic means (UPGMA) cluster analysis using the SAHN (sequential, agglomerative, hierarchical, and nested) option of NTSYS-pc 2.02k version (Rohlf, 1994). Mean values per accession were used and standardized prior to analyses.

RESULTS AND DISCUSSION

Qualitative traits

The results of qualitative traits are given in Table 1. Variations were observed for leaf color in the evaluated germplasm. In most of the sorghum genotypes, light green leaves were common while some of the genotypes had dark green leaves. On the contrary, Elangovan et al. (2007) had earlier reported dark green leaves for most of the 400 accessions of his study. The possible reason for this could be differences of genetic material in both the studies for this trait. Midrib color among the sorghum genotypes displayed ample variation. Five different colors were observed for midrib viz. white, light yellow, yellow, light green and dark green. White color was the most frequent and was observed in 12 accessions. Variation among the sorghum genotypes was depicted for panicle shape. Open panicle was the most frequent and was observed in 13 genotypes while intermediate panicle was present in eight genotypes. Three accessions had only compact panicle. Elangovan et al. (2007) also observed the same results for midrib color and panicle shape while studying 400 sorghum accessions. No variations among the available sorghum were observed for node type and presence/absence of auricles and ligules. The only node type observed was glabrous, while ligules were present in all the sorghum genotypes. However, all the sorghum did not display auricles. These results are compatible with the findings of Geleta and Labuschagne (2005) who also reported similar results for qualitative traits in a study of 45 accessions of sorghum.

Quantitative traits

The results of quantitative traits are presented in Table 2. The important results of these traits are as follows:

Days to 50% flowering

Days to 50% heading serve as a useful criterion for determining the maturity range of the genotypes. Performance of the genotypes for this trait depicted considerable variation. Means for days to 50% flowering among the genotypes ranged from 63 to 81 days. Fsd sorghum took minimum days (63) to reach 50 % maturity, followed by SP-1832 (64 days) and Local Pindi (64 days).

Table 1. Comparison for qualitative traits in the sorghum genotypes.

Accession	Node type	Leaf color	Midrib color	Presence/absence of auricle	Presence/absence of ligule	Shape of panicle
Local Bahawalpur	Glab	Light green	Yellow	Absent	Present	Intermediate
Acc. 1728	Glab	Light green	White	Absent	Present	Compact
Acc. 1692	Glab	Light green	Light yellow	Absent	Present	Lose
Acc. 1803	Glab	Dark green	White	Absent	Present	Lose
Fsd Sorghum	Glab	Light green	White	Absent	Present	Lose
Indian 111	Glab	Light green	Yellow	Absent	Present	Lose
Acc. 1828(2001)	Glab	Light green	White	Absent	Present	Lose
SP-1832	Glab	Dark green	Light green	absent	Present	intermediate
Acc. 1827	Glab	Dark green	White	Absent	Present	compact
Acc. 1763	Glab	Light green	White	Absent	Present	Lose
Fsd Sorghum	Glab	Light green	Dark green	Absent	Present	Lose
Jowar Okara	Glab	Light green	Light yellow	Absent	Present	intermediate
Local Pindi	Glab	Light green	White	Absent	Present	Lose
F-9806	Glab	Dark green	White	Absent	Present	Lose
F-9603	Glab	Light green	Light yellow	Absent	Present	Intermediate
Local Qetta	Glab	Light green	Dark green	Absent	Present	Intermediate
PARC-SV-2	Glab	Light green	Dark green	Absent	Present	Intermediate
Local T.Jam	Glab	Light green	Light green	Absent	Present	Intermediate
T3-Dadu	Glab	Light green	White	Absent	Present	Lose
F-9601	Glab	Light green	White	Absent	Present	Lose
F-9809	Glab	Light green	White	Absent	Present	Compact
BR-*123*	Glab	Light green	White	Absent	Present	Lose
SS-98-5(SS)	Glab	Light green	Light green	Absent	Present	Intermediate
SS-94-4	Glab	Dark green	Yellow	Absent	Present	Lose

Germplasm line PARC-SV-2 took maximum days (81) to reach 50 % maturity. Viswanthan and Francis (2002) also obtained considerable variability for this trait.

Number of nodes, leaves and tillers plant^{-1}

Number of nodes is an important character of sorghum in relation to fodder yield as the leaves are borne on the nodes. Mean data for number of nodes plant^{-1} among the genotypes ranged from 9 to 14. Maximum number of nodes plant^{-1} (14) were observed for accession 1803, 1827 and F-9809, followed by Local Bahawalpur with 13 number of nodes plant^{-1}. Minimum nodes plant^{-1} (9) was recorded for Fsd sorghum. The number of leaves varied form 9 to 14 per plant. Accession 1803, 1827 and F-9809 had maximum number of leaves plant^{-1} (14), followed by Local Bahawalpur having 13 leaves plant^{-1}. Minimum leaves plant^{-1} (9) were recorded in Fsd sorghum. Similar results for leaves plant^{-1} were also observed by Chaudrhy et al. (1990) and Naeem et al. (2002).

The available sorghum germplasm showed variations for tillers plant^{-1}. Maximum tillers plant^{-1} (4) were observed in accession 1728, followed by Fsd sorghum, accession 1763, F-9809 and SS-98-5 (SS), each having 3 tillers plant^{-1}. Minimum tillers plant^{-1} (1) was recorded for genotypes BR-*123*, F-9601, T3-Dadu, Local Quetta, F-9603, F-9806, Local Pindi, SP-1832, accession 1828 (2001) and accession 1803.

Table 2. Mean values for days to 50% flowering (DF), plant height (PH), tiller plant^{-1}, internode length (IL), leaves plant^{-1} (LPP), leaf area (LA), flag leaf area (FLA), peduncle length (PDL), nodes plant^{-1} (NPP), root lodging (RL) and green fodder yield at 50% maturity (GFYHM) of sorghum genotypes.

Accession	DF	PH (cm)	TPP	IL (cm)	LPP	LA (cm^2)	FLA (cm^2)	PL (cm)	NPP	RL (%)	GFYHM (t ha^{-1})
Local Bahawalpur	76	167	2	16	13	270	49	18	13	10	20
Acc. 1728	67	149	4	14	12	570	92	43	12	0	22
Acc. 1692	77	232	2	23	12	393	73	16	12	3	53
Acc. 1803	73	200	1	24	14	322	71	31	14	10	37
Fsd Sorghum	63	174	3	18	9	225	74	33	9	1	46
Indian 111	79	218	2	21	12	387	145	21	12	5	34
Acc. 1828(2001)	79	173	1	14	12	444	129	35	12	0	24
SP-1832	64	156	1	14	12	351	117	35	12	0	33
Acc. 1827	80	147	2	15	14	596	174	25	14	0	27
Acc. 1763	80	209	3	22	12	412	123	24	12	0	58
Fsd Sorghum	63	179	2	19	11	270	65	35	11	0	45
Jowar Okara	65	195	2	23	11	305	90	25	11	2	34
Local Pindi	64	186	1	20	10	263	55	39	10	1	46
F-9806	72	197	1	21	12	407	126	37	12	50	36
F-9603	77	196	1	23	11	350	82	24	11	10	36
Local Qetta	80	177	1	20	11	401	115	32	11	20	32
PARC-SV-2	81	162	2	18	11	280	47	31	11	30	37
Local T.Jam	77	163	2	20	11	270	60	29	11	20	27
T3-Dadu	79	191	1	21	11	292	46	26	11	30	26
F-9601	80	186	1	19	11	269	46	25	11	0	37
F-9809	69	224	3	25	14	359	65	26	14	30	41
BR-*123*	66	211	1	26	10	290	85	33	10	0	43
SS-98-5(SS)	71	216	3	20	12	357	83	25	12	1	50
SS-94-4	77	192	2	21	11	387	112	38	11	10	23

Five observations were used to get the mean values for each trait.

Leaf and flag leaf area (cm^2)

Leaf area is a prominent yield component regarding fodder yield and all the genotypes showed considerable variation for leaf area (Table 2). Genotypes accession 1827 ranked first with a maximum leaf area of 447 cm^2, followed by accession 1728 (428 cm^2) and 1828(2001) (333 cm^2). The minimum leaf area (169 cm^2) was recorded in Fsd Sorghum. Similar variations for leaf area in sorghum were also observed by Chaudrhy et al. (1990), Din et al. (2002) and Nabi et al. (2006).

On the other hand, variations for flag leaf area were observed among the available genotypes as presented in Table 2. Flag leaf area varied from 34 to131 cm^2. Maximum value of 131 cm^2 was observed for accession 1827, followed by Indian 111 and accession 1828(2001) with flag leaf area of 109 and 97 cm^2, respectively. Minimum flag leaf area (34 cm^2) was observed for T3-Dadu and F-9601 each.

Plant height, internode and peduncle length (cm)

Plant height is the main yield component and is directly proportional to yield. Variations were observed for plant height among the genotypes (Table 2). Maximum plant height of 232 cm was recorded for accession 1692, followed by F-9809 (224 cm) and Indian 111 (215 cm) while minimum plant height was recorded for accession 1827 which was 147 cm. Similar results for plant height in sorghum were also recorded by Chaudrhy et al. (1990), Nasim et al. (1993), Naeem et al. (1993), Hussain et al. (1995) and Din et al. (2002).

Furthermore, in all the genotypes, the 6th internode was kept as standard. Variations were observed for internode length as reported in Table 2. Maximum internode length (26 cm) was recorded in BR-123 followed by F-9809 (25 cm) and accession 1803 (24 cm). Minimum internode length of 14 cm was observed for Acc.1728, Acc. 1828(2001) and SP-1832 each. Ayana and Bekele (1999) observed variation for internode length while studying 415 sorghum accessions in Ethiopia.

Moreover, the data reported in Table 2 showed that peduncle length varied from 18 to 43 cm in the evaluated genotypes. Maximum peduncle length of 43 cm was recorded in germplasm line accession 1728, followed by Local Pindi and SS-94-4 with peduncle lengths of 39 and 38 cm, respectively. The minimum peduncle length was 18 cm, recorded in genotype Local Bahawalpur. Ayana and Bekele (1999) also observed variation for peduncle length while studying 415 sorghum accessions in Ethiopia.

Root lodging (percentage)

Variations were observed in the evaluated genotypes for root lodging (Table 2). Most of the available genotypes were resistant to root lodging. However, some of the genotypes were extremely susceptible to lodging. Maximum percentage of root lodging (50 %) was observed in germplasm line F-9806 followed by PARC-SV-2, F-9809 and T3-Dadu, each with a lodging of 30%. However, genotypes BR-123, SS-98-5(SS), F-9601, accession 1728, Fsd sorghum, accessions 1692, 1828(2001), SP-1832, 1827 and 1763, Fsd sorghum, Jowar Okara and Local Pindi were resistant to lodging.

Green fodder yield at 50% maturity (t ha^{-1})

The main objective of all sorghum breeding programs is either grain yield or fodder yield and we are particularly interested in green fodder yield. Variation was found for green fodder yield at 50% maturity in the evaluated sorghum germplasm. Maximum green fodder yield (58 t ha^{-1}) was recorded in accession 1763, followed by accession 1692 (53 t ha^{-1}) and SS-98-5 (SS). Minimum green fodder yield (20 t ha^{-1}) was observed in Local Bahawalpur. Lodhi and Bangarwa (1983), Nasim et al. (1993) and Naeem et al. (1993) also obtained the same results for GFY in sorghum.

Cluster analysis

The qualitative traits dendrogram shows that four clusters were formed at dissimilarity coefficient of 1.63 (Figure 1). The first cluster comprised five genotypes viz. Local Bahawalpur, Indian 111, SS-94-4, Jowar Okara and F-9603. The second cluster comprised ten genotypes viz. accession1692, Fsd Sorghum, accessions 1828 and 1763, BR-123, F9601, Local Pindi, T3 Dadu, accession 1803 and F9606. The third cluster composed of three genotypes viz. accessions 1728, 1827 and F-9809. The fourth cluster consisted of six genotypes viz. SP 1832, Local T. Jam, Fsd Sorghum, Local Quetta and PARC-SV-2.

Meanwhile, the quantitative traits dendrogram indicated differences among the cluster of genotype in the germplasm (Figure 2). Nine clusters were formed at dissimilarity coefficient of 4.00. The first cluster contained only one genotype (Local Bahawalpur). The second cluster comprised seven genotypes; Local T. Jam, Local Quetta, PARC-SV-2, SS-94-4, F9603, F 9601 and T3 Dadu. The third cluster composed of five genotypes; Fsd sorghum, Fsd sorghum, Local Pindi, BR-123 and Jowar Okara. The fourth cluster comprised genotypes accession1827 and SP-1832. The fifth cluster was composed of only one genotype (F 9806). Accessions 1692, 1763 Indian 111 and SS-98-5(ss) were grouped in the sixth cluster. F 9809 and accession 1803 made the seventh clusters, while cluster the eighth and nineth contained accessions 1728 and 1827, respectively. The dendrogram for combined qualitative and quantitative traits showed eight clusters at dissimilarity level of 4.70 (Figure 3). The first cluster comprised seven genotypes viz; Local Bahawalpur, F-9603, F-9601, T3-Dadu, Local Quetta, PARC-sv-2 and Local T.Jam. The second cluster comprised four genotypes viz. Acc. 11692, Acc. 1763, Indian 111 and SS-98-5(SS) , third cluster combined five genotypes (Fsd sorghum, Local Pindi, BR-123, Fsd sorghum and Jowar Okara). The forth cluster comprised three genotype viz. Acc. 1803, F-9806 and SS-94-4. The fifth cluster was composed of two genotypes viz. Acc. 1828 and SP-1832 while the sixth, seventh and eighth clusters consisted genotypes F-9809, Acc. 1728 and Acc. 1827, respectively.

From this study, we concluded that diversity exists among the genotypes of the sorghum germplasm studied. The information obtained from this study will help the breeders in future sorghum breeding programs for green fodder yield. Diversity for sorghum accessions was also reported by Hamblin et al. (2004), Medraui et al. (2007) and Mace et al. (2008).

Conclusions

This study reveals sufficient genetic diversity in the

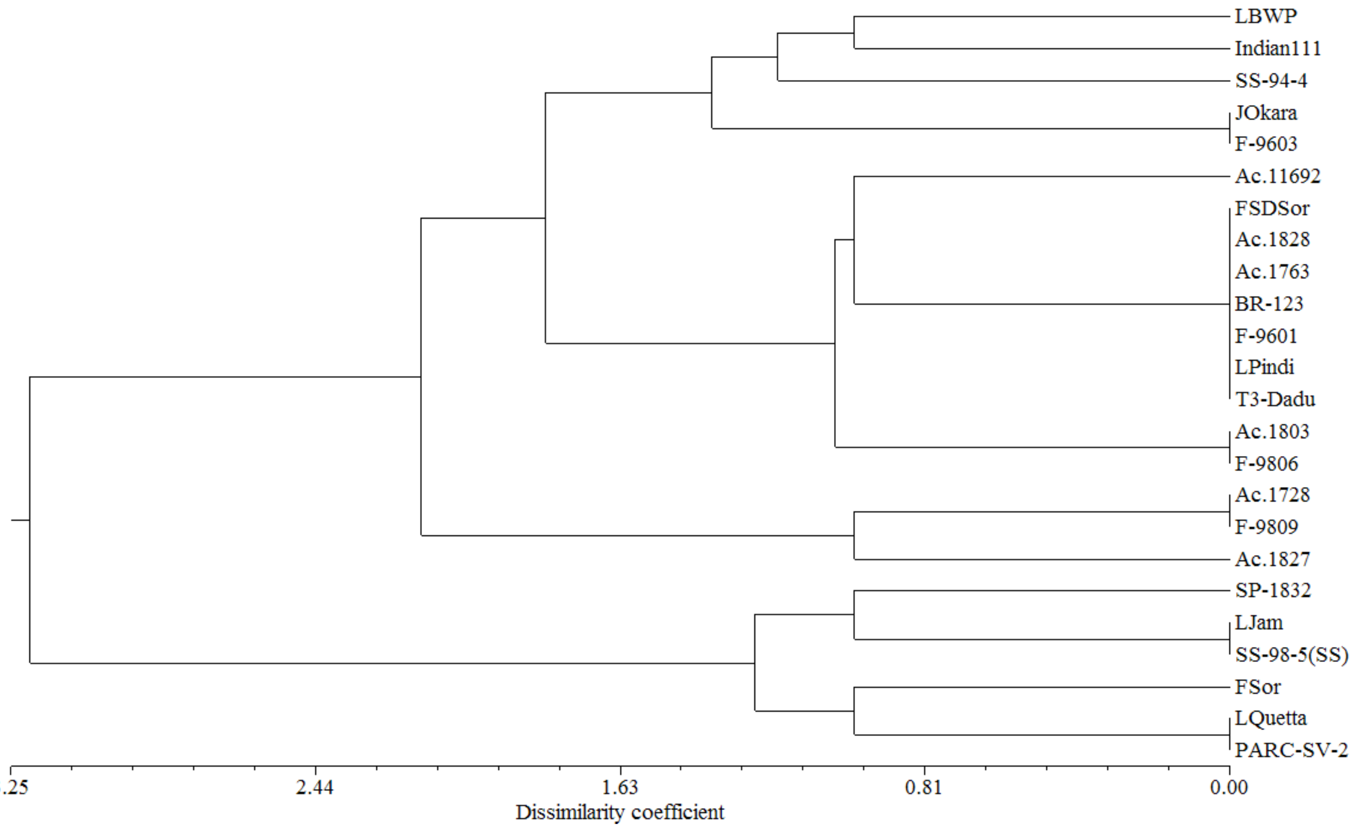

Figure 1. Dendrogram of sorghum germplasm based on dissimilarity matrix of Euclidean distances for qualitative traits.

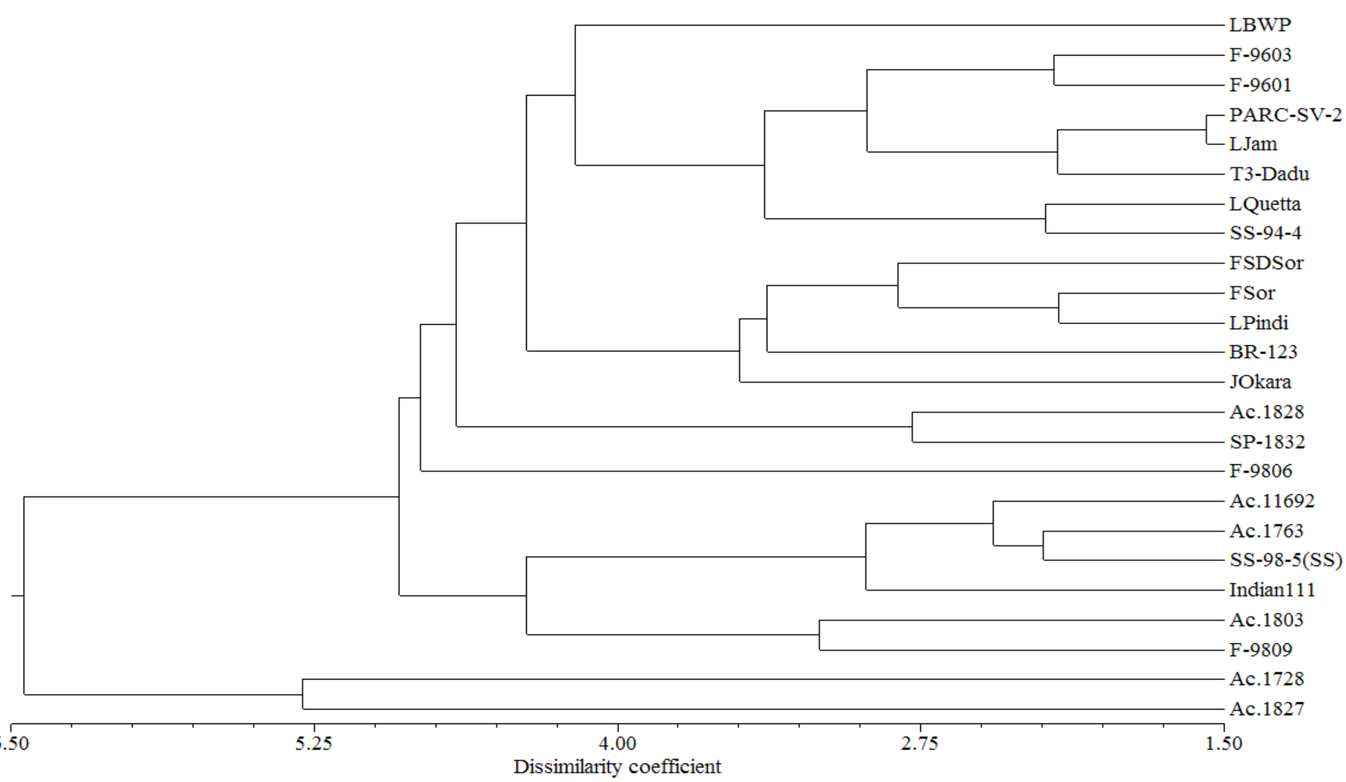

Figure 2. Dendrogram of sorghum germplasm based on dissimilarity matrix of Euclidean distances for quantitative traits.

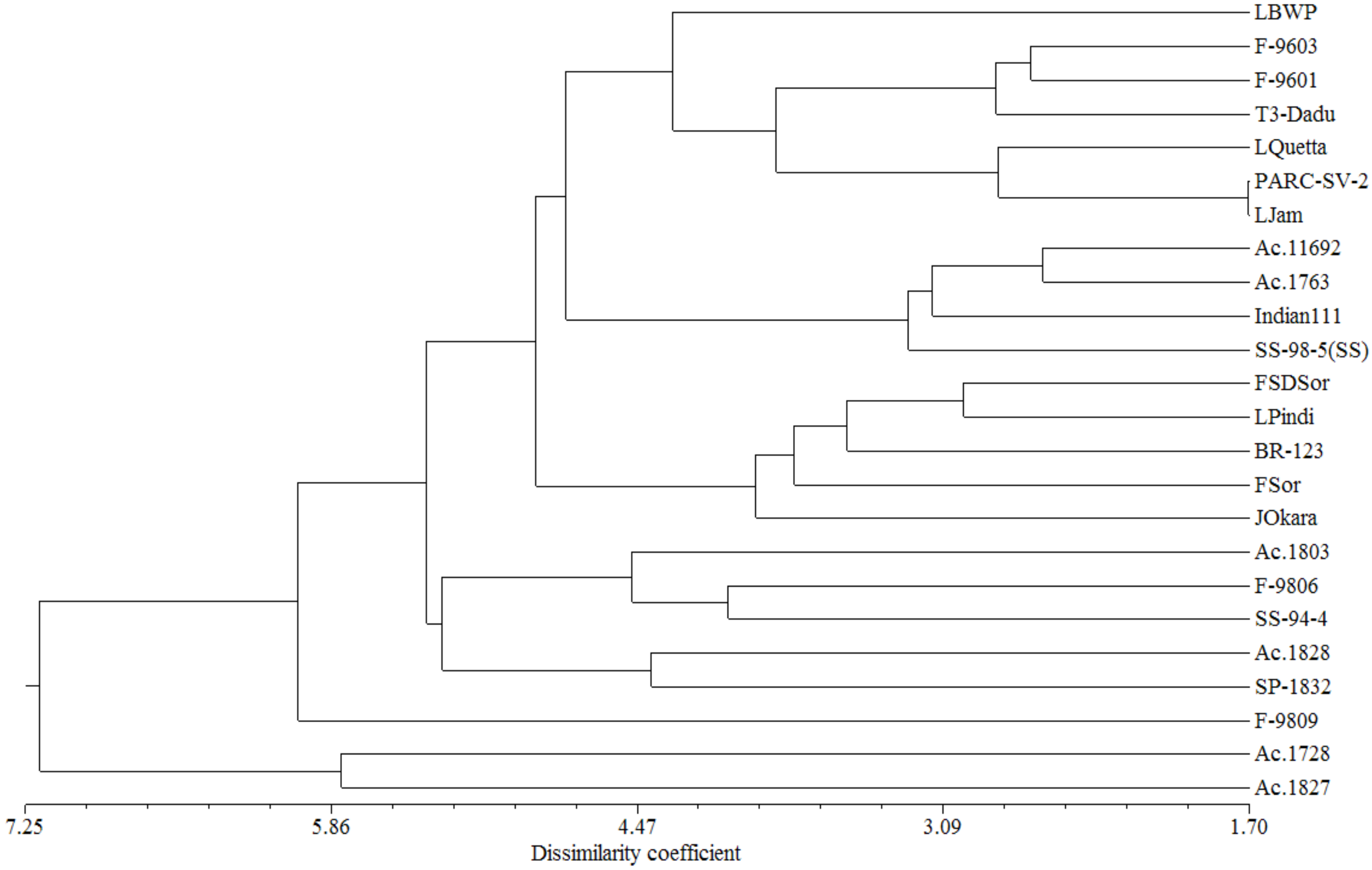

Figure 3. Dendrogram of sorghum germplasm based on dissimilarity matrix of Euclidean distances for both qualitative and quantitative traits.

available sorghum germplasm for different traits. Different genotypes of sorghum displayed potential for selection of the desired characters. Based on maturity traits, Fsd sorghum, Local Pindi and SP-1832 exhibited minimum days to maturity. Acc. 1692, F-9809, Indian 111 and SS-98-5(SS) were the tallest genotypes among the studied accessions. On the basis of leaf area, accessions 1827, 1728, 1828(2001) and 1763 performed well for this trait. Based on green fodder yield, it could be concluded that the accessions 1763, 1692, SS-98-5(SS) and Local Pindi were high yielding genotypes. The above mentioned genotypes can be recommended for commercial cultivation after multi-location trials and their genetic potential can also be exploited in sorghum breeding programs.

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