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Screening of guar accessions [*Cyamopsis tetragonoloba* (L.) Taub.] for higher yield potential under irrigated conditions

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Twelve quantitative traits such as germination percentage, days to 50% flowering, plant height, branches plant^{-1}, clusters plant^{-1}, pod length, days to maturity, 1000-seed weight and grain yield plot^{-1} were studied to determine ample variation and association between 100 Guar [*Cyamopsis tetragonoloba* (L.) Taub.] genotypes to screen out the best performing lines. Variance study of quantitative traits in various genotypes showed substantial level of variability. The largest variation was found for germination percentage, days to 50% flowering, plant height, branches plant^{-1}, clusters plant^{-1}, days to maturity and grain yield plot^{-1}. It was found that grain yield plot^{-1}, was positively correlated with germination percentage, clusters plant^{-1}, pods cluster^{-1}, seeds pod^{-1} and pod length. However, branches plant^{-1} and days to maturity were significant but negatively correlated with grain yield plot^{-1}. Principal component analysis indicated the quantity of variation by principal components 1 to 4 viz., 38.9, 14.7, 10.6 and 8.3%, respectively. Cluster analysis based on different quantitative traits arranged 100 guar accessions into eight groups. Ward clustering method was used to construct dendrogram based on quantitative traits of genotypes. Genotypes having desirable plant traits like early maturity and higher yield potential were screened for guar variety development under irrigated conditions.

Key words: Guar, cluster analysis, variations, principal component analysis, dendrogram, ward cluster method.

INTRODUCTION

Guar [*Cyamopsis tetragonoloba* (L.) Taub.] is commonly known as cluster bean and is a highly self-pollinated crop belonging to the family, Fabaceae (Leguminosae). Its centre of origin is Indo-Pakistan subcontinent (Whistler and Hymowitz, 1979). Guar is a prospective spring summer, annual, legume crop and is drought-tolerant due to its ability to extract water from deep soil layers by its deep tap root system (Farencois et al., 1990). Guar is mainly grown in arid and semi-arid regions of Pakistan, India, South Africa and United States (Ashraf et al., 2005). It requires a hot climate, takes benefit of fertilization (Omer et al., 1993) and irrigation (Alexander et al., 1988).

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Table 1. Phenological data recorded for some quantitative traits.

Trait	Scale	Description of the trait
Days to emergence	Days	No. of days from seed sowing to plant germinate in each accession
Germination %	No.	No. of plants germinate in each accession
Days to 50% flowering	Days	Days count from seed sowing until 50% of plants has a least one flower in each accession
Plant height	cm	Average height of five random plants from ground to apex of stem
Branches plant^{-1}	No.	Total number of branches originating from main stem
Clusters plant^{-1}	No.	Total number of clusters on a single plant
Pod length	cm	Distance from the base to the tip of five randomly selected pod
Pods cluster^{-1}	No.	Total number of pods in a cluster
Seeds pod^{-1}	No	Average no. of seeds obtain from five randomly selected pods
Days to maturity	Days	No. of days from seed sowing to plant reached maturity
1000-seed weight	g	Weight of 1000 randomly dried seeds
Grain yield plot^{-1}	g	Seed weight of accessions in a plot

Guar has a high salinity tolerance (Farencois et al., 1990; Ashraf et al., 2005) and a good capability to fix atmospheric nitrogen (Wetselaar, 1967; Elsheikh and Ibrahim, 1999; Sultan et al., 2012; Sohrawardy and Hossain, 2014).

Seeds of guar contain galactomannans (guar gum, 25-35%) which is being used in wide range of industries such as textile, paint, cosmetics, detergents and food industry as well as stabilizer in ice cream and other frozen desserts (Farencois et al., 1990; Jukanti et al., 2015). Guar gum is also used in numerous pharmaceutical and nutraceutical additives (Morris, 2004; Kays et al., 2006) as well as laxatives, paper, petroleum, oil well drilling, mining industry, meat binder, processed cheese product, sauces, pet foods, dairy products, baby pampers, photography and beverages (Whistle and Hymowitz, 1979; Undersander et al., 1991; Pathak et al., 2010). Seed of guar contain about 4% edible oil (Mehta and Ramakrishanan, 1957), and a protein content ranging between 27 and 37% (Whistler and Hymowitz, 1979). It is also cultivated as a vegetable for human consumption, particularly in Pakistan and India, as a green manure crop and feed for livestock. Recently, guar gum has also been studied as a substitute for fat in human food (Anjum et al., 2001; Zambrano et al., 2004; Arora and Pahuja, 2008) to decrease total caloric content.

In Pakistan, Thal and Tharparkar are the core areas for the guar crop in Punjab and Sindh provinces, respectively. Legume crops play an important role in the economy of arid and semiarid areas of the world as they are a major source of protein (Sohrawardy and Hossain, 2014). Legumes help improve soil fertility because of their inherent capability to fix atmospheric nitrogen (Sohrawardy and Hossain, 2014). This crop is highly drought tolerant and grows well in water deficient areas of these regions. Therefore, there is no other crop like the guar that fits well in cropping patterns of these areas. However, the yield of guar in Pakistan is very low as compared to other countries. The main reason is that the existing varieties of guar have lost their yield potential which results in low yield and causes significant losses to the growers. Therefore, large numbers of accessions of the guar collected from different places were screened and evaluated for yield and other desirable traits under irrigated conditions. Therefore, the main objective of this study was to develop guar varieties having higher yield potential by screening programme.

MATERIALS AND METHODS

The seeds of 100 accessions of the guar were collected from the guar growing areas of various provinces, that is, Punjab, KPK, Sindh, Baluchistan and also from Plant Genetic Resources Institute PGRI, National Agricultural Research Centre, Islamabad. The sowing was conducted on 28 May 2016 and harvesting on 11 November, 2016 in the experimental area of Agricultural Research Station, Bahawalpur. The experiment was laid out according to Augmented Design. Each entry was planted in two rows plot^{-1} with row to row distance of 45 cm at 25 kg ha^{-1} seed rate. The sowing was done with single row hand drill and after germination, plant to plant distance of 15 cm was maintained by manual thinning. For weed control, Pendimathline at 2.5L ha^{-1} was sprayed as weedicide at the time of land preparation. Cultural and agronomic practices were applied from sowing to the maturity stage for healthy and vigorous plants. Fertilizer N-P-K was applied at 30-60-60 kg ha^{-1}. Three irrigations, first at the time of 35-40 days after sowing, 2nd irrigations at the time of flowering and last at the time of pod formation were applied. At maturity, the data concerning the quantitative traits were recorded on five randomly selected plants from each entry viz., days to emergence, germination percentage, 50% flowering, plant height, number of branches plant^{-1}, clusters plant^{-1}, pods cluster^{-1}, pod length, number of seeds pod^{-1}, days to maturity, 1000-seed weight and grain yield plot^{-1} were used for statistical analysis (Table 1). Crop was harvested when more than 90% pods turned brown in color in each accession.

The means data were statistically analyzed, to calculate means, frequency distribution, standard deviation and simple correlation coefficients. Data were analyzed for variation using computer software Minitab 15 for windows (Minitab Inc.2007). Wards method was used to construct the dendrogram and distance between the accessions as an estimate of the genetic distances (Ward 1963). The means for quantitative traits within each cluster were calculated to estimate the inter cluster variation.

Table 2. Basic statistics of quantitative traits in guar accessions.

Trait	Mini	Maxi	Mean	SD	CV%	Variance
Days to emergence	2	5	3	0.78	26	0.60
Germination %	50	9	72	8.79	12.2	77.2
Days to 50% Flowering	53	85	70.5	9.9	14.0	98
Plant height	72	234.4	155.6	36.69	23.6	1346
Branches plant^{-1}	0	25.8	7.5	8.05	107.3	64
Clusters plant^{-1}	9.4	37.4	31.9	10.99	34.5	120.7
Pods cluster^{-1}	2.2	15	8.4	0.56	6.7	0.31
Pod length	4.14	7.76	5.18	4.68	90.4	21.9
Seeds pod^{-1}	5.2	11.4	8.5	1.14	13.4	1.29
Days to maturity	124	149	136.5	9.14	6.7	83.5
1000-seed weight	21.2	30.1	24.35	3.18	13	10.1
Grain yield plot^{-1}	192.39	493.86	369.4	72.9	19.9	5314

Table 3. Correlation coefficients among various quantitative traits.

Trait	DE	G%	D.50%F	P.H	B/P	C/P	P/C	P. L	S/P	D.M	1000S.W	G.Y/P
D.E	1											
G%	-0.04	1										
D.50%F	0.16	0.06	1									
P.H	0.01	0.39	-0.04	1								
B/P	0.06	-0.37**	0.34**	-0.5*	1							
C/P	-0.13	0.13	-0.21	0.28	-0.36	1						
P/C	0.02	0.4**	-0.25**	0.42**	-0.72	0.39*	1					
P. L	0.03	0.31	-0.1	0.23	-0.3	0.13	0.22	1				
S/P	0.06	0.35	-0.1	0.23	-0.3	0.21	0.24	0.92	1			
D.M	-0.02	-0.42	0.29	-0.5	0.80	-0.28	-0.68	-0.37	-0.34	1		
1000-S.W	0.28	-0.19	0.29	-0.1	0.4	-0.33	-0.28	0.04	-0.03	0.5*	1	
G.Y/P	-0.001	0.7**	-0.18	0.445	-0.7	0.29	0.6**	0.36	0.36	-0.8**	-0.27	1

Traits= DE (Days to emergence), G% (Germination percentage), D. 50% F (Days to 50% flowering), P.H (Plant height), B/P (Branches plant^{-1}), C/P (Clusters plant^{-1}), P/C (Pods Cluster^{1}) P. L (Pod length), S/ P (Seeds pod^{-1}), D. M (Days to maturity), 1000-S.W (1000-seed weight), G.Y/P (Grain yield plot^{-1}).

RESULTS AND DISCUSSION

The analysis of variation described substantial level of variability between various accessions for a number of quantitative traits. Basic statistics (mean, standard deviation and coefficient of variation) for quantitative traits are presented in Table 2. Accessions differed in numerous traits of different pattern of variation and economic importance between the accessions was shown for different quantitative traits. The largest variation was present for germination percentage, days to 50% flowering, plant height (cm), branches plant^{-1}, clusters plant^{-1}, pod length (cm), days to maturity, 1000-seed weight (g) and grain yield plot^{-1} (g). Comparatively, low variation below 3% was shown for days to emergence, pods cluster^{-1} and seeds pod^{-1} (Morris, 2007, 2008, 2010). Similar findings are in agreement with the present study. Pod length and branches plant^{-1} have strong relationship results in agreement with Krishnan et al. (2011).

Correlation coefficient for different quantitative traits was arranged in Table 3. Clusters plant^{-1} and pods cluster^{-1} were positively correlated with grain yield plot^{-1} (Sultan et al., 2012; Rai et al., 2012). The trait of 1000-seed weight was negatively correlated with pods cluster^{-1}, while it indicated positive correlation with grain yield plot^{-1} and pod length results agreement with Morris (2010) and Manivannan et al. (2015).

Variations among 100-guar accessions were estimated by using principal component analysis. A total of 72.5% variability between the accessions for quantitative traits was observed for first five principal components (Table 4). First principal component (PC1) showed a 38.9% variance of the total variation. Similarly, PC2 showed14.7%, PC3 10.6% and PC4 8.3% of the total variation. PC1 showed variation in days to emergence, days to 50% flowering, days to maturity and branched plant^{-1} (Figure 1). PC2 was generally correlated with days

Table 4. Principle components for 12 quantitative traits in Guar.

Trait	PC1	PC2	PC3	PC4
Eigenvalue	4.65	1.76	1.26	0.99
Cumulative eigenvalue	4.65	6.41	7.67	8.66
Proportion of variance	38.9	14.7	10.6	8.3
Cumulative variance	38.9	53.6	64.2	72.5
Eigenvectors				
Days to emergence	0.03	0.31	-0.41	0.63
Germination %	-0.29	-0.16	-0.26	-0.48
Day to 50% flower	0.15	0.29	-0.43	-0.45
Plant height	-0.28	0.03	-0.27	-0.09
Branches plant^{-1}	0.39	0.15	0.08	-0.17
Clusters plant^{-1}	-0.21	-0.2	0.21	-0.01
Pods cluster^{-1}	-0.3	-0.12	-0.17	0.19
Pod length	-0.24	-0.2	0.51	0.39
Seeds pod^{-1}	-0.25	0.49	0.4	-0.01
Days to maturity	0.4	0.08	0.1	-0.16
1000-seed weight	0.19	0.43	-0.2	0.19
Grain yield plot^{-1}	-0.39	0.02	-0.2	-0.11

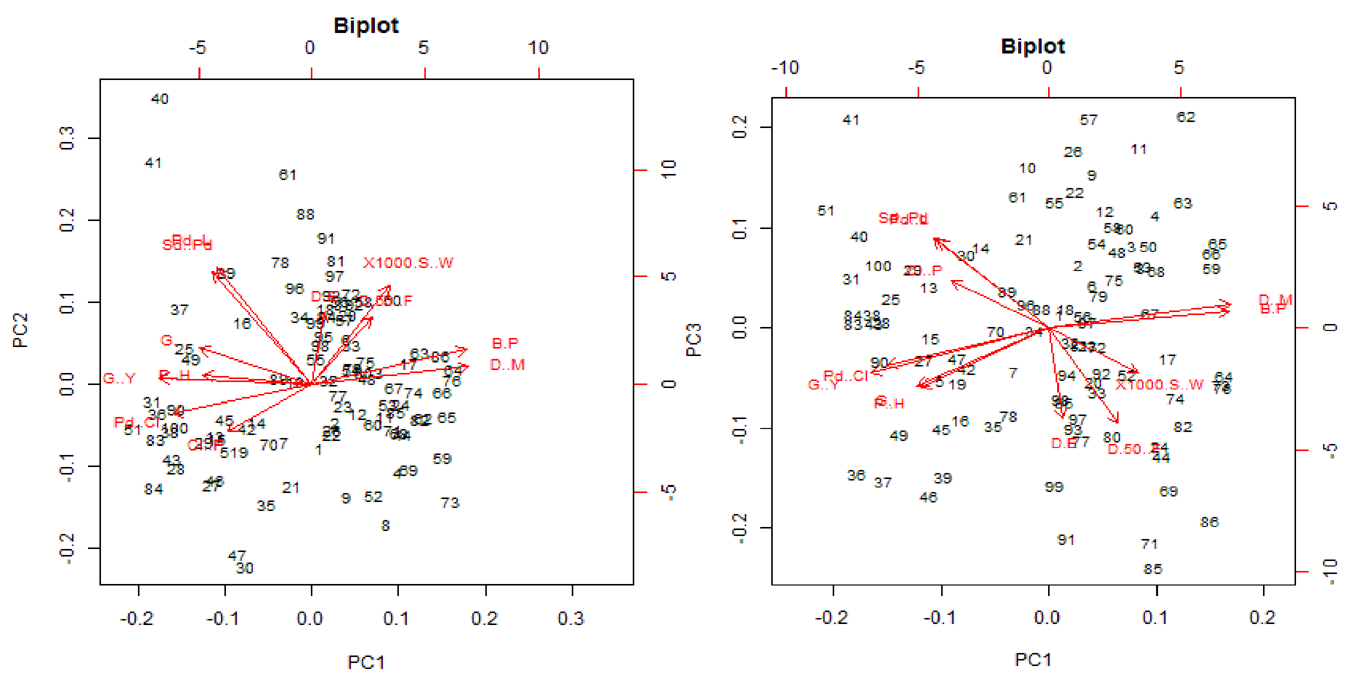

Figure 1. Contribution of quantitative traits in the first three principal components.

to emergence, days to 50% flowering, branched plant^{-1}, plant height, seeds pod^{-1}, 1000-seed weight, days to maturity and grain yield plot^{-1}. PC3 was associated with pod length, clusters plant^{-1} and seeds pod^{-1}, whereas 1000-seed weight, pod length, pods cluster^{-1} and PC4 made positive correlation with days to emergence but with very small degree.

Cluster analysis

Accessions were arranged into 8 clusters at 13% genetic distance from each other on the basis of cluster analysis (Figures 2 and 3). The highest mean for grain yield plot^{-1} were found in cluster-1 while cluster-5 had the lowest (Table 6). Since guar is mostly grown for yield and best fit

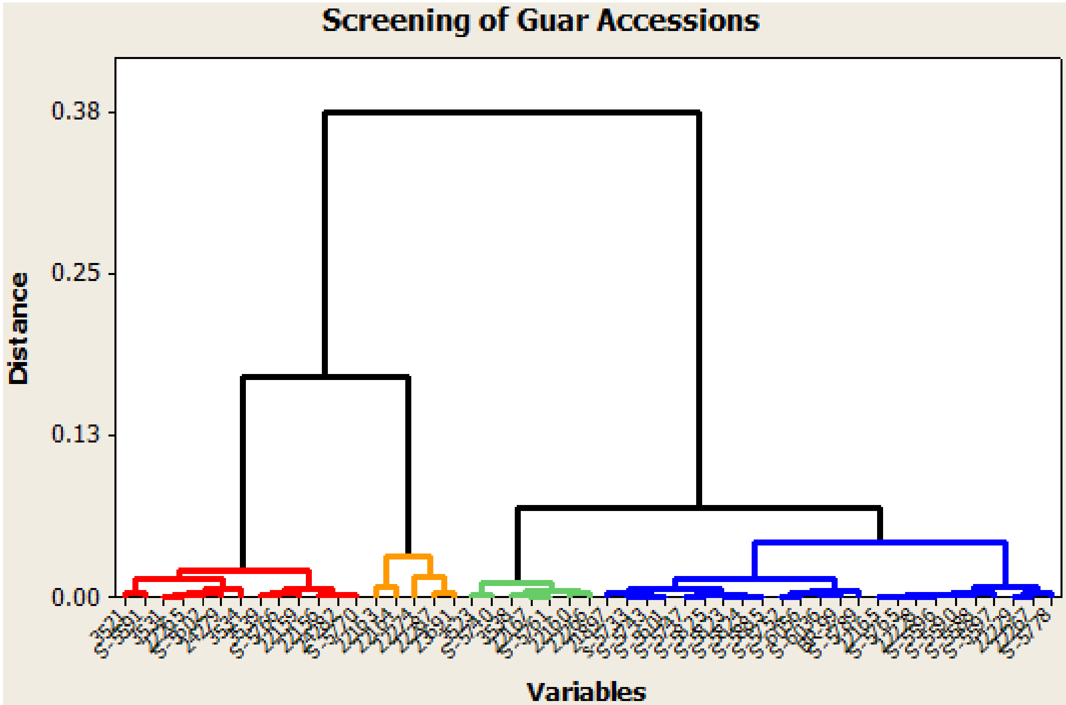

Figure 2. Dendrogram of 50 accessions of guar germplasm obtained through cluster analysis.

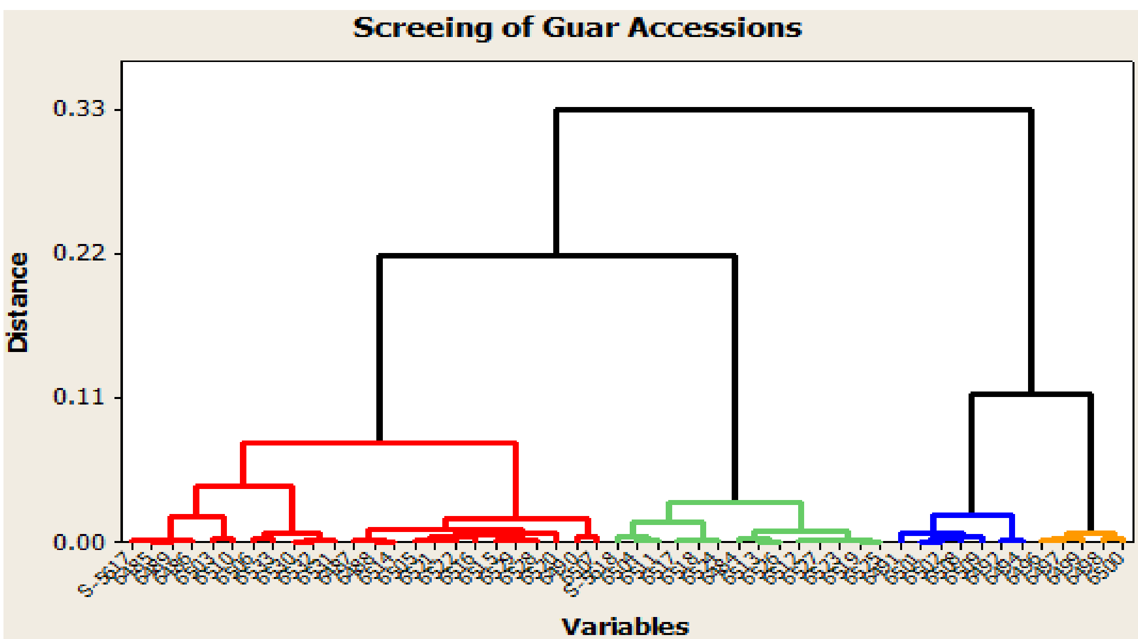

Figure 3. Dendrogram of 50 accessions of guar germplasm obtained through cluster analysis.

in cropping pattern, so, accessions in cluster-1 can be used to develop cultivars with more yield and early maturity. Inter cluster variation was found for branches plant^{-1} which was highest in case of cluster-5 and lowest in cluster-1, so branches have negative relation with grain yield plot^{-1}. Maximum seeds pod^{-1} were found in cluster-1 and minimum in cluster-5. The accessions of guar having mostly zero branches were found in cluster-1 which are very useful for yield improvement program (Table 5). Colors shows similarities distance within accessions of

Table 5. List of guar some accessions screened for higher yield.

Acc.	D.E	G%	50% F	P. H	B/P	C/P	P/C	P.L	S/P	D.M	1000-SW	G.Y/P
5733	3	85	59	191.8	0	28	8	5.72	9.2	136	27.8	421.68
5747	4	75	48	183.4	0	26.2	7.2	5.36	8	125	23.5	431.55
5752	3	80	55	170.8	0.2	27.4	5.8	5.52	8.2	135	24.4	435.59
5789	3	75	70	144.2	0.2	21	2.4	4.7	6.6	130	23.7	457.36
5823	3	85	60	206.8	0	20.8	15	5.2	8	133	28	490.34
5824	4	88	65	201.8	0	21.8	10.6	5.58	8.6	135	28.9	469.32
5825	3	80	56	206.4	0	21.2	6.8	5.62	8.4	128	23.5	449.8
5885	4	85	70	209	7.3	22.6	4.6	5.62	8.4	130	29.3	493.86
6036	3	80	80	182.8	5.2	20.4	6.2	7.76	10.8	127	29.6	478.46
6056	3	80	57	175.2	6	19.6	9.6	7.54	11.2	135	28.6	446.44
5588	4	65	53	216.2	0.2	23.4	3.4	5.18	7.6	135	26.5	439.1
BR-99	3	72	60	175	0	26.4	6	5.4	9.2	125	23.8	470.8

Table 6. Inter cluster variation for different quantitative characters in guar.

Cluster	No. of acc.	Means value											
		DE	G%	50%F	PH	B/P	C/P	P/C	P.L	S/P	D.M	1000-SW	G.Y/P
Clustr-1	25	3.2	78.3	61.9	192.7	1.4	24.6	7.7	5.5	8.2	134.3	26.3	426.6
Clustr-2	7	2.9	78.6	62.6	140	10.2	28.2	4.7	5.4	7.9	143.4	25.1	370.3
Clustr-3	13	2.9	70.4	70	156.5	14.4	24.9	3.9	5.0	7.5	147	26.3	314.4
Clustr-4	5	3	65.8	60.7	188.5	11.9	23.3	2.6	5.3	8.1	146.7	27.1	254.3
Clustr-5	5	3.7	78.4	67.1	159.5	6.3	24.2	6.3	5.3	8.1	135.6	25.7	399.4
Clustr-6	7	3.6	72.9	62.6	88.7	16.3	18.4	2.8	5.1	7.8	148.1	27	329.3
Clustr-7	14	3.7	71.2	69.8	162.2	15.4	20.6	3.4	5.1	7.7	145.6	27.7	305.8
Clustr-8	24	3.6	57.6	63.6	94.9	18.4	16.2	2.5	5.2	7.3	148	27.2	230.1

Table 7. List of guar accessions in cluster.

Color	Cluster	Names of accessions
Blue	Clustr-1	5778, 22267, 22229, 5597, 5588, 5590, 5596, 22228, 5765, 22165, 5789, BR-99, 6036, 6056, 5557, 5752, 5885, 5824, 5823, 5825, 5747, 5601, 5743, 5733, 21897
	Clustr-6	6494, 6497, 6509, 6508, 6502, 6501, 6491
Green	Clustr-2	22266, 22160, 5761, 22167, 3538, 5740, 3523,
	Clustr-7	6525, 6519, 6523, 6527, 6512, 6526, 6513, 6484, 6524, 6518, 6517, 6511, 6504, 5618
Red	Clustr-3	5770, 24282, 22156, 22159, 5766, 3539, 3534, 24279, 5602, 22265, 3531, 5591, 3521
	Clustr-8	6507, 6490, 6520, 6528, 6529, 6515, 6516, 6522, 6521, 6505, 6514, 6488, 6487, 6531, 6532, 6530, 6533, 6506, 6510, 6503, 6486, 6489, 6485, 5617
Brown	Clustr-4	23691, 22287, 22274, 22164, 22163
	Clustr-5	6500, 6498, 6499, 6497, 6496,

cluster, clusters right to left show decrease in trait potential while, right sides of both figures of the dendrogram show maximum trait potential. All the accessions showed similarity within cluster as compared to the clusters (Table 7).

Conclusion

It is concluded that accessions in clusters-1 and 5 were the best performer with regards to grain yield, plant height, number of pods plant^{-1} and number of grains pod^{-1}

having compact plant type. The correlation studies revealed that number of branches plant^{-1} was negatively correlated with grain yield, plant height, number of pods plant^{-1} and number of grains pod^{-1}, while all the other characters were positively correlated with one another. The accessions in clusters-1 and 5 will be used for the improvement of yield potential and evolution of new cultivars of guar.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest.

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