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SEED MASS VARIATION IN SEED LOTS OF FIFTEEN GERMPLASMS OF GUAR [*CYAMOPSIS TETRAGONOLOBA* (L.) TAUB.]

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ABSTRACT

Seed weight variation is in fifteen guar germplasms of Pakistan is investigated. The mean individual seed weight of the germplasms was found to follow an order as given below (mean seed wt. (mg) given in parenthesis).

S – 5798 (35.52mg) ≈ BR-90 (35.33) > S -5784 (33.66) > S -5797 (32.49) = S -5733 (32.48) > BR- 2/1(31.88) > S - 5785 (30.33) = S – 5759 (30.32) > BR-2017 (29.90) ≈ S5825 (29.36) ≈ S -5747(29.19) > BR- 99 > S (28.96) S - 5765 (28.16) ≈ S - 5742 (27.91) ≈ S – 5761 (27.95).

Seed weight distribution in all germplasms tested, except S 5765, was symmetrical with insignificant KS-z values. Seed weight distribution of line S 5765 was leptokurtic ($g2 = 1.088$) and negatively skewed ($g1 = - 0.761$) with KS-z: 1.362 ($p < 0.047$). The seed weight distribution of pooled sample of seeds ($N = 1500$) was asymmetrical (KS-z = 1.830, $p < 0.002$). The mean seed weight averaged to 30.82 ± 0.1539 mg varying from 11 to 51 mg (CV: 19.33%).

Inter-germplasm similarity varied considerably. Cluster analysis indicated that there were only two broader groups on the basis of group extraction at 12 % dissimilarity – cluster I harbouring lighter seeded (≤ 30 mg) and cluster II with heavier seeded (≥ 30 mg) germplasms. On the basis of group extraction at a distance of 3% dissimilarity, six clusters were identifiable. Cluster 1-3 was composed of low seed weight germplasms (≥ 30 mg) and cluster 4-6 composed of higher seed weight germplasms (≥ 30 mg). The results are discussed in view of available literature on guar of Pakistan.

Key words: Guar [*Cyamopsis tetragonoloba* (L.) Taub.], Guar varieties and lines, Seed weight variation

INTRODUCTION

Guar (Sanskrit “go” or “gav”) or cluster bean (*Cyamopsis teteragonoloba* (L.) Taub.) is an annual semelparous legume of great economic importance in arid and semi-arid areas. It bears around 122 names in various languages (Whisller and Hymowitz, 1979). It shows a life cycle of 80-160 days. It is drought resistant and called non-thirsty crop in spate irrigation areas. Guar originated in Indo-Pak subcontinent (Purseglove, 1981; Whistler and Hymowitz, 1979). It is the best adapted crop to tropical and subtropical regions. It is mainly cultivated in India, Pakistan and USA (Sortino and Gresta, 2007). This crop is tolerant to insect pests but highly sensitive to row spacing – optimum row spacing is reported to be 30 cm (Akhtar *et al.,* 2012). A great range of germplasm diversity of guar exists in Pakistan. Sultan *et al. (*2013) have investigated genetic diversity in 30 land races of guar. Sultan *et al. (*2012) have studied genotypic divergence in 101 accessions and identified promising genotypes. Guar has multiple uses – Vegetable, forage, and cover crop (Arora and Pahuja, 2008). It enhances soil productivity by fixing atmospheric nitrogen (Bewal *et al.*, 2009). Several pharmaceutical and nutraceutical products are made from this valuable plant. Guar seed contain substantial amount of endosperm (35-42% of the seed) (El-Daw, 1994). The seeds of guar have generally moisture 11.13 ± 0.06, ash 3.49 ± 0.06, crude protein 29.10 ± 0.01, crude fat 1.58 ± 0.01, crude fiber 9.01 ± 0.01 and carbohydrate 45.70 ± 0.05% (El-Daw, 1994). Endosperm carbohydrate is referred to as ‘guar gum’ or ‘guaran’ which is rapidly hydrating carbohydrate polymer and highly valued industrially owing to the presence of galactomannan which is effective also in osteoarthritis, transdermal drug delivery system as cancer therapy specially in treatment of colorectal cancer (Elias *et al.,* 2010; Shyale *et al.,* 2006, Patel *et al.*, 2014), in food (ice cream manufacture), explosive (dynamite placement in rock crevices), paper industry, textile, cosmetics and tobacco industry (El-Daw, 1994).

According to Vahidy and Yousufzai (1991) there is no true breeding cultivar of guar grown in Pakistan. The locally available seeds are generally recognized by their sources. However, some varieties (var. BR-90. BR-99, BR-2/1 and BR-2017) have now been developed and released for general cultivation by Agricultural Research Station, Bahawalpur. An agronomic description of the varieties and lines in hand, to investigate their seed weight variation, is given in Table 1.

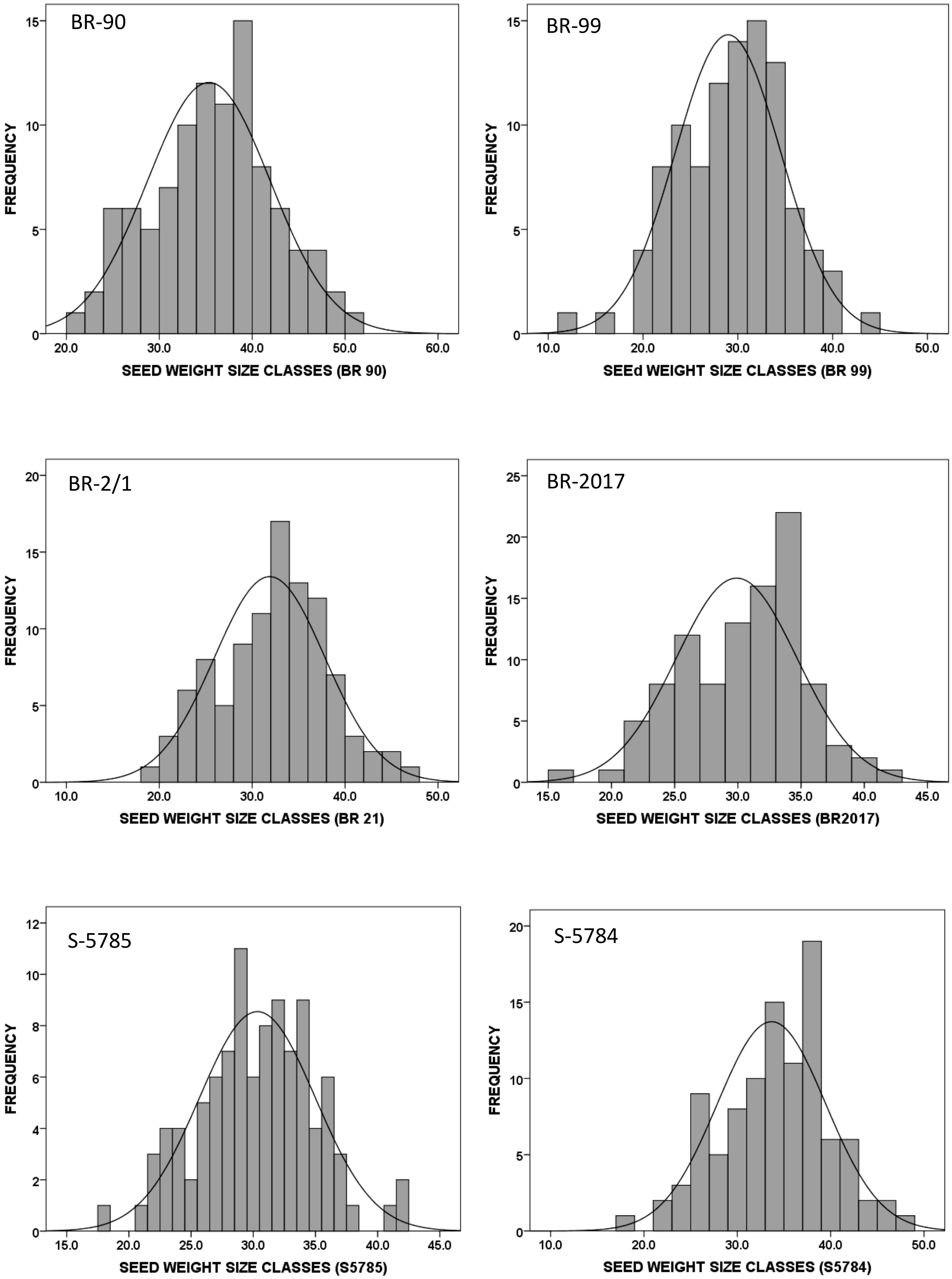
MATERIALS AND METHODS

One hundred seeds randomly drawn from each of the lots of fifteen guar germplasms supplied by Regional Agricultural Research Station, Bahawalpur, Pakistan, were weighed individually on an electronic balance with an accuracy of 0.1 mg. The location and dispersion parameters for each germplasm were calculated. The symmetry, skewness and kurtosis were calculated (Sokal and Rholf, 1995). Normal distribution of seed mass data was tested by Kolmogorov-Smirnoff test (KS-z test). This test assesses whether the observations could reasonably have come from the population following normal distribution. The germplasms were compared on the basis of seed size and they were linked by hierarchical cluster analysis by Ward’s (1963) method using Euclidean distances with respect to their seed masses. The statistical analyses were performed with software viz. ‘SPSS version ‘19’.

Table 1.Morphological traits of some guar varieties / lines.*

Variety/ Lines	**Year of Release**	**Yield Potential (Kg ha^{-1})**	**Salient Features**
BR2/1	1984	Grain Yield = 1200 Kg ha^{-1} Fodder Yield = 26 t ha^{-1}	Hairy, Long stature, long duration, branched, grain bold & dark brown, suitable for fodder purpose.
BR-90	1991	Grain Yield = 1400 Kg ha^{-1} Fodder Yield = 28 t ha^{-1}	Hairy, short stature, long duration, profusely branched, golden grain colour, suitable for fodder & grain purpose
BR-99	2000	Grain Yield = 1900 Kg ha^{-1} Fodder Yield = 30 t ha^{-1}	Hairy, Single stemmed, no branching, medium duration, seed colour-grey, tolerant to sucking pests and diseases, suitable for grain, fodder and vegetable purposes.
BR-2017	2017	Grain Yield = 2400 Kg ha^{-1} Fodder Yield = 35 t ha^{-1}	Hairy, erect type, 0-1 branch, higher gum & protein contents, early maturing and short duration variety with heavy fruiting, requires very low inputs, tolerant to sucking pests and diseases, suitable for grain, fodder and vegetable purposes.
S-5274	-		**Approved as BR-2017**
S-5733	Advance line under testing in yield trials	Grain Yield = 1800 Kg ha^{-1} Fodder Yield = 29 t ha^{-1}	Hairy, erect type with 1-3 branches, long duration, tolerant to insect pests & diseases suitable for fodder and seed purposes.
S-5742	-do-	Grain Yield= 1750 Kg ha^{-1} Fodder Yield= 32 t ha^{-1}	Hairy, single stemmed with no branch, early maturing, tolerant to insect pests & diseases, suitable for seed and vegetable purposes.
S-5747	-do-	Grain Yield= 1900 Kg ha^{-1} Fodder Yield= 26 t ha^{-1}	Hairy, erect type with no branch, short duration, tolerant to insect pests & diseases, suitable for seed and vegetable purposes.
S-5759	-do-	Grain Yield= 1700 Kg ha^{-1} Fodder Yield= 27 t ha^{-1}	Hairy, erect type with no branch, short duration, tolerant to insect pests & diseases, suitable for seed and vegetable purposes.
S-5761	-do-	Grain Yield= 1900 Kg ha^{-1} Fodder Yield= 30 t ha^{-1}	Hairy, 0-1 branch, early maturing & short duration, tolerant to insect pests & diseases, suitable for seed, fodder and vegetable purposes.
S-5765	-do-	Grain Yield= 2000 Kg ha^{-1} Fodder Yield= 34 t ha^{-1}	Hairy, no branch, erect type, early maturing & short duration, tolerant to insect pests & diseases, suitable for seed, fodder and vegetable purposes.
S-5784	-do-	Grain Yield= 1800 Kg ha^{-1} Fodder Yield= 24 t ha^{-1}	Hairy, non-branched, early maturing, tolerant to insect pests & diseases, suitable for seed purpose.
S-5785	-do-	Grain Yield = 2200 Kg ha^{-1} Fodder Yield = 22 t ha^{-1}	Hairy, branches 2-4, long duration, tolerant to insect pests & diseases, suitable for seed purpose.
S-5797	-do-	Grain Yield= 1400 Kg ha^{-1} Fodder Yield= 34 t ha^{-1}	Hairy, branches 6-10, long duration, tolerant to insect pests & diseases, suitable for fodder purpose.
S-5798	-do-	Grain Yield = 1300 Kg ha^{-1} Fodder Yield = 33 t ha^{-1}	Hairy, branches 8-10, long duration, tolerant to insect pests & diseases, suitable for fodder purpose.
S-5825	-do-	Grain Yield = 1500 Kg ha^{-1} Fodder Yield = 32 t ha^{-1}	Hairy, branched, long duration, tolerant to insect pests & diseases, suitable for fodder purpose.

*, Courtesy Regional Agricultural Research Station, Bahawalpur, Pakistan.



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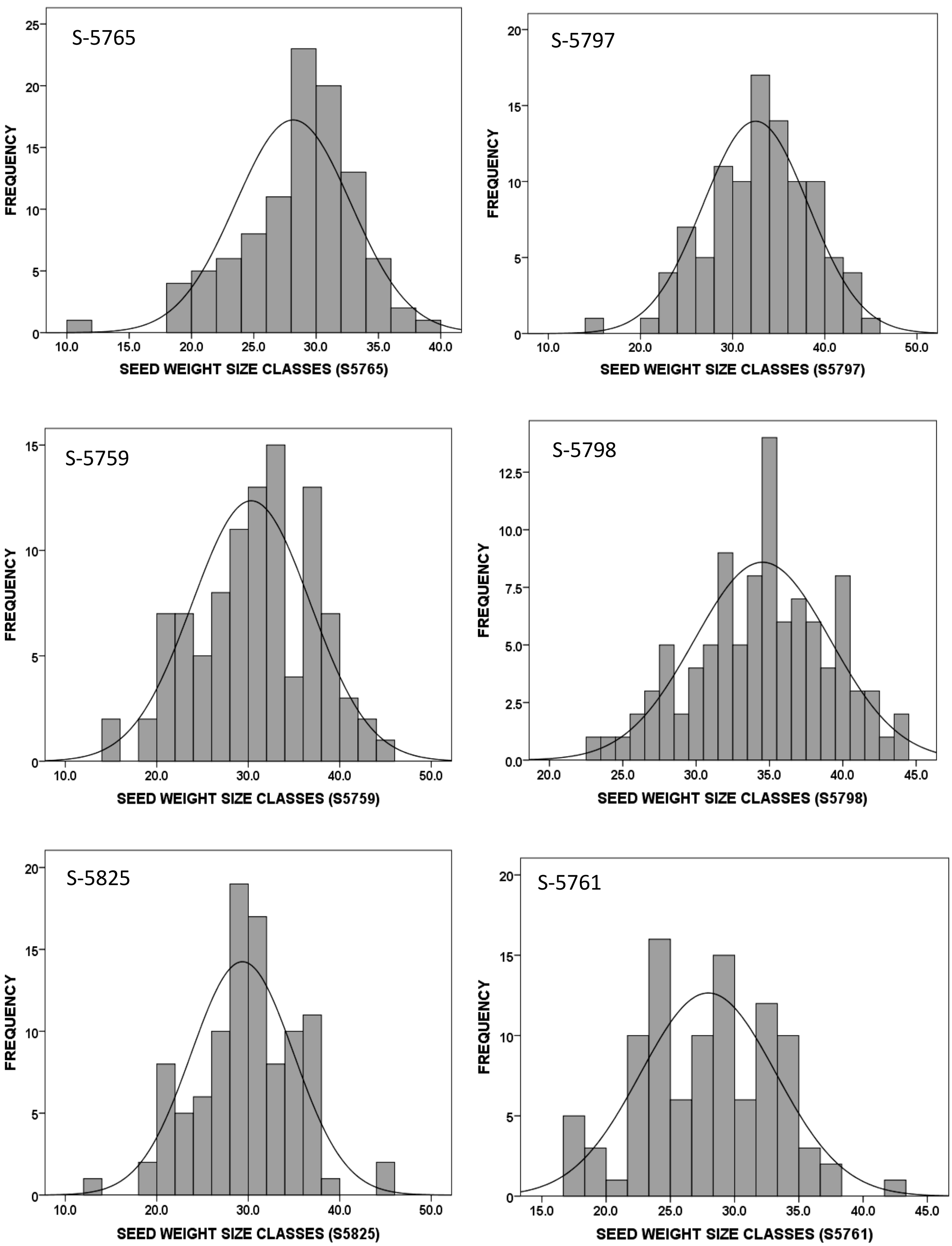

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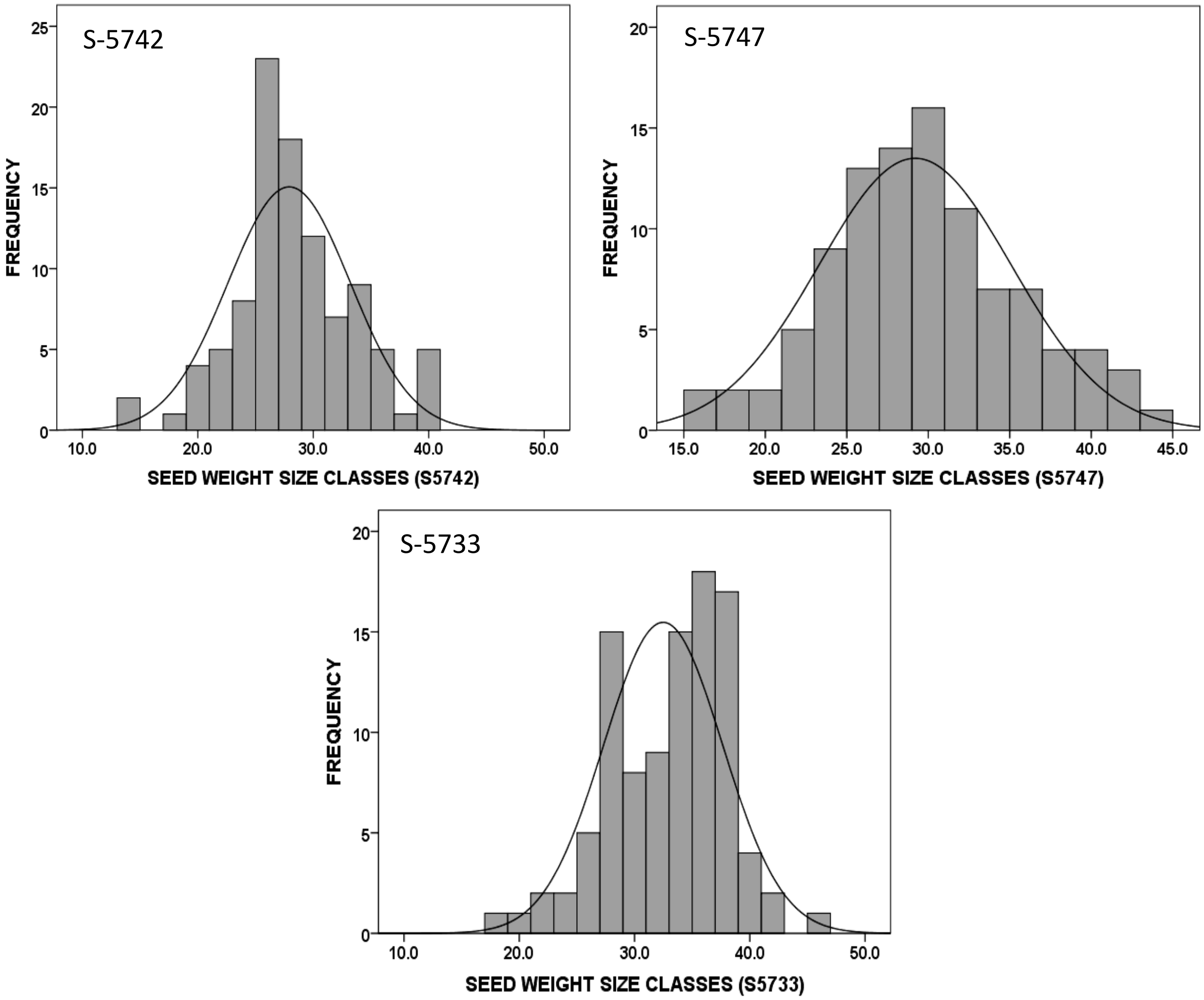

Fig. 1. Frequency distribution of seed weight of fifteen germplasms of guar. In each case N = 100 seeds. The location and dispersion parameters of the distribution are given in Table 1.

Table 2. Location and dispersion of seed mass of various guar varieties. (N = 100 in each germplasm).

Varieties	Mean	SE	CV (%)	Mode	Min	Max	G1	G2	KS-z	p	Dist.	Ratio **
BR 90	35.33	0.6626	18.75	35 *	21.0	51.0	-0.118	-0.442	0.701	0.709	S	0.050
BR 99	28.96	0.5569	19.22	30	12.0	43.0	-0.2510	0.173	0.941	0.339	S	0.063
BR 2/1	31.88	0.5955	17.47	33 *	19.0	47.0	-0.009	-0.196	0.780	0.576	S	0.046
BR 2017	29.90	0.4792	16.03	33	16.0	42.0	-0.343	-0.033	1.108	0.172	S	0.064
S 5785	30.33	0.4667	15.38	29	18.0	42.0	-0.020	0.008	0.598	0.867	S	0.100
S 5784	33.66	0.5814	17.27	37	18.0	48.0	-0.215	-0.091	1.033	0.236	S	0.075
S 5765	28.16	0.4631	16.45	28	11.0	38.0	-0.761	1.088	1.362	0.049	AS	0.059
S5797	32.49	0.5711	17.58	33	15.0	45.0	-0.314	-0.013	0.856	0.457	S	0.041
S 5759	30.32	0.6458	21.30	31 *	14.0	45.0	-0.255	-0.292	0.917	0.371	S	0.063
S5798	35.52	0.4644	13.45	35	23.0	44.0	-0.216	-0.372	0.812	0.525	S	0.039
S 5825	29.36	0.5600	19.07	29 *	13.0	44.0	-0.127	0.204	0.841	0.480	S	0.047
S 5742	27.91	0.5279	18.98	26	14.0	40.0	0.105	0.373	1.085	0.190	S	0.053
S 5747	29.19	0.5911	20.25	25	16.0	43.0	0.207	-0.174	0.755	0.619	S	0.073
S 5733	32.48	0.5155	18.87	33 *	18.0	46.0	-0.397	-0.029	1.102	0.176	S	0.055
S 5761	27.95	0.5256	18.80	29	17.0	43.0	-0.045	-0.219	0.695	0.720	S	0.063

g1, skewness, g2 kurtosis, SEg1 = 0.241; SEg2 Kurtosis = 0.478; Dist., Distribution, – S, symmetrical, AS, Asymmetrical. *, Multiple modes exist. The smallest value is shown. **, grain / fodder ratio calculated on the basis of grain and fodder yield data given in Table 1.

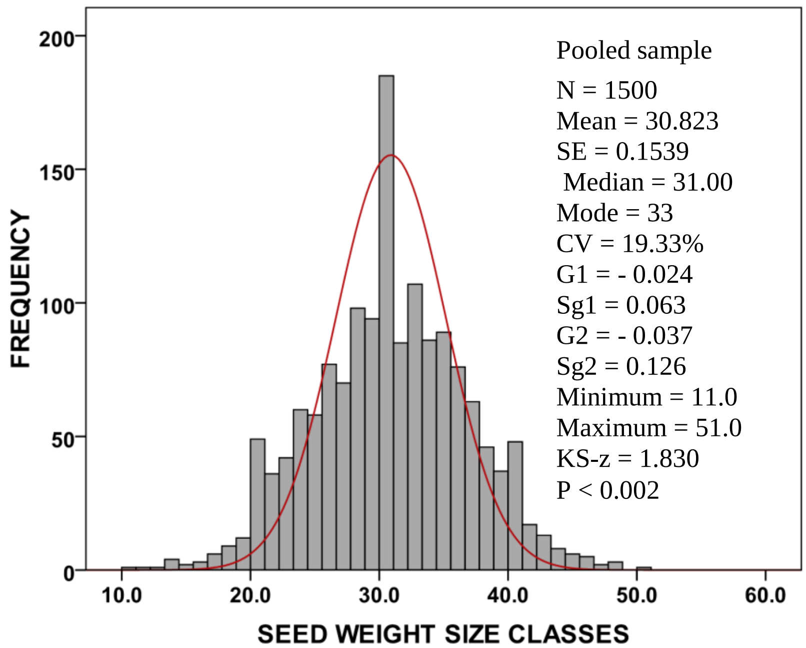

Fig. 2. Frequency distribution of seed weights of pooled sample of seeds of guar germplasms (N = 1500).

RESULTS AND DISCUSSION

Seed weight variation

The individual mean seed weight in guar varied in each germplasms and the pooled sample of the germplasms substantially (Fig. 1 and Table 2). The mean individual seed weight decreased in germplasms in an order as given below (mean seed wt. (mg) in parenthesis).

S – 5798 (35.52mg) ≈ BR-90 (35.33) > S -5784 (33.66) > S -5797 (32.49) = S -5733 (32.48) > BR-2/1(31.88) > S -5785 (30.33) = S – 5759 (30.32) > BR-2017 (29.90) ≈ S5825 (29.36) ≈ S -5747(29.19) > BR- 99 > S (28.96) S - 5765 (28.16) ≈ S - 5742 (27.91) ≈ S – 5761 (27.95).

Seed weight distribution in all germplasms tested, except S 5765, was symmetrical with insignificant KS-z values. Seed weight distribution of line S 5765 was leptokurtic (g2 = 1.088) and negatively skewed (g1 = - 0.761) with KS-z: 1.362 ($p < 0.047$). The mean seed weight was the maximum in line S-5798 (35.52 mg per seed) and Var. BR-90 (35.33mg per seed) varying from 23 to 44mg and from 21 to 51, respectively. It was the minimum in two germplasms S-5761 and S-5742 (27.95 and 27.91 mg, respectively) varying from 17 to 43 and from 14 to 40 mg, respectively (Fig. 1; Table 2). In seven germplasms mean seed wt. was higher than 30mg and in eight germplasms mean seed weight was lower than 30mg but not lesser than 27.90mg). Amongst the 15 germplasms seed weight variation was the lowest (CV: 13.45%) in S-5798 and the highest (CV: 21.30%) in S-5759. From the criterion that any variety or line with the highest magnitude of mean seed weight and the lowest variation value should be desirable, the line S-5798 (mean seed wt. 35.52mg, CV: 13.45%) appeared to be the best followed by BR-90 (mean seed wt. 35.53 mg; CV: 18.75%). However, the recorded heaviest seed was observed in BR-90 (51 mg). The recorded heaviest seed in S-5798 amounted to 44.0 mg. It follows from the results that Var. BR-90 and line S-5798 are the heaviest-seeded.

The seed weight distribution of pooled sample of seeds (N = 1500) was asymmetrical (KS-z = 1.830, $p < 0.002$). The mean seed weight averaged to 30.82 ± 0.1539 mg varying from 11 to 51 mg (CV: 19.33%) (Fig. 2). By this distribution seeds ≤ 20.0 mg were 3.9%, 21-25 mg 15.0% and 26 – 30mg around 28.1%. More seeds were found in the size class of 31-35mg (31.2%). The seeds belonging to size class of 36-40 mg were 16.8% and seeds above 40 mg of weight were 4.2% only. Seeds heavier than 45mg were only 0.7%. Median class of 31.0 mg nearly bisected the data into two almost equal halves.

Table 3. Seed weight of some accessions and varieties of guar.

Guar accessions	100-seeds weight	Individual seed weight (mg)	Reference
Bahawalpur (Pakistan)	3.6	36	Vahidy and Yousufzai (1991)
Mirpur (Pakistan)	3.7	38	
D-safed (India)	3.6	36	
TX 71 -3292 (USA)	3.1	31	
TX 73 – 2731 (USA)	3.2	32	
TX 76 – 2646 (USA)	2.6	26	
TX 76 -3114 (USA)	2.3	23	
TX 76 – 3285 (USA)	2.4	24	
TX 77 – 3347 (USA)	2.4	24	
TX 78 – 3337 USA)	2.7	27	
TX 78 – 3726 USA)	2.6	26	
TX – 7941 (USA)	2.6	2.6	
5733 (Pakistan)	27.8	27.8	Khalid *et al.* (2017)
5747 (Pakistan)	23.5	23.5	
5752 (Pakistan)	24.4	24.4	
5789 (Pakistan)	23.7	23.7	
5823 (Pakistan)	28.0	28.0	
24 (Pakistan)	28.9	28.9	
5885 (Pakistan)	23.5	23.5	
6036 (Pakistan)	29.3	29.3	
6056 (Pakistan)	28.6	28.6	
5588 (Pakistan)	26.5	26.5	
BR-99 (Pakistan)	23.8	23.8	

Varieties (India)	1000-seeds Wt. (g)	Individual seed Wt. (mg)	Reference
HG 365	32.2	32.2	Ramaja-neyulu *et al.* (2018) (Indian Varieties)
H563	31.6	31.6	
RGC 936	32.3	32.3	
RGC 1002	32.2	32.2	
RGC 1035	31.6	31.6	
RGC 1066	32.1	32.1	
Mean	**32.0**	**32.0**	
LSD	**1.32**	**1.32**	
HFG 53	21.05	21.1 b	El-Daw, G. El-Awad (1994) (Sudan)
HFG 182	32.65	32.65 a	
HFG 363	28.28	28.28 c	
LSD	**0.19**	**0.19**	
'Malosan'	> 30.0 mg (USA cultivars)		Sortino and Gresta (2007)
'S. Cruz'			
'Kinman'			

Table 4. Similarity matrix (%) amongst the guar germplasms on the basis of seed weight composition.

SIMILARITY MATRIX

A	A															
B	63	B														
C	73	75	C													
D	84	84	87	D												
E	48	85	75	64	E											
F	52	76	86	**94**	61	F										
G	58	92	82	72	**90**	65	G									
H	74	86	92	**92**	72	65	81	H								
I	58	92	82	74	**93**	68	68	79	I							
J	52	89	81	68	**96**	**90**	**90**	**94**	**95**	J						
K	**90**	70	80	**91**	55	89	62	83	61	59	K					
L	71	92	95	84	77	83	76	89	84	81	84	L				
M	86	77	97	**98**	62	**94**	72	**90**	69	68	**94**	84	M			
N	86	61	71	82	46	85	56	74	53	50	89	69	86	N		
O	63	**98**	89	79	85	76	**92**	87	**92**	89	70	76	77	61	O	
P	73	**90**	94	88	77	84	85	93	82	89	80	80	**90**	71	90	P

Acronyms:
A, Varieties BR-90; B, BR-99; C, BR-2/1; D, BR-2017;

Lines
E, S-5742 F, S-5733; G, S-5747; H, S-5759; I, S-5761; J, S-5765; K, S-5784; L, S-5785; M, S-5797; N, S-5798; O, S-5825 and P, Pooled sample.

The seed weight of some guar germplasms reported from USA, Pakistan, India and Sudan is presented in Table 3. The individual seed weight of most of the germplasms has been reported to be lesser than 30 mg. The individual seed weight of cultivars – 'Malosan', 'Santa Cruz' and 'Kinman' were reported to be higher than 30 mg (Sortino and Gresta, 2007). The accessions Bahawalpur and Mirpur of Pakistan, D-safed of India and TX 71 -3292 and TX 73 – 2731 of USA also exhibited heavier seeds (> 30 mg). Other accessions exhibited individual seed weight ranging from 23 to 26 mg (Vahidy and Yousufzai, 1991).

The yield of guar is known to vary widely year to year and 1000-grain weight of guar germplasms varies from 35-37g (Saleem *et al*., 2002). Saleem et al. (2002) reported that Var. BR-99, in comparison to Var. BR-90 and Var. BR 2/1, is relatively high yielding and has wider range of adaptability. In our studies Var. BR-90, Var. BR 2/1and lines S- 5798, S-5785, S-5784, S-5797 and S-5733 had the mean seed weight higher than 30 mg. Some varieties of India are also reported to bear heavier seeds (Ramajaneyulu *et al.* (2018).

Similarity amongst germplasms on the basis of seed weight composition

The similarity matrix amongst the germplasms as calculated for 105 pairs of the germplasms on the basis of seed weight distribution following Brock (1977) is outlined in Table 4. The similarity amongst the germplasms varied substantially (46-98%).

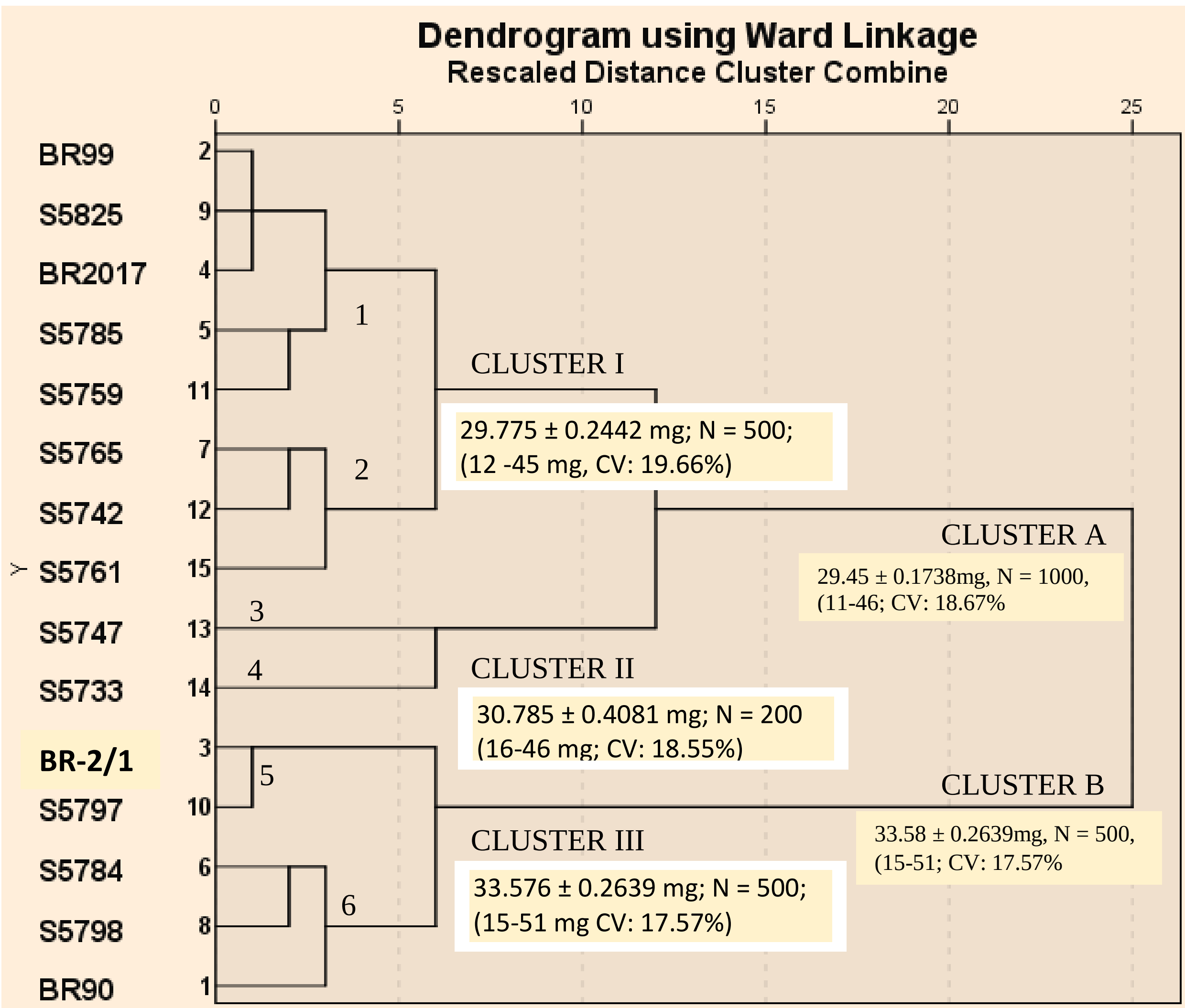

Fig. 3. Dendrogram of agglomerative cluster analysis by Ward's method (Euclidean distances) of guar germplasms on the basis of their seed sizes. Each group is shown with mean individual seed weight (mg) and sample size and variation parameters.

There was no case of similarity amongst the germplasms lesser than 46 %. Amongst the four varieties, the inter-varietal similarity ranged from 63 to 87%. The seed weight distribution pattern of Var. BR-90, BR-99 and BR-2/1 resembled more closely with Var. BR-2017. Similarity of Var. BR-90 with Var. BR-99 or BR-2/1 was relatively low as was also the case of BR-99 with BR-2017. The lowest similarity (46%) was observed between line S- 5798 and S-5742. The highest similarity between seed weight distribution pattern was 98% observed between lines S-5828 and Var. BR-99 and also between line S-5797 and Var. BR-2017 (Table 4). Out of the total pairs of germplasms tested (105) for their inter-germplasm similarity on the basis of seed weight distribution pattern (SWDP), 20% of the pairs had 71-80% similarity. Around 33.3% pairs had 81-90% similarity and only 18.1 of the pairs had similarity in SWDP more than 90% (maximally 98%). The SWDP-based similarity of the individual germplasms with the pooled sample was moderately high (84.4%) ranging from 71 to 94%. The similarity pattern as observed above may perhaps be attributed to the variation of the modal classes, the number of modes and the range of the seed weights. It should, in turn, be regulated by the genetic makeup of the germplasms, seasonal effects, and differences of the environmental and cultural practices.

Agglomerative clustering of germplasms on the basis seed weight distribution

There were only two broader groups on the basis of group extraction at 12 % of dissimilarity (Fig. 3).

CLUSTER A: Var. BR-99, Var. BR-2017 and lines S-5825, S5785, S5759, S5765, S-5742, S5761, S-5747 and S – 5733 (10 germplasms).

CLUSTER B: Var. BR-2/1, Var. BR-90 and lines S-5797, S-5784 and S-5798 (5 germplasms)

The mean seed weight in cluster - A was 29.45 ± 0.1738mg, N = 1000 varying from 11 to 46 mg (CV: 18.67%). The mean seed in cluster-B was significantly higher amounting to 33.58 ± 0.2639mg, N = 500 varying from 15 to 51 (CV: 17.57%) (Fig. 3).

On group extraction at distance of 7% dissimilarity, there were three identifiable clusters as

CLUSTER I: Var. BR-99, Var. BR- 2017 and lines S5785, S5759, S5765, S-5742, S5761 and S-5825 (8 germplasms)

CLUSTER II: Lines S-5747, S-5733 (2 germplasms)

CLUSTER III: Var. BR-2/1, Var. BR-90 and lines S5797, S5784, and S-5798 (5 germplasms)

On the basis of group extraction at distance of 3% dissimilarity, six clusters were identifiable as follows:

Cluster (1): Var. BR-99, Var. BR-2017 and lines S-5825, S-5785 and S- 5759 (5 germplasms)

Cluster (2): Lines S- 5765, S-5742, and S- 5761 (3 germplasms)

Cluster (3): S – 5747 (single germplasm)

Cluster (4): S – 5733 (single germplasm)

Cluster (5): S- Var. BR-2/1 and Line S – 5797 (2 germplasms)

Cluster (6): Var. BR-90 and lines S-5784 and S- 5798 (3 germplasms)

Table 5. Seed weight characteristics of the six guar clusters at 3% dissimilarity amongst the germplasms.

Seed Weight Parameters	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
N	500	300	100	100	200	300
Single seed Wt. (mg)	29.78	28.01	29.19	32.48	32.19	34.50
SE of mean	0.2442	0.2918	0.5911	0.5155	0.4121	0.3333
Range (mg)	12-45	11-43	16-43	18-46	15-47	18-51
CV (%)	18.33	18.04	20.25	18.87	18.11	16.73

Obviously, the seeds of cluster 1-3 were relatively lighter in weight as compared to the cluster 4-6 which were comparatively heavier in seed weight, particularly the cluster 6 resulting due to the agglomeration of Var. BR-90 and lines S-5784 and S-5798 (Table 5).

The studies of Khalid *et al.* (2017) on agglomeration of 100 accessions of guar (including 7 germplasms from the in-hand fifteen germplasms such as var. BR-99 and lines 5733, 5747, 5733, 5761, 5765, 5825), based on 13 agronomic characters (days of emergence, germinability, days to 50% flowering, plant height, number of branches per plant, clusters per plant, pod length, pods per clusters, seeds per pod, days to maturity, 100-seed weight and grain yield), yielded eight clusters of guar accessions. Of these 8 clusters, the cluster # 1 was the largest one with 25 accessions. Besides other accessions, the lines 5765, 5747 and 5733 also entered this cluster along with the variety BR99. In our studies, Var. BR-99 and Var. BR-90 entered the different clusters and Var. BR-90 was heavier in seed weight than Var. BR-99. Anderson (1949) had studied 163 spp. of legumes as source of endosperm gum. He reported guar seed to contain c 50% endosperm and to yield c. 42% gum. It may be hypothesized that Larger seeds should bear larger endosperm and, therefore, larger amount of galactomannan.

In view of the data presented in Table 1 Var. BR- 2/1 and lines S-5797, S – 5798 and S - 5825 are considered suitable for fodder production, Line S – 5784 suitable for grain and the remaining 10 germplasms suitable for fodder as well as grain or vegetable. The maximum grain / fodder ratio (0.100) is observed for line S – 5785 and minimum for line S – 5798. This ratio for the in-hand germplasms averaged to 0.0598 ±0.00404 and therefore Var. BR-99, BR- 2017and lines S – 5785, S- 5784, S- 5759, S- 5747 and S -5761 appeared to be relatively above average in grain production and Var. BR-90, BR-2/1, and lines S-5765, S-5798, S–5825, S-5797, S–5742 and S-5733 appeared relatively below average grain producers.

Genetic analysis showed that plants with short height, more number of branches, clusters and pods per plant are the important traits to be given priority to develop high yielding cultivars as they influence economic importance positively and significantly (Ramajaneyulu *et al.*, 2018). With this criteria for the in-hand germplasms, short-statured and profusely-branched golden-grained variety, BR-90, bears larger seeds (Mean seed wt. = 35.33 ± 0.6626mg) appears to be quite suitable for grain. Var. BR- 2/1 is branched and has larger seeds (31.88 ± 0.5955) but long-statured, suitable for fodder and grain. Var. BR-2017 is 0-1 branched, but has seeds of moderate size (29.90 ± 0.4792 mg) and similarly Var. BR-99 is single-stemmed and bears moderately-sized seeds (28.96 ± 0.5569 mg) may be suitable for fodder, vegetable and somewhat less suitable for grains. These varieties need further trial at national level. Besides, some lines such as S- 5784, S - 5733, S-5785, S- 5759 bearing heavy seeds (≥ 30 mg) may be given attention in the agronomic investigations. The line, S- 5798, is branched (8-10 branches) and tolerant to insect pests and diseases and considered more suitable for fodder purposes. In spite of the fact that it shows relatively longer period of maturity, it may, in view of larger seeds (35.52 ± 0.464 mg) may be further investigated for grain value or in breeding programmes related to the guar development.

REFERENCES

Akhtar, L.H., S. Bukhari, S. Salahuddin and R. Minhas (2012). Response of new guar strains to various row spacing. *Pak. J. Agric. Sci.* 49(4): 469-471.

Anderson, E. (1949). Endosperm mucilages of legumes occurrence and composition. *Industrial Engg. Chem*. 41: 2887-2890.

Arora, R.N. and S.K. Pahuja (2008). Mutagenesis in guar (*Cyamopsis teteragonoloba* (L.) Taub. Plant Mutation Reports, 2(1). 7-9.

Bewal, S., J. Purohit, A. Kumar, R. Khedasana and S. Rama Rao (2009). Cytological investigations in colchicines – induced tetraploids of *Cyamopsis teteragonoloba* L. *Czech. J. Genet. Plant Breeding*. 45: 143-154.

Brock, D.A. (1977). Comparison of community similarity indices*. J. Water Pollution Control Federation* 49: 2488-2494.

El-Daw, G. El-Awad (1994). *A study of guar seed and guar gum properties (Cyamopsis teteragonoloba*). M.Sc. Thesis, dept. Food Sci. Tech, Faculty Agric., Univ. Khartoum, Sudan.

Elias, E.J., S. Anil, S. Ahmad and A. Daud (2010). Colon targeted cucurmin delivery using guar gum. *J. Nat. Prod. Comm.* 5(6):9158-918.

Khalid, M. Azeem ur Rahman, L.H. Akhtar, R. Minhas, S.J. Bukhari, M. Zubair and M.A. Iqbal (2017). Screening of guar accessions [*Cyamopsis teteragonoloba* (L.) Taub.] for higher yield potential under irrigated conditions. *Afr. J. Agric. Res.* 12(37): 2788-2794.

Patel, J.J., M. Karve, and N. K. Patel (2014). Guar gum: A versatile material for pharmaceutical industries. *Int. J. Pharmacy & Pharmaceutical Sci.* 6n (8):13-19.

Purseglove, J.W. (1981). Leguminosae. In: *Tropical Crops: Dicotyledons.* Longman Group Ltd. Essex, UK. Pp. 250-254

Ramajaneyulu, A.V., A. Madhavi, M.V. Ramana, T.L. Neelima, K. Indudhar, A. Srinivas, G. Anuradha and C.V. Sameer Kumar (2018). Agronomic and genetic analysis of performance of guar varieties under rain-fed conditions in a semi-arid climate on alfisols. *Int. J. Curr. Microbiol. App. Sci.* 7(8): 2795-2805.

Saleem, M.I., S.A. Hussain and L.H. Akhtar (2002). 'BR-99'. A new cultivar released for general cultivation in Punjab province. *Asian J. Plant Sciences* 1(3): 266-268.

Shyale, S., K. Chowdary, Y. Krishnaiah and N.K. Bhat (2006). Pharmocokinetic evaluation and studies on the clinical efficacy of guar gum-based oral drug-delivery systems of albendazole and albendazole-β-cycloclextrin for colon targeting in human volunteers. *Drug Development Res*. 67: 154-165.

Sokal, R.R. and E.J. Rholf (1995). Biometry. III edition. Freeman, San Francisco, CA, USA.

Sortino, O. and F. Gresta (2007). Growth and yield performance of five guar cultivars in a Mediterranean environment. *Ital, J. Agron. Riv. Agron.* 4: 359-364.

Sultan, M., M.A. Rabbani, Z.K. Sherwani and M.S. Masood (2012). Phenotypic divergence in guar (*Cyamopsis teteragonoloba). Land* races genotypes of Pakistan. *Pak. J. Bot.* 44: 203-210.(Special issue 2012).

Sultan, M., N. Zakir, M. Ashiq Rabbani, Z. Khan Shinwari and M.S. Masood (2013). Genetic diversity of guar (*Cyamopsis teteragonoloba* L.) land races from Pakistan based on RAPD markers. *Pak. J. Bot.* 45(3): 865-870.

Vahidy, A.A. and A. S. Yousufzai (1991). Variation and correlation studies of vegetative and reproductive characteristics in twelve accessions of guar, *Cyamopsis teteragonoloba* (L.) Taub. *J. Islamic Acad. Sci*. 4(3): 245-248.

Ward, J.H. (1963). Hierarchical grouping to optimize an objective function. *J. Am. Statistical Assoc*., 58(301): 236-244.

Whisller, R.L. and T. Hymowitz (1979). *Guar Agronomy, Production, Industrial use and Nutrition.* Purdue Univ. Purdue, West Lafayette, Indiana, ix +124 Pp.

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