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Research Note

Analysis of variability and correlations among different forage traits in guar (*Cyamopsis tetragonoloba* L.Taub.)

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Abstract
The present study was conducted with 15 genotypes at experimental area of Punjab Agricultural University, Ludhiana during *Kharif* 2021 with an objective to assess the variability, correlations and path coefficients among different forage and quality traits. The traits like leaf stem ratio followed by number of branches per plant, stem girth, number of leaves per plant, dry matter yield and green fodder yield exhibited high PCVand GCVvalues. High heritability (> 90%) was observed for plant height, number of branches per plant, number of leaves per plant, stem girth, days to flowering and leaf stem ratio while more than 85% heritability was observed for green fodder yield. Higher genetic advance was observed for leaf stem ratio (48.9%) followed by number of branches per plant (35.9%), stem girth (32.1%) and number of leaves per plant (25.3%). Traits like plant height (0.42), number of branches per plant (0.75), stem girth (0.61) had significant positive correlation with green fodder yield. High positive direct effects were observed for number of branches per plant (0.890), acid detergent fiber (0.620), Leaf stem ratio (0.514), dry matter yield (0.508) and number of leaves (0.419).The results revealed that traits like number of leaves per plant, leaf stem ratio and number of branches per plant are the main forage yield components which can be improved through selection.

Keywords: Variability, Correlation, Path coefficients, Green fodder, Guar

Guar (*Cyamopsis tetragonoloba* L.Taub.) is an important legume crop grown during *kharif* season in north-western parts of India. It is a drought tolerant crop, requires low agronomic inputs and is cultivated on sandy to sandy loam light textured soils. Other countries of the world like, Brazil, South Africa and Australia also grow guar for grain, vegetable, fodder and industrial purpose, (Patel *et al.*, 2018). Guar fodder is very nutritious for livestock as it contains 10-18 % crude protein, 25-43% crude fiber, 1.5-2.3% ether extract and 35-48% nitrogen free extract with high dry matter digestibility (Mahanta *et al.*, 2001). Guar meal is also very rich in protein ranging from 29 to 46% which is used as feed for farm animals (Rodge, 2008). Despite, guar being an important crop for animal feed, very little information is available for the improvement of fodder yield and its related traits. Fodder yield being a quantitative character, is dependent on various yield components traits. The assessment of genetic variability, character association among fodder yield and its components traits is a pre requisite for initiating crop improvement programs in guar. Hence, the present study was under taken to assess the genetic variability and associations among fodder yield, its components and quality parameters.

A total of fifteen genotypes of guar were sown for evaluation during *Kharif* 2021. These dual purpose genotypes which can exclusively be utilized both for fodder or grain purpose, were being maintained at experimental area of Punjab Agricultural University, Ludhiana. The above said experimental material was raised in three replications using randomized block design.Each plot consisted of two rows of 4m length with row to row spacing of 50 cm. The weather conditions were favorable during the entire crop season. All the recommended practices were followed to raise a good crop. Data were collected from five randomly selected plants from each entry for twelve forage and quality traits *viz*., plant height(cm)(PH), number of leaves per plant (NOL), number of branches per plant (NOB), Days to flower (DTF), stem girth (SG) , Leaf stem ratio (LSR), green fodder yield(kg/plot) (GFY), dry matter yield (kg/plot) (DMY) (kg/plot) and four quality parameters *viz*. crude protein (CP %), acid detergent fiber (ADF %), neutral detergent fiber (NDF %) and *in vitro* dry matter digestibility (IVDMD %).

Sampling and laboratory analysis: The crude protein was estimated as per AOAC (2005). The dried grinded samples was analyzed for nitrogen content using kjeldahl digestion procedure. The percent crude protein content was estimated using the relationship:

$$\text{Crude protein } \% = N\% \times 6.25$$

Cell wall components were analyzed by the method of Van Soest (1991). *In-vitro* dry matter digestibility content was estimated from protocol given by Tilley and Terry (1963)

The data obtained from the present experiment were analyzed for variability, heritability, genetic advance, correlation and path coefficient study by following standard statistical procedures (Burton and De Vane, 1953; Burton, 1952; Allard, 1960; Johnson *et al*. (1955); Deway and Lu, 1959).

Genetic improvement of forage yield alone is not possible through phenotypic selection because of polygenic nature and low heritability. In breeding program, the selection of parents for hybridization is largely based upon high yielding potential and genetic diversity. The findings of analysis of variance (ANOVA) revealed that genotypes differed significantly among themselves for all the traits under study (**Table 1**).

The present study revealed apparent effect of environmental factors on expression of these traits (**Table 2**) as the phenotypic coefficient of variation (PCV) was invariably higher as compared to genotypic coefficient of variation (GCV) for all the traits. Identical results were reported for fodder traits in maize (Kapoor and Batra, 2015; Chaudhary *et al.*, 2016), oats (Sahu and Tiwari, 2020), cowpea (Sahu, M, 2021) and barley (Singh and Singh, 2011). The high PCV and GCV were recorded for leaf stem ratio followed by number of branches per plant, stem girth, number of leaves per plant, green fodder yield and dry matter yield which indicated that a lot of variability exists at genotypic and phenotypic level for these traits. Hence, selection could be the best option for improvement of these characters (Panchta *et al.,* 2020; Kapoor, 2014). The traits like plant height, number of leaves per plant, number of branches per plant, days to flowering, stem girth, leaf stem ratio, both green fodder and dry matter yield recorded high heritability (>70%) which showed that these characters were highly heritable. In the present study, all the quality traits such as crude protein, neutral detergent fiber, acid detergent fiber and in vitro dry matter digestibility have moderate heritability, so, it is possible to suggest that these quality

Table 1. Analysis of variance for 12 characters of 15 cluster bean genotypes

S.No.	Character	Replication Mean sum of squares	Genotypes Mean sum of squares	Error Mean sum of squares
	Degree of freedom	**2**	**14**	**28**
1	Plant Height	15.94**	283.95**	0.23
2	Number of leaves per plant	91.66**	282.92**	2.00
3	Number of branches per plant	0.70*	3.78**	0.01
4	Days to flowering	90.33**	86.74**	2.22
5	Stem girth	0.20*	0.04**	0.02
6	Leaf stem ratio	0.10*	0.11**	0.01
7	Green fodder yield	1.17**	3.18**	0.16
8	Dry matter yield	0.03**	0.06**	0.04
9	Crude Protein	9.08	2.88**	0.21
10	Acid detergent fibre	18.14**	23.53**	1.88
11	Neutral detergent fibre	9.06*	20.51**	1.22
12	In vitro dry matter digestibility	11.00**	14.28**	1.14

*, **= significant at 5% and 1% levels, respectively

Table 2. Genetic parameters of different forage and quality characters in guar

Traits	Heritability (%)	Genetic Advance (%)	Phenotypic coefficient of variation (PCV)	Genotypic coefficient of variation (GCV)	Mean	Range	
						Min	Max
PH	99.75	24.46	11.90	11.89	81.78	65.30	96.40
NOL	97.90	25.37	12.58	12.44	77.72	55.00	92.00
NOB	99.19	35.97	17.60	17.53	6.39	4.30	7.90
DTF	92.68	16.42	8.60	8.28	64.10	51.00	74.00
SG	95.43	32.11	16.33	15.95	0.69	0.53	0.89
LSR	91.48	48.91	25.95	24.82	0.76	0.36	1.00
GFY	86.00	21.52	12.14	11.26	8.91	7.00	11.40
DMY	84.31	22.20	12.78	11.74	1.18	0.88	1.50
CP	80.66	12.24	7.36	6.61	14.25	11.20	16.70
ADF	79.30	14.23	8.71	7.76	34.60	27.60	39.40
NDF	83.97	10.98	6.35	5.82	43.56	35.40	48.70
IVDMD	79.29	6.19	3.79	3.37	61.94	58.21	67.40

PH= Plant Height; NOL= Number of leaves/plant; NOB = Number of branches per plant; DTF = Days to Flowering; SG= Stem girth; LSR= Leaf Stem ratio; DMY=Dry matter yield/plot; CP (%) =Crude Protein (%); ADF (%) = Acid Detergent Fiber (%); NDF (%) = Neutral Detergent Fiber (%); IVDMD (%) = *In vitro* dry matter digestibility (%)

traits are governed by multiple genes with additive effects (Maruthi and Rani, 2015). Previous studies on guar by different workers also showed similar trends (Mahla and Kumar, 2006; Kapoor, 2014; Meena and Nagar, 2017). High genetic advance were recorded for leaf stem ratio, number of leaves, stem girth, number of leaves per plant, plant height, green fodder yield and dry matter yield which indicated that these traits can be improved by selection which leads to accumulation of additive genes.

The genotypic and phenotypic correlation coefficients were estimated among forage yield and its components in all possible character combinations presented in **Table 3**. The magnitude of genotypic correlations was higher than that of phenotypic correlations for most of the characters. Highly significant positive correlation were obtained for green fodder yield with plant height, number of leaves per plant, stem girth, while its correlations with leaf stem ratio was negative both at genotypic and phenotypic levels. Dry matter yield also showed significant positive correlation both at genotypic and phenotypic levels with plant height, number of leaves per plant, stem girth and green fodder yield and it showed significant negative correlation with leaf stem ratio. The correlation coefficient observed between green fodder and dry matter yield was highly significant positive and was highest value (0.94 and 0.93) which was followed by neutral detergent fibre and acid detergent fibre (0.83 and 0.73) dry matter yield and number of branches (0.76 and 0.69), stem girth and number of branches (0.72 and 0.70), days to flowering and *in vitro* dry matter digestibility (0.67 and 0.61), *in vitro* dry matter digestibility and leaf stem ratio (0.54 and 0.49) and highly significant negative correlation between *in vitro* dry matter digestibility and neutral detergent fiber (-0.83 and -0.73) . Digestibility being the major critical indicator of forage quality always remained a matter of major concern. In general, digestibility of a plant is always inversely associated with fiber content of forages. The findings in correlation analysis also reported positive although low correlations between dry matter yield and cell wall components such as acid detergent fibre and neutral detergent fibre and negative correlations between dry matter yield and *in vitro* dry matter digestibility. Earlier workers have also reported that the more fibrous nature of vascular bundle present in stem of a plant restrained its digestion in animals (Martinez *et al.*, 2010; Icoz and Kara, 2009; Salama and Nawar, 2016).

The green fodder yield is a quantitative and complex character which is dependent on many yield contributing characters. Therefore, due to more effect of environmental fluctuations on yield, direct selection for yield as such will not be effective. So, as to obtain maximum gain, selection criteria should be based on yield components where relative weight age should be given to different yield contributing traits (Patel *et al.*, 2018).

In **Table 4**, when green fodder yield was taken as dependent trait, maximum positive direct effect were obtained for number of branches per plant followed by acid detergent fibre, leaf stem ratio, dry matter yield while maximum negative effect were obtained for neutral detergent fibre and crude protein. Same results were reported by earlier workers (Mahanta *et al.,* 2001;

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Table 3. Genotypic and phenotypic correlations analysis for green fodder yield and its attributing traits in guar

Traits		PH	NOL	NOB	DTF	SG	LSR	GFY	DMY	CP	ADF	NDF	IVDMD
PH	G	1	0.244	0.457**	0.023	0.368**	-0.315*	0.423**	0.335*	-0.168	0.135	0.311*	-0.135
	P	1	0.243	0.456**	0.023	0.360*	-0.300*	0.392**	0.303*	-0.151	0.115	0.280	-0.115
NOL	G		1	0.012	-0.277	0.263	-0.434**	0.173	0.108	0.190	0.005	0.309*	-0.005
	P		1	0.010	-0.266	0.245	-0.410**	0.151	0.097	0.189	0.015	0.277	-0.015
NOB	G			1	-0.021	0.720**	-0.344*	0.748**	0.758**	-0.186	0.265	0.424**	-0.265
	P			1	-0.014	0.700**	-0.325*	0.693**	0.694**	-0.188	0.233	0.382**	-0.233
DTF	G				1	-0.292*	0.671**	0.033	0.157	-0.190	-0.668**	-0.385**	0.668**
	P				1	-0.273	0.625**	0.030	0.136	-0.214	0.608**	-0.319*	0.609**
SG	G					1	-0.683**	0.608**	0.606**	0.091	0.377**	0.441**	-0.377**
	P					1	-0.666**	0.554**	0.542**	0.093	0.311**	0.365**	-0.311*
LSR	G						1	-0.397**	-0.277	-0.275	-0.544**	-0.493**	0.544**
	P						1	-0.350**	-0.254	-0.250	-0.489**	-0.410**	0.489**
GFY	G							1	0.943**	-0.158	0.257	0.219	-0.257
	P							1	0.938**	-0.104	0.200	0.210	-0.200
DMY	G								1	-0.297*	0.153	0.216	-0.153
	P								1	-0.214	0.148	0.208	-0.148
CP	G									1	-0.296*	-0.481**	0.297*
	P									1	-0.230	-0.417**	0.230
ADF	G										1	0.831**	-1.00
	P										1	0.728**	-1.00**
NDF	G											1	-0.832**
	P											1	-0.728**
IVDMD	G												1
	P												1

** and * Significant at 1% and 5% respectively

Table 4. Path coefficient analysis for direct (diagonal and bold) and indirect effects on green fodder yield in Guar

Traits	PH	NOL	NOB	DTF	SG	LSR	DMY	CP	ADF	NDF	IVDMD	Correlations with GFY
PH	**-0.178**	0.102	0.406	-0.013	0.008	-0.161	0.167	0.085	0.425	-0.274	-0.144	0.423
NOL	-0.043	**0.419**	0.010	0.166	0.005	-0.222	0.054	-0.096	0.471	-0.224	-0.367	0.173
NOB	-0.081	0.005	**0.890**	0.012	0.016	-0.176	0.372	0.094	0.284	-0.308	-0.360	0.748
DTF	-0.004	-0.115	-0.018	**-0.330**	-0.487	0.344	0.078	0.096	-0.030	0.279	0.220	0.033
SG	-0.065	0.110	0.640	0.175	**0.022**	-0.350	0.302	-0.046	0.980	-0.320	-0.840	0.608
LSR	0.056	-0.181	-0.305	-0.404	-0.15	**0.514**	-0.210	0.139	-0.160	0.358	0.740	-0.397
DMY	-0.059	0.045	0.674	-0.110	0.013	-0.142	**0.508**	0.150	0.945	-0.156	-0.930	0.938
CP	0.029	0.079	-0.165	0.114	0.002	-0.141	-0.147	**-0.508**	-0.140	0.349	0.370	-0.158
ADF	-0.024	0.005	0.235	0.402	0.008	-0.279	0.074	0.150	**0.620**	-0.604	-0.330	0.257
NDF	-0.055	0.135	0.377	0.232	0.009	-0.253	0.107	0.244	0.720	**-0.727**	-0.330	0.219
IVDMD	0.024	-0.001	-0.237	-0.402	-0.008	0.279	-0.076	-0.150	-0.620	0.604	**0.330**	-0.257

PH= Plant Height; NOL= Number of leaves/plant; NOB = Number of branches per plant; DTF = Days to Flowering; SG= Stem girth; LSR= Leaf Stem ratio; DMY=Dry matter yield/plot; CP (%) =Crude Protein (%); ADF (%) = Acid Detergent Fiber (%); NDF (%) = Neutral Detergent Fiber (%); IVDMD (%) = *In vitro* dry matter digestibility (%)

Shekhawat and Singhania (2005) and Kapoor 2014). Number of branches per plant exhibited positive indirect effect on dry matter yield, neutral detergent fibre, and stem girth, negative indirect effect for *in vitro* dry matter digestibility, neutral detergent fibre, leaf stem ratio and significant positive correlation with green fodder yield. Acid detergent fibre showed positive indirect effect for days to flowering, number of branches per plant, crude protein and negative indirect effects for neutral detergent fibre, *in vitro* dry matter digestibility, leaf stem ratio and positive correlation with green fodder yield.

The traits like plant height, number of branches per plant, number of leaves per plant, days to flowering, stem girth, recorded high heritability accompanied with high genetic advance which is due to additive gene action and direct selection for such traits is rewarding for the improvement of both green and dry matter yield .The present study also showed positive correlation between green fodder yield with both acid detergent fibre, neutral detergent fibre and negative correlation with *in vitro* dry matter digestibility. Therefore, selection for high green fodder yield would increase plant fibre content, hence decreasing the digestibility. It is suggested that marker assisted selection approach would be appropriate in order to select high yielding guar genotypes with acceptable fibre content with good digestibility

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