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Analysis of genetic variability and selection for high fodder productivity in cluster bean (*Cyamopsis tetragonoloba* L. Taub.) under rainfed condition

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Abstract
Cluster bean (*Cyamopsis tetragonoloba* L. Taub.) is an important annual legume crop which is mainly grown in north-western India during rainy (*kharif*) season. It is used for vegetable, feed, forage and variety of products of industrial use. Two hundred thirty germplasm lines of cluster bean were evaluated at IGFRI-Western Regional Research Station, Avikanagar during *kharif* 2011-2013 for fodder yield. The analysis of variance showed significant variability for green and dry fodder yields, plant height, number of branches/plant, number of leaves/plant, per cent dry matter and leaf: stem ratio. The estimate of genotypic coefficient of variance was ranged from 11.5% (leaf: stem ratio) to 46.6% (green fodder yield) and heritability ranged from 27.5% (leaf: stem ratio) to 65.2% (number of branches/plant). Genotypic correlation coefficient showed that green fodder yield was positive and significantly associated with days to flowering, plant height, number of branches/plant, number of leaves/plant and leaf: stem ratio. The green fodder yield ranged from 194 to 298 q/ha with mean value of 232 q/ha while dry fodder yield ranged from 42 to 66 q/ha with mean value of 54 q/ha. Dry matter and leaf: stem ratio ranged from 19.7 to 27.8% and 0.9 to 1.6, respectively. In general fodder type genotypes are late maturing and taller in height with more branches and high leaf: stem ratio. Six genotypes *viz*., AVKG-181, AVKG-179, AVKG-192, AVKG-177, AVKG-146 and AVKG-162 showed superiority for green and dry fodder yields ranging from 3.1 to 15.5% and 5.5 to 16.7%, respectively over best check.

Keywords: Cluster bean, Correlation, Genotypic coefficient of variation, Green fodder

Introduction
Cluster bean (*Cyamopsis tetragonoloba* L. Taub.) also known as *Guar* is an important annual legume which is well suited for cultivation in arid and semi-arid regions. The long deep taproot system enables plant to grasp all the water in soil making it an ultimate drought resistant crop. Therefore, it is cultivated in rainy season mainly as rainfed crop. Guar is a multi-purpose plant, used as vegetable, livestock forage/feed (fresh foliage, young pods, straw, guar meal), and variety of products of industrial importance like gum and the water-soluble resin extracted from the seeds are also used in paper manufacturing, cosmetics, mining and oil drilling (Vaughan and Geissler, 1998). Cluster bean plays an important role in diversification of cropping system for sustaining soil fertility due to its nitrogen fixation ability. The plant is also used as a green manure and cover crop. Crop residues (stubble and header trash) are a source of valuable, high protein animal feed.

India is one of the main producers of cluster bean covering 80% of total production of the world, whereas Rajasthan occupies 82% area of the country followed by Gujarat, Haryana and Punjab (Pathak *et al*., 2010). Guar fodder is very nutritious for livestock as it contains 10-18% crude protein, 25-43% crude fibre, 1.5- 2.3% ether extract and 35-48% nitrogen fee extract with high dry matter digestibility in various species of livestock (Pachauri and Upadhyaya, 1985; Ranjhan, 1991; 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). In arid and semi-arid regions productivity of livestock is often low due to inadequate and nutritionally unbalanced supply of feeds and green fodder. Despite the importance of this crop as animal feed, development of fodder type cluster bean varieties was not addressed properly for cultivation under diversified climatic conditions. Meager information is available for genetic variability in cluster bean for fodder yield and related traits. Hence, there was a need to accelerate the programme for identification of suitable genotypes for arid and semi-arid regions with high fodder yield. The present investigation was carried out to assess extent of genetic variability and characters association between fodder yield and contributing traits and selection of genotypes with high fodder yield.

Materials and Methods

Plant material and study site: Two hundred thirty germplasm accessions of cluster bean lines collected from six districts of *Sekhawati* region of Rajasthan were planted at research farm of Western Regional Research Station, ICAR-Indian Grassland and Fodder Research Institute, Avikanagar (between latitude 26°18'-37" N and longitude 75°25'-50" E at 326 m above msl). The climate of experimental site is semi-arid with an average rainfall of 600 mm and mean maximum temperature varied from 40-45 °C in summer and minimum of 5-6 °C in winter. The soil was sandy with low water retention capacity and light in texture.

Experimental details: For evaluating 2230 germplasm lines, the experiment was laid in augmented block design in five blocks with three check varieties [Bundel guar (BG-1, BG-2 and BG-3)] during *kharif* 2011 under rainfed condition. In each block there were 49 lines including three check varieties. Each entry was accommodated in 2.4 sq. m plot size containing 2 rows of 4 m length with inter row spacing of 30 cm. Comprising twenty best performing lines for fodder yield selected during 2011 from above said trial again planted for evaluation under replicated trial during *kharif* 2013. The material was then grown in randomized complete block design with three replications. Each entry was accommodated in 7.2 sq. m plot size containing 6 rows of 4 m length with inter row spacing of 30 cm. The crop was raised under rainfed condition with recommended dose of fertilizers. Ten plants from each entry was randomly selected at 50% flowering stage for recording observations on plant height, branches/plant, leaves/plant, green and dry fodder yields, dry matter content and leaf-shoot ratio. Day to 50% flowering was visually observed on whole plot basis for each entry. Leaf: stem ratio was calculated on oven dried and fresh weight basis. Analysis of variance was performed by using software SPAD developed by IASRI, New Delhi. Genotypic coefficients of correlation were calculated from genotypic co-variances and variances as described by Singh and Chaudhary (1977).

On farm trial: Evaluation trial of six promising cluster bean genotypes and three check varieties (BG-1, BG-2, and BG-3) was also conducted at farmer's field in village Hathaki, Tonk (Rajasthan) during *kharif* 2014. Each line was planted in the strips of 4×15 m. These promising genotypes were selected from 20 genotypes evaluated during *kharif* 2013 which showed superiority in fodder production ranging from 5-15% over the best check. For fodder yield 1x1m area from three locations within the strip for each genotype was recorded at 50 % flowering stage. Dry matter (%) was calculated on the basis of sun dried samples. Per cent superiority over the best check variety was calculated for identifying better genotypes.

Results and Discussion

Estimates of genetic variability: Analysis of variance revealed that significant amount of variability was present in the germplasm for fodder yield and other related traits. It is evident from the high value of coefficient of variation among the genotypes evaluated for different traits. The range of green fodder yield was 37.0-176.3 with average of 93.5 g/plant, dry fodder yield 10.7-62.0 with average of 25.4 g/plant, dry matter 16.4-29.8 with average of 21.0 % and plant height 15.2 to 110.4 with average of 90.4 cm. The value of phenotypic coefficient of variation (PCV) was invariably higher as compared to genotypic coefficient of variation (GCV) for all the traits indicating apparent effect of environmental factors on expression of these traits (Table 1). Identical results were reported for fodder traits in oat (*Aveona sativa*) and barley (Shekhawat *et al.,* 2006; Ahmed *et al.,* 2011; Singh and Singh, 2011). The estimate of GCV ranged from 18.5 to 56.7% for different traits with highest value (56.7%) for green fodder yield along with moderate heritability (48.3%). While lowest value of GCV was for leaf: stem ratio (18.5%) coupled with lowest heritability (27.6%). Pathak *et al.* (2011), Kapoor (2014), Singh *et al.* (2005) and Sood *et al.* (2016) also observed similar trends for GCV and PCV in cluster bean/ legume crops. The estimated heritability was ranged from 27.7% (leaf: stem ratio) to 65.2% (branches/plant). Similar results were observed earlier in cluster bean by different workers (Shekhawat and Singhania, 2005; Mahla and Kumar, 2006; Buttar *et al.*, 2008; Kapoor, 2014). This suggests that the present material has adequate genetic variability for green fodder yield and related traits and response to selection may be expected for fodder type cluster bean genotypes suitable for cultivation under rainfed condition.

Genotypic and phenotypic correlation coefficients: Fodder yield is a complex trait controlled by several component traits in legumes like cluster bean consists chiefly of plant height, number of branches/plant, number of leaves/plant, dry matter content, leaf: stem ratio (Arora and Lodhi, 1998; Henry *et al.,* 1986; Shekhawat and Singhania, 2005; Ahmed *et al.*, 2011). For improving fodder yield and its components, knowledge of association among these traits provides a basis for formulating suitable selection methods. Thus, genotypic correlation coefficient was worked out among fodder yield

Table 1. Estimate of genetic parameters for fodder yield and related traits in cluster bean germplasm lines

Characters	Mean	Range	GCV	PCV	Heritability (%)
Plant height (cm)	90.4	15.2-110.4	38.52	44.62	55.46
Days to 50% flowering	47.0	37.3-52.2	19.43	22.53	45.67
No. of Branches/plant	5.1	0.0-11.6	25.84	31.32	65.23
No. of Leaves/plant	38.9	28.9-55.6	31.71	36.13	59.54
Green fodder yield (g/plant)	93.5	37.0-176.3	56.65	62.41	48.26
Dry fodder yield (g/plant)	25.4	10.7-62.0	35.64	37.89	34.29
Dry matter (%)	21.0	16.4-29.8	23.43	29.35	72.34
Leaf-shoot ratio	1.2	0.3-2.1	18.51	24.26	27.56

Table 2. Genotypic correlations among fodder yield and related traits in cluster bean germplasm lines

Characters	Plant height (cm)	Days to 50% flowering	No. of branches / plant	No. of leaves/ plant	Green fodder yield	Dry fodder yield	Dry matter (%)
Days to 50% flowering	0.107						
Branches/plant	0.055	-0.025					
Leaves/plant	0.142*	-0.045	0.630**				
Green fodder yield (g/plant)	0.139*	0.138*	0.148*	0.140*			
Dry fodder yield (g/plant)	0.141*	-0.021	-0.027	-0.004	0.766**		
Dry matter (%)	-0.008	-0.026	0.096	0.095	-0.051	0.461**	
Leaf-shoot ratio	0.166*	0.208**	-0.02	-0.057	0.299**	-0.127	-0.109

*Significant at P=0.05, ** Significant at P=0.01

and related traits. The present study revealed that green fodder yield was positive and significantly associated with days to flowering (0.138), plant height (0.139), branches/plant (0.148), leaves/plant (0.140) and leaf: stem ratio (0.299). Dry fodder yield was also positively associated with green fodder yield (0.766), plant height (0.141) and dry matter (0.461). Leaves/plant showed positive relationship with plant height and branches/plant (Table 2). Buttar *et al.* (2008), Kapoor (2014) and Singh *et al.* (2005) observed positive correlation of biological yields with plant height and branches/plant while, negative correlation with seed yield and 1000-seed weight. Based on correlation study it was concluded that traits which exhibited positive association with green and dry fodder yields are important traits and should be considered while selecting fodder type genotypes of cluster bean.

Selection of high fodder yielding genotypes: Station trial of 23 genotypes including three check varieties (BG-1, BG-2, and BG-3) of cluster bean was conducted during *kharif* 2013 in RBD with three replications. Analysis of variance showed significant difference between check varieties and test genotypes for all the characters studied (Table 3). Green fodder yield ranged from 194 to 298 with mean value of 232 q/ha while dry fodder yield ranged from 42 to 66 with mean value of 54 q/ha. Percent dry matter content at 50% flowering stage and leaf: stem ratio are important traits for selecting high fodder yielding genotypes which are positively associated with green and dry fodder yield. More proportion of leaf also enhances quality of fodder *viz*., crude protein content, digestibility and palatability in animals. Dry matter and leaf: stem ratio both showed significant difference and ranged from 19.7 to 27.8% and 0.9 to 1.6, respectively. In general fodder type genotypes are late maturing and tall in height with more branches and high leaf: stem ratio, but lines with high dry matter content may not be high fodder yielder. Six genotypes *viz*., AVKG-181, AVKG-179, AVKG-192, AVKG-177, AVKG-146 and AVKG-162 showed superiority ranging from 3.1 to 15.5% for green fodder yields over the best check (BG-1) and 5.5 to 16.7% for dry fodder yields over the best check (BG-2).

On farm evaluation of promising genotypes: On farm trial of 6 promising genotypes and three check varieties of cluster bean was conducted at farmer's field during *kharif* 2014 at Malpura block, Tonk. These promising genotypes were selected from 20 genotypes evaluated during *kharif* 2013 which showed superiority in green and dry fodder yields. The cultivation of crop was done under rainfed condition. On the basis of percent increment in green and dry fodder yield three genotypes (AVKG-179, AVKG-181 and AVKG-192) showed superiority ranging from 2.6 to 8.1 for green fodder and 9.5 to 12.2 % for dry fodder yield over the best check variety, that is Bundel Guar-1 (Table 4).

Table 3. Fodder production performance of cluster bean genotypes under rainfed condition

Genotype	Plant height (cm)	No. of branches / plant	No. of leaves / plant	Green fodder yield (q/ha)	Dry fodder yield (q/ha)	Dry matter (%)	Leaf: stem ratio	% superiority (DFY) over best check
AVKG-16	86.0	3.8	20.9	200	44.2	22.1	1.2	-
AVKG-20	76.3	3.9	22.3	195	54.2	27.8	1.3	-
AVKG-42	91.7	3.7	25.5	209	51.2	24.5	1.1	-
AVKG-73	81.3	4.4	22.4	200	42.4	21.2	1.3	-
AVKG-94	79.3	5.8	29.6	194	42.2	21.7	1.3	-
AVKG-102	81.0	4.7	29.1	212	56.6	26.7	1.1	-
AVKG-121	90.3	5.3	30.4	209	46.8	22.4	1.4	-
AVKG-133	80.3	4.1	28.2	201	49.2	24.5	1.4	-
AVKG-143	75.7	4.4	20.3	230	54.4	23.6	1.3	-
AVKG-146	82.0	3.4	20.2	272	61.5	22.6	1.0	9.4
AVKG-148	78.0	3.5	22.8	214	54.1	25.3	1.0	-
AVKG-150	77.0	4.0	28.1	214	42.6	19.9	1.4	-
AVKG-152	78.3	3.9	23.7	209	53.2	25.4	1.3	-
AVKG-160	78.3	4.1	28.3	220	52.1	23.7	1.5	-
AVKG-162	79.7	5.5	33.2	266	59.3	22.3	1.2	5.5
AVKG-177	85.7	6.1	36.3	274	60.8	22.2	1.3	8.2
AVKG-179	91.3	5.6	30.1	268	60.6	22.6	1.4	7.8
AVKG-181	99.0	4.7	23.0	287	64.3	22.4	1.2	14.4
AVKG-189	84.3	4.1	25.0	221	54.2	24.5	0.9	-
AVKG-192	99.3	4.1	31.3	298	65.6	22.0	1.6	16.7
BG-1(Check)	98.0	5.7	27.8	258	56.7	22.3	1.5	
BG-2(Check)	91.0	5.5	25.6	252	55.4	22.4	1.4	
BG-3(Check)	85.3	5.6	23.1	226	51.9	23.1	1.5	
Mean	84.7	4.6	26.4	231.7	53.5	23.2	1.3	
SE(m)±	2.8	0.4	2.0	12.1	3.2	1.4	0.1	
CD at 5%	8.0	2.4	5.6	34.5	9.2	3.6	0.3	

Table 4. Performance of cluster bean promising lines in on farm trial during *kharif* 2014

Genotypes	Plant height (cm)	Green fodder yield (q/ha)	Dry matter (%)	Dry fodder yield (q/ha)	% superiority (DFY) over best check
AVKG-146	92.4	235	27.2	63.9	-0.9
AVKG-162	83.6	227	28.2	64.0	-0.8
AVKG-177	87.7	225	29.4	66.2	2.6
AVKG-179	96.3	278	25.4	70.6	9.5
AVKG-181	102	281	25.5	71.7	11.2
AVKG-192	107.3	293	24.7	72.4	12.2
BG-1 (Check)	105	271	23.8	64.5	
BG-2 (Check)	96	237	25.3	60.0	
BG-3 (Check)	90.3	221	26.8	59.2	
Mean	95.6	252	26.3	65.8	
Range	83.6-107.3	221-293	23.8-29.4	59.2-72.4	

Farmer's observations regarding cluster bean as a green fodder: In general the sole cultivation of cluster bean as green fodder is not being practiced. However, sole cultivation grain/gum type varieties are preferred as cash crop under raifed condition and available crop residues/ straws are used to feed to dry cattle, goat, sheep and camel, but not to milching and pregnant animals. It is believed that it reduces milk production and enhances chance of abortion. Mixed cultivation of cluster bean with pearl millet is long back practice but crop is harvested at full pod stage rather than 50% flowering stage. When harvested at full pod stage large number of leaves are shattered, which reduces quality of fodder.

Conclusion

The analysis of variance showed significant variability for fodder yield among the genotype. Genotypic correlation coefficient showed that green fodder yield was positive and significantly associated with days to flowering, plant height, number of branches/plant, number of leaves/plant and leaf: stem ratio. Fodder type genotypes are late maturing, tall in height, more branches and high leaf: stem ratio. Six genotypes *viz*., AVKG-181, AVKG-179, AVKG-192, AVKG-177, AVKG-146 and AVKG-162 showed superiority for green and dry fodder yields ranging from 3.1 to 15.5% and 5.5 to 16.7%, respectively over the best check.

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