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Variation and association studies for fodder yield and related traits in interspecific hybrids of bajra [*Pennisetum glaucum* (L.) R. Br.] × napier grass [*Pennisetum purpureum* (K.) Schum.]

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Abstract
Twenty bajra x napier hybrids were evaluated for genetic variability, correlation and path coefficients during *Kharif* 2019 at Forage Research Farm, Punjab Agricultural University, Ludhiana. The genotypes were significantly different for most of the characters, which indicated substantial variability among them. High heritability along with high genetic advance was recorded for plant height, leaf Length, number of tillers per plant, and leaf stem ratio indicating the predominance of additive gene effects in the inheritance of these characters. The phenotypic coefficients of variation (PCV) estimates were invariably higher than their corresponding genotypic coefficient of variation (GCV) values thereby suggesting the environmental influence. High estimates of GCV and PCV were observed for most of the traits except stem girth and number of leaves per plant, suggesting that selection based on these characters would facilitate successful isolation of desirable genotypes. Traits like plant height, leaf length and dry matter yield had positive and significant correlation at genotypic as well as phenotypic level with green fodder yield, thus the selection based on these traits would result in improving green fodder yield in bajra napier hybrid. Most of the yield contributing traits like plant height, leaf length, stems girth, number of tillers per plant and dry matter yield exhibited positive direct effect on green fodder yield.

Keywords: Correlation and path coefficient, Green fodder yield, Heritability, Multicut

The genus *Pennisetum* is predominantly grown in Africa and Asia. It is one of the most important members of Poaceae family. The genus comprises about 140 species (Brunken, 1977) and distributed based on morphological characteristics (Stapf and Hubbard, 1934) in five sections i.e. *Penicillaria, Brevivalvula, Gymnothrix, Heterostachya* and *Eu-Pennisetum*. The section *Penicillaria* comprises the most important species *viz*., pearl millet used as cereal and forage, and napier grass as forage (Martel *et al.,*2004). *Pennisetum glaucum*is a diploid (2n = 2x = 14, AA), annual, allogamous species and constitutes the primary gene pool of genus *Pennisetum*. It is well adapted to poor and infertile soils. Its forage has better nutritional quality in terms of crude protein content (%) and dry matter digestibility along with good palatability. *P. purpureum* is tetraploid (2n = 4x = 28, A'A'BB), perennial, allogamous species which belongs to the secondary gene pool of this genus with genomic DNA content of 4.60 pg (Martel *et al.,* 1997). It is an important crop for diary production in tropics. It is the forage of choice not only in the tropics but worldwide, due to its desirable traits such as drought tolerance and wide adaptability to soil conditions (Anderson *et al.,* 2008). It has high forage production potential coupled with high biomass and is of multicut nature that usually provides 5-8 cuts/year. Furthermore, it has an excellent regeneration potential along with its perennial growth behavior which makes it highly favorable among the dairy farmers. It is also being used as biofuel.

Due to heterogeneous nature of napier grass (pollen parent), clonal selection in napier bajra hybrid is very effective breeding tool to develop high green fodder yielding cultivars. The great challenge for bajra napier hybrid breeders lies in identifying the genetic make-ups that are superior in green fodder yield. Green fodder yield is dependent on several other metric traits and is the result of a number of complex morphological and physiological processes affecting each other and occurring in different growing stages. Therefore, the knowledge of association of this economically important character with other characters would be quite useful to select better genotypes having high green fodder yield with better quality parameters (Roy *et al*., 2019).

To reach this goal, the information on the extent of variability, heritability, expected genetic gain and degree of genetic association among the different characters need to be ascertained. An attempt was, therefore, made to estimate the extent of variability for different yield contributing traits, magnitude and direction of association among different characters both at genotypic and phenotypic levels and to investigate the direct and indirect effects of yield components on green fodder yield in bajra napier hybrid.

The experiment was conducted at Forage Research Farm, Punjab Agricultural University, Ludhiana, situated in Trans-Gangetic Agro-Climatic Zone and represents the Indo-Gangetic Alluvial Plains. It is located at 30.56^{o} N latitude, 75.52^{o} E longitude and at an altitude of 247 m above mean sea level. The climate of the area is characterized as sub-tropical and semiarid with hot and dry spring-summer from April to June, hot and humid summer from July to September and cold autumn-winter from November to January. The average annual rainfall is about 705 mm, most of which is received during the monsoon period from July to September, while few showers are received during the winter season. The average maximum temperature ranged from 15.1 to 44.5 ^{o}C and average minimum temperature from 3.8 to 28.1 ^{o}C. A total of 256.8 mm rainfall was recorded during the crop growth season. Total weekly evaporation ranged from 6.8 to 91.2 mm. Mean daily sunshine hours ranged from 0.6 to 13.1 h. The overall weather during crop growth period remained favorable for bajra napier hybrid crop.

The plant material was comprised a total of 20 bajra × napier hybrids, which were synthesized during *Kharif* 2017 using diverse bajra male sterile lines and napier lines. Being sterile, bajra napier hybrids are propagated through stem cuttings/ root slips. The experiment was conducted during *Kharif* 2019 and the hybrids were planted using root slips in randomized complete block design (RBD) with three replications. In each replication the size of plot consisted of 12 sq. m. with 5 rows of 4 m length. The spacing between and within the rows was maintained at 60 cm each. Standard agronomic practices were followed to raise the crop. Observations were recorded on ten randomly selected plants from each entry on nine quantitative variables *viz*., plant height (PH), leaf length (LL), leaf width (LW), number of leaves per plant (NOL), stem girth (SG), leaf stem ratio (LSR), dry matter yield (DMY) and green fodder yield (GFY) for 5 cuts. The data were analyzed for variability, divergence, correlation and path coefficient study. Genotypic and phenotypic coefficients of correlation were calculated from genotypic and phenotypic covariances and variances as described by Singh and Chaudhary (1985) and Johnson *et al.* (1955). Direct and indirect effects were calculated by the path coefficient analysis as suggested by Dewey and Lu (1959) at both phenotypic and genotypic levels. Genotypic and phenotypic correlation coefficients were calculated using the formulae as used by Burton and De Vane (1953) and Johnson *et al.* (1955). Heritability in broad sense was estimated as suggested by Burton (1952). The expected genetic advance at 5 per cent selection intensity was calculated by the formula as used by Johnson *et al.* (1955).

It was evident from the range of mean values for different traits among the genotypes evaluated (Table 1) that these had diverse genetic background. The traits like plant height (112.6 -225.0 cm), leaf length (51.7- 85.0 cm), leaf width (3.1-7.2 cm), number of leaves per plant (86.4 - 182.1), dry matter yield (112.4- 414.8 q/ha) and green fodder yield (468.3-1654.8 q/ha) had wide range of mean values. Genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), broad sense heritability (h^2) and genetic advance as percent of mean (GA %; Table 1) revealed that GCV and PCV values were invariably higher for most of the traits except SG and NOL indicating primarily the genetic control for these traits rather the environment effect alone. Also high estimates of GCV and PCV were observed for number of tillers, leaf stem ratio, dry matter yield and green fodder yield, suggesting that selection based on these characters would facilitate successful isolation of desirable genotypes. However, the genetic variability together with heritability estimates would give a better idea on the amount of GA expected from selection (Burton, 1952). Stem girth and number of leaves/plant had low GCV values indicating little scope for improvement in these traits in the materials studied.

High h^2 along with high GA was recorded for plant height, leaf length, number of tillers, and leaf stem ratio. Heritability along with phenotypic variance and the severity of selection provide estimableness of genetic advance or responding to the selection which is very useful in the selection of promising lines (Burton, 1952). Traits having high h^2 and high GA are supposed to be under control of additive genes; hence, these can be improved by selection based on phenotypic performance (Singh *et al*., 2005). Green fodder yield had lowest h^2 (28.97) followed by dry matter yield (32.60), thus, are difficult to be improved by phenotype guided selection. Traits like leaf width and stem girth and number of leaves per plant had high h^2 but low values of GA suggesting the involvement of non-additive gene action in their inheritance. Traits like leaf stem ratio exhibited high h^2 coupled with high PCV suggesting greater scope for selection of these traits on phenotypic basis.

Table 1. Estimates of genetic parameters for different forage traits in bajra napier hybrids

Characters	Range of mean values	h^2 (%)	GA (%)	PCV	GCV	GM
PH	112.6 – 225.0	82.31	33.75	19.90	18.06	105.40
LL	51.7 – 85.0	96.90	36.87	18.47	18.18	69.76
LW	3.1 – 7.2	97.41	38.13	19.00	18.75	2.55
SG	2.2 – 3.8	87.26	28.70	15.97	14.92	1.07
NOL	10.1 – 14.1	73.41	22.49	14.87	12.74	6.18
NOT	20.0 – 48.0	91.24	51.84	27.58	26.35	25.63
LSR	0.35 - 0.85	99.21	93.02	45.52	45.34	1.58
DMY	112.4 – 414.8	98.62	70.07	34.49	34.25	318.36
GFY	468.3 – 1654.8	96.43	68.14	32.56	33.22	903.70

h^2: Heritability (broad sense); PCV: Phenotypic coefficient of variability; CV: Genotypic coefficient of variability; GA (%): Genetic advance as percentage of mean; GM: Grand mean

Table 2. Genotypic and phenotypic correlation coefficients among different forage traits of bajra napier hybrids

Characters		PH	LL	LW	SG	NOL	NOT	LSR	DMY
LL	G	0.74**							
	P	0.64**							
LW	G	0.35**	0.35**						
	P	0.32**	0.34**						
SG	G	0.60**	0.59**	0.63*					
	P	0.49**	0.55**	-0.05*					
NOL	G	0.44**	0.30**	0.26**	0.46**				
	P	0.34**	0.27**	-0.01	0.18*				
NOT	G	0.22**	-0.04	-0.20*	-0.06	0.20*			
	P	0.18**	-0.03	-0.11	0.12	0.20*			
LSR	G	-0.46**	-0.20*	0.15	-0.14	-0.35**	-0.54**		
	P	-0.42**	-0.20*	0.03	-0.08	0.05	-0.06		
DMY	G	0.72**	0.50**	0.25*	0.33**	0.51**	0.34**	-0.55**	
	P	0.64**	0.49**	0.18	0.16*	0.08	0.10	-0.12	
GFY	G	0.72**	0.50**	0.25**	0.34**	0.51**	0.34**	-0.54**	0.90**
	P	0.65**	0.49**	-0.25**	-0.11	0.03	-0.10	-0.22**	0.76*

*Critical value of 'r' at 5% = 0.16; **Critical value of 'r' at 1% = 0.21; G: Genotypic correlation coefficient; P: Phenotypic correlation coefficient

Green fodder yield is a complex character controlled by several components which reflect positive and negative effects on this trait. It is important to note that whenever two traits are correlated, selecting for one would ensure selection for the other trait, therefore, selecting for the best of the traits that correlated with yield in this study would result in increased yields. Thus for achieving rational improvement in fodder yield and its components, knowledge of mechanism of association, cause and effect relationship provides a basis for formulating suitable selection methods for the yield components.

Results indicated that many yield contributing traits *viz.*, plant height, leaf length and dry matter yield had positive and highly significant correlation at genotypic as well as phenotypic level with green fodder yield (Table 2) and the selection based on these traits will result in improving the green fodder yield in bajra napier hybrid. It was reported by Kapoor (2017) that the green forage yield was positively correlated with stem diam-eter. Further perusal of the data revealed that except leaf stem ratio (LSR), none of the trait exhibited significant negative correlation with green fodder yield indicating that it is difficult to select for high yielding genotypes with high LSR at the same time. LSR also showed negative correlation with many of the traits under study. Plant height showed high and positive correlation with all other important yield contributing traits except LSR. This was in accordance to the results obtained by Sood and Singh (1982), Mali *et al*. (2015) and Kapoor (2017) who reported strong correlation of plant height with leaf length, leaf width, number of leaf/plant and number of tillers/plant. Partitioning of the total correlation coefficient into direct and indirect effects for green fodder yield showed a high

Table 3. Path coefficient analysis for direct (bold) and indirect effects on green fodder yield (kg/plot) in bajra napier hybrids

Traits	PH	LL	LW	SG	NOL	NOT	LSR	DMY	Genotypic correlation with GFY
PH	**-0.0267**	0.0043	-0.0009	0.009	-0.0022	0.0011	-0.0016	0.7338	0.72**
LL	-0.0197	**0.0058**	-0.0009	0.0088	-0.0015	-0.0002	-0.0007	0.5093	0.50**
LW	-0.0094	0.002	**-0.0026**	0.0094	-0.0013	-0.001	0.0005	0.2567	0.25**
SG	-0.0161	0.0034	-0.0016	**0.0149**	-0.0023	-0.0003	-0.0005	0.3387	0.34**
NOL	-0.0118	0.0017	-0.0007	0.0069	**-0.0051**	0.001	-0.0012	0.5215	0.51**
NOT	-0.0057	-0.0002	0.0005	-0.0009	-0.001	**0.005**	-0.0018	0.3448	0.34**
LSR	0.0124	-0.0012	-0.0004	-0.002	0.0018	-0.0027	**0.0034**	-0.556	-0.54**
DMY	-0.0192	0.0029	-0.0006	0.0049	-0.0026	0.0017	-0.0019	**1.0000**	1.00**

PH: Plant height; LL: Leaf length; LW: Leaf width; SG: Stem girth; NOL: Number of leaves per plant; NOT: Number of tillers per plant; LSR: Leaf stem ratio; DMY: Dry matter yield; GFY: Green fodder yield

direct effect of many yield contributing traits *viz*., leaf length, stem girth, number of tillers/plant and dry matter yield (Table 2). Highest value of positive and significant correlation was observed between green fodder yield and dry matter yield (0.90, 0.76) closely followed by plant height and green fodder yield (0.72, 0.65), plant height and dry matter yield (0.72, 0.64). Leaf stem ratio and green fodder yield exhibited highest value of negative and significant correlation (-0.54, -0.22). This was in accordance to the results obtained by Mali *et al*. (2015) and Kumari *et al*. (2018) who reported strong correlation of plant height with leaf length, leaf width, number of leaf/ plant and number of tillers/plant.

Partitioning of the total correlation coefficient into direct and indirect effects for green fodder yield showed a positive direct effect of many yield contributing traits. It showed a high direct effect of many yield contributing traits *viz*., leaf length, stem girth, number of tillers/plant and dry matter yield (Table 3). Kumar and Singh (2004), Mali *et al*. (2015), Kapoor (2017) and Toor *et al.* (2017) reported that the dry forage yield/ plant is significantly and positively asso-ciated with green fodder yield and yield components such as plant height, number of leaves/ plant, and stem diam-eter. Thus the improvements in characters such as plant height, leaf length, and stem girth will help improve fodder yield both directly and indirectly. Negative direct effect contributed by traits like leaf width and number of leaves per plant, however, deluded the positive and direct effect of earlier traits on green fodder yield.

The positive indirect effects were contributed through most of the traits *viz.*, leaf length, stem girth and dry matter yield. High and significant genotypic correlation values of traits like leaf length (0.50), stem girth (0.34), number of tillers/plant (0.34) and dry matter yield (1.00) with green fodder yield and their high direct effect values on green fodder yield *i.e*. 0.0058, 0.149, 0.0050 and 1.000, respectively indicated a true picture of association between these traits. Kumari *et al.* (2018), Toor *et al.* (2017) reported that plant height and stem diameter is not related to dry mat-ter yield. However, Kumar and Singh (2004) demonstrated that plant height and stem diameter is related to dry matter yield. Thus clonal selection in the clonal nursery of bajra napier hybrids for taller plants with longer leaves will be significant for the improvement of green fodder yield.

Hence, selection for taller plants with more number of broader and longer leaves with thicker stem and having high tillering ability will be significant for the improvement of green fodder yield in bajra napier hybrid genotypes under study. At the same time progress in breeding for enhanced green fodder yield might be adversely affected by selection for high leaf stem ratio, due to a strong negative association of these traits with green fodder yield. It was concluded that these significant findings will be effectively utilized for developing high yielding genotypes of bajra napier hybrid.

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