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VARIABILITY AND CHARACTER ASSOCIATION STUDIES IN ELITE FODDER MAIZE (*ZEA MAYS* L.) GENOTYPES

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SUMMARY

The present investigation was conducted at the Forage Research Area, CCS Haryana Agricultural University, Hisar during the *kharif* season of 2024. Data was collected on 12 quantitative traits to perform PCV, GCV, heritability, genetic advance as *per cent* of mean, correlation and path analysis using 35 elite fodder maize genotypes. High value of PCV was observed for leaf weight/plant and moderate GCV were observed for leaf weight/plant, stem weight/plant, leaf: stem, number of leaves/plant, dry matter yield/ plot. High broad sense heritability was observed for leaf weight/plant, stem weight/plant, days to 50% flowering, leaf: stem, green fodder yield/plot, leaf breadth. High GAM was observed for leaf weight/plant, stem weight/plant, leaf: stem. High heritability coupled with high genetic advance was observed for leaf weight/plant, stem weight/plant, leaf: stem. Green fodder yield/plot was significant and positively associated with plant height, leaf weight/plant, stem weight/plant, leaf: stem, leaf length, leaf breadth, number of leaves/plant, dry matter yield/plot. Path coefficient analysis indicated the positive direct effect of plant height, leaf weight/plant, days to 50% flowering, leaf length, leaf breadth, internode length, number of leaves/plant, dry matter yield/plot on green fodder yield/plot.

Key words: Fodder maize, correlation, path analysis, green fodder yield and quantitative traits

Maize (*Zea mays* L.) is an important cereal crop belongs to the tribe Maydeae, of the grass family, Poaceae. *Zea mays* is the only species in the genus *Zea* with chromosome number 2n=20 and is native to South America. Vavilov (1926), suggested that the most likely center of origin for maize is Mexico or Central America, with a secondary origin in South America. Globally, maize is known as "Queen of cereals" because of its highest genetic yield potential and wider adaptability which makes it cultivable at elevations ranging from up to 3000 meters above mean sea level. Its demand is increasing very fast particularly with the expansion of dairy, poultry and maize-based industries. It is a fast-growing, succulent, high-yielding, nutritious crop (Arya *et al.,* 2020; Sehwag et al., 2021). It is an ideal fodder crop due to its rapid growth, strong palatability, rich nutrition, excellent taste, high succulence, and higher yields, making it suitable for feeding at any stage of its growth. Maize is cultivated year-round in India because it can adapt to various temperatures and rainfall patterns. Due to diverse climatic conditions and different cropping seasons, it can be grown in *kharif* (monsoon), *rabi* (winter), and *summer* (Banik *et al.,* 2023; Kiran *et al.,* 2023).

The maize plant, transformed into silage, has been used with great success by the dairy and beef industries. The silage industry is growing slowly in the Punjab and has huge scope in Haryana also. For this purpose, improved varieties/hybrids which are resistant against biotic and abiotic stresses, can give high green and dry fodder yield needed to be bred. Maize is predominantly grown as *kharif* fodder in the northwestern regions of India, it outshines sorghum and pearl-millet in quality. Under Haryana conditions, *kharif* fodder maize crop should be sown during June 25 to July 10 with a crop geometry of 30 cm x 10 cm with a fertilizer dose of 80 kg N+40 kg P_2O_5 per hectare for ensuring high fodder yield along with economical production (Satpal *et al.*, 2024). The green fodder maize (variety African Tall) contains dry matter (22.2%), crude protein (7.1%), crude fiber (30.2%), *in-vitro* dry matter digestibility (65.0%), neutral detergent fiber (67.6%), acid detergent fiber (38.3%) and total ash (6.0%). (Raghuwanshi *et al.,* 2023). The superiority of maize fodder is also evident from the fact that sorghum and pearl millet contain anti-nutritional components like HCN and oxalate, respectively.

The simple measures of variability can be used to estimate the variability in germplasm, but that variability may not be heritable. Hence to predict the selection response heritability along with genetic advance as per cent of mean is more effective. Since yield is complex polygenic trait, understanding correlations, both direct and indirect is essential for formulation of effective selection strategies (Nguyen *et al*., 2019). Therefore, considering above points present study was conducted.

MATERIALS AND METHODS

The experimental material consisted of 35 diverse fodder maize genotypes were evaluated in the field experiments conducted during the *kharif* -2024 at Forage Research Area, Department of Genetics & Plant Breeding, CCS Haryana Agricultural University, Hisar, Haryana in a Randomized Block Design (RBD) with three replications (Table 1). Each genotype was grown in paired row of 2-meter length, following row to row distance 30 cm and plant to plant spacing 10 cm. The experimental crop was sown on July 16, 2024. Observations were recorded on five randomly selected plants from each replication for 12 quantitative traits *viz*. plant height (cm), leaf weight/plant (g), stem weight/ plant (g), leaf- stem ratio, days to 50% flowering, leaf length (cm), leaf breadth (cm), stem girth (cm), number of leaves/plant, internode length (cm), dry matter yield/ plot (DMY/plot) (kg), green fodder yield/plot (GFY/ plot) (kg). Statistical analysis was carried out according to Fisher (1925) for analysis of variance; Burton and De Vane (1953) for estimation of phenotypic and genotypic coefficients of variation, heritability and genetic advance; Al-Jibouri *et al.* (1958) for correlation coefficient and Dewey & Lu (1959) for path analysis.

RESULTS AND DISCUSSION

Genetic variability

Significant differences were found among 35 genotypes for quantitative traits except plant height (cm), leaf length (cm) revealed the presence of considerable genetic variability for all the characters under study. Rathod *et al.* (2021); Pavithra *et al.* (2022); Singh *et al.* (2023); Bashir *et al.* (2024); Prasad *et al.* (2024) also observed substantial genetic variation for different quantitative traits among the fodder maize genotypes in their study material. The phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV) indicating the influence of environmental factors on the expression of the all traits studied. Leaf weight/ plant exhibited the high PCV and moderate GCV but the difference was narrow and the narrow difference between phenotypic coefficient of variation and genotypic coefficient of variation revealed that the environment played little role in the expression of this trait. Stem weight/plant (kg), leaf: stem, number of leaves/plant, DMY/plot (kg) exhibited moderate GCV and PCV in fodder maize (Table 2). Above findings corroborated with the results of earlier studies Rathod

TABLE 1
List of 35 fodder maize genotypes evaluated during the study

S. No.	Genotype	Source	S. No.	Genotype	Source
1.	GK 3270	Ganga Kaveri Seed	19	DFH 2022-1	GBPUAT, Pantnagar
2.	TNFMH-21-25	TNAU, Coimbatore	20	ADFM-4	IARI, RS, Dharwad
3.	JH 17026	PAU, Ludhiana	21	PMC-14	MPUAT, Udaipur
4.	DFH 2023-1	GBPUAT, Pantnagar	22	HPFM-12	CSKHPKV, Palampur
5.	GK 3237	Ganga Kaveri Seed	23	PMC-16	MPUAT, Udaipur
6.	J-1006	PAU, Ludhiana	24	AFM-23	AAU, Anand
7.	JHFM-23-2	IGFRI, Jhansi	25	ADFM-5	IARI, RS, Dharwad
8.	African Tall	MPKV, Rahuri	26	DFH-2	GBPUAT, Pantnagar
9.	GK 3122	Ganga Kaveri Seed	27	KDFM-11	SKUAST, Srinagar
10.	JHFM 2023-3	IGFRI, Jhansi	28	ADFM 8	IARI, RS, Dharwad
11.	GK 3271	Ganga Kaveri Seed	29	AH-4750	IARI, New Delhi
12.	NMH 40F	Nuzivedu Seeds	30	MAH- 20-45	UAS ZARS, Mandya
13.	JH 19014	PAU, Ludhiana	31	MAH-20-32	UAS ZARS, Mandya
14.	BAIF Maize-8	BAIF, Urulikanchan	32	KDFM 10	SKUAST, Srinagar
15.	FSM 2023-1	Foragen Seeds	33	JHFM-24-3	IGFRI, Jhansi
16.	KDFM-8	SKUAST, Srinagar	34	AH-4754	IARI, New Delhi
17.	MAH 15-84	UAS ZARS, Mandya	35	MFH 2445	DRRPCAU, Dholi
18.	COHM-8	IIMR hybrid			

TABLE 2

Mean, range, phenotypic and genotypic coefficient of variation, heritability and GAM for various traits in fodder maize

Traits	Mean±SE(m)	Range	Coefficient of Variation (%)		Heritability (%)	Genetic Advance as % of mean
			GCV	PCV		
Plant Height (cm)	184.69 ± 36	206.33 - 145.00	6.57	10.23	41.23	8.68
Leaf Weight/Plant (g)	187.42 ± 7.8	256.33- 133.33	19.03	20.36	87.38	36.65
Stem Weight/Plant (g)	452.77 ± 13.00	550 - 380.33	11.84	12.85	85.01	22.5
LS ratio	0.41 ± 0.02	0.57 - 0.30	12.66	16.18	61.22	20.4
Days to 50% flowering	61 ± 0.30	66 - 57.67	3.13	3.24	93.43	6.23
Leaf length (cm)	81.33 ± 4.14	96.33 -68.33	7.61	11.66	42.53	10.22
Leaf breadth (cm)	7.77 ± 0.20	9.16 - 6.97	8.12	9.29	76.43	14.63
Stem Girth (cm)	4.15 ± 0.14	4.73 - 3.67	5.36	8.07	44.17	7.34
Number of leaves/plant	11 ± 0.82	14.67 - 8.67	11.22	16.64	45.5	15.6
Internode length (cm)	19.62 ± 1.22	22.67 - 16.00	4.68	11.77	15.81	3.83
DMY/Plot (kg)	0.87 ± 0.06	1.07 - 0.68	11.28	16.12	49.02	16.27
GFY/Plot (Kg)	4.02 ± 0.14	4.74 - 3.46	7.92	10.04	62.29	12.88

et al. (2021); Pavithra *et al.* (2022); Borkhatariya *et al.* (2022); Bashir *et al.* (2024).

Heritability is the ratio of genotypic variance to the total variance. It is a good index of the transmission of characters from parents to their offspring (Falconer, 1960). Estimates of heritability and genetic advance together help to predict gain under selection rather than heritability alone. High heritability and genetic advance offer the best condition for selection as they indicate the presence of additive gene action for the trait and crop improvements by selecting for such traits are rewarding (Oo *et al.*, 2023; Hasan *et al.*, 2025). High broad sense heritability was observed for leaf weight/plant, stem weight/plant, days to 50% flowering, leaf: stem, GFY/plot, leaf breadth. High GAM was observed for leaf weight/plant, stem weight/plant, leaf: stem. High heritability coupled with high genetic advance was observed for leaf weight/ plant, stem weight/plant, leaf: stem. These findings were substantiated by Kapoor *et al.* (2017); Rathod *et al.* (2021); Pavithra *et al.* (2022); Borkhatariya *et al.* (2022); Bashir *et al.* (2024).*Correlation coefficient analysis*: The correlation coefficient for 12 quantitative traits in 35 fodder maize genotypes were investigated to find out the relationship among quantitative traits (Table 3). GFY/plot exhibited a positive and highly significant correlation with plant height (0.471**), leaf weight/plant (0.439**), stem weight/plant (0.288**), leaf: stem (0.327**), leaf length (0.569**), leaf breadth (0.543**), and number of leaves indicating simultaneous selection based on these characteristics would be effective for GFY/plot. Plant height exhibited a positive and highly significant correlation with leaf weight/plant (0.344**), stem weight/plant (0.234*), leaf: stem (0.247*), leaf length (0.296**), leaf breadth (0.472**), number of leaves/plant (0.391**), DMY/plot (0.361**), and GFY/plot (0.471**). These results were supported for either one or more than one trait indicated as earlier reported by Kapoor and Batra (2015); Kapoor *et al.* (2017); Singh *et al.* (2019); Rathod *et al.* (2021); Borkhatariya *et al.* (2022); Singh *et al.* (2023); Bashir *et al.* (2024). *Path coefficient analysis*: Path analysis is a powerful measure to estimate the contribution of direct and indirect effects of various independent characters on a dependent character *i.e.*, GFY/plot. Positive direct effect of trait DMY/plot (0.685), leaf breadth (0.295), leaf weight per plant (0.211), leaf length (0.096), days to 50% flowering (0.080), number of leaves per plant (0.080), internode length (0.033), and plant height (0.010) indicated that these are important components of GFY/plot (Table 4). The value of residual effect in path analysis was 0.0178, which implies that most of the variability in GFY/ plot was well explained by the traits included in the path analysis model. The direct selection for high GFY/ plot based on these characters would be effective. Similar findings were recorded earlier by Kapoor and Batra (2015); Kapoor *et al.* (2017); Rathod *et al.* (2021); Borkhatariya *et al.* (2022); Palaniyappan *et al.* (2023); Bashir *et al.* (2024).

CONCLUSION

In the current study, fodder maize germplasm studied exhibited substantial variability for all the characters. High magnitude of heritability coupled with high genetic advance as *per cent* of mean was observed for for leaf weight/plant, stem weight/plant, leaf: stem. These characters can be improved through selection. Association studies revealed that the GFY/plot is positively and significantly correlated with plant height,

TABLE 3

Phenotypic correlation coefficient among various traits of fodder maize

Phenotypic Correlations Matrix	Plant height (cm)	Leaf weight/ plant (g)	Stem weight/ plant (g)	Leaf: stem	Days to 50% flowering	Leaf length (cm)	Leaf breadth (cm)	Stem girth (cm)	Number of leaves/ plant	Internode length (cm)	DMY/ Plot (kg)	GFY/ Plot (kg)
Plant Height (cm)	1.00											
Leaf Weight/Plant (g)	0.344**	1.00										
Stem Weight/Plant (g)	0.234*	0.622**	1.00									
LS ratio	0.247*	0.770**	-0.011	1.00								
Days to 50% flowering	-0.028	-0.157	-0.009	-0.193*	1.00							
Leaf length (cm)	0.296**	0.278**	0.222*	0.172	-0.064	1.00						
Leaf breadth (cm)	0.472**	0.448**	0.378**	0.255**	0.120	0.332**	1.00					
Stem Girth (cm)	0.116	0.218*	0.307**	0.054	0.143	0.033	0.194*	1.00				
Number of leaves/plant	0.391**	0.332**	0.159	0.310**	-0.054	0.413**	0.303**	0.115	1.00			
Internode length (cm)	-0.182	-0.101	-0.167	-0.006	0.082	-0.187	-0.262**	-0.140	-0.341**	1.00		
DMY/Plot (kg)	0.361**	0.282**	0.100	0.282**	-0.433**	0.485**	0.217*	-0.018	0.482**	-0.131	1.00	
GFY/Plot (kg)	0.471**	0.439**	0.288**	0.327**	-0.197*	0.569**	0.543**	0.056	0.539**	-0.183	0.803**	1.00

*Significant at 5%, ** Significant at 1%.

TABLE 4

Path coefficient direct (diagonal) and indirect effects of various traits on green fodder yield per plot of fodder maize

Traits	Plant height (cm)	Leaf weight/ plant (g)	Stem weight/ plant (g)	Leaf: stem	Days to 50% flowering	Leaf length (cm)	Leaf breadth (cm)	Stem girth (cm)	Number of leaves/ plant	Internode length (cm)	DMY/ Plot (kg)	Correlation coefficient
Plant Height (cm)	**0.010**	0.072	-0.010	-0.033	-0.002	0.028	0.139	-0.004	0.031	-0.006	0.245	**0.471**
Leaf Weight/Plant (g)	0.003	**0.211**	-0.027	-0.101	-0.013	0.027	0.132	-0.007	0.027	-0.003	0.191	**0.439**
Stem Weight/Plant (g)	0.002	0.131	**-0.044**	0.001	-0.001	0.021	0.111	-0.009	0.013	-0.005	0.067	**0.288**
LS Ratio	0.002	0.163	0.000	**-0.146**	-0.016	0.017	0.073	-0.001	0.025	0.000	0.215	**0.332**
Days to 50% flowering	0.000	-0.033	0.000	0.025	**0.080**	-0.006	0.035	-0.004	-0.004	0.003	-0.293	**-0.197**
Leaf length (cm)	0.003	0.059	-0.010	-0.023	-0.005	**0.096**	0.098	-0.001	0.033	-0.006	0.326	**0.569**
Leaf Breadth (cm)	0.005	0.094	-0.017	-0.032	0.010	0.032	**0.295**	-0.006	0.024	-0.009	0.147	**0.542**
Stem Girth (cm)	0.001	0.046	-0.014	-0.006	0.011	0.003	0.057	**-0.031**	0.009	-0.005	-0.014	**0.059**
Number of leaves/plant	0.004	0.070	-0.007	-0.040	-0.004	0.040	0.089	-0.004	**0.080**	-0.011	0.323	**0.539**
Internode length (cm)	-0.002	-0.021	0.007	0.001	0.007	-0.018	-0.077	0.004	-0.027	**0.033**	-0.089	**-0.183**
DMY/Plot (kg)	0.004	0.060	-0.004	-0.042	-0.035	0.046	0.064	0.001	0.038	-0.004	**0.685**	**0.812**

Residual effect = 0.0177.

leaf weight/plant, stem weight/plant, leaf: stem, leaf length, leaf breadth, and number of leaves. In addition, direct positive effect was exerted by DMY/plot, leaf breadth, leaf weight per plant, leaf length, days to 50% flowering, number of leaves per plant, internode length, and plant height on GFY/plot, suggesting that the simultaneous selection based on these characters would be effective for GFY/plot.

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