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EXAMINATION OF THE RELATIONSHIPS AMONG MORPHOLOGICAL AND BIOCHEMICAL TRAITS AFFECTING GREEN FODDER YIELD IN FORAGE MAIZE (*ZEA MAYS* L.) USING CORRELATION AND PATH COEFFICIENT ANALYSIS

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ABSTRACT

Sustainable production of the forage crop is one of the primary goals for plant breeders to meet the needs of an ever-increasing livestock population required to supply the demand for milk. Maize (*Zea mays* L.) is a dual-purpose crop used for seed and fodder, mostly cultivated in *Rabi* and *Kharif* seasons in India. Forage maize performs well under the cooler environment and thus fifty genotypes of forage maize were evaluated during *Rabi* 2021-22 at Main Forage Research Station, Anand Agricultural University, Gujarat, India. The association of Green fodder yield per plant with the different morphological as well as biochemical traits was analyzed, and path coefficient analysis was performed to assess the direct and indirect effects of the different traits. Results revealed the significantly positive association of days to 50% tasseling, days to 50% silking, number of leaves per plant, plant height, stem thickness, leaf length, leaf width, neutral detergent fibre (NDF) and Acid detergent fibre (ADF) at both genotypic as well as phenotypic level with green fodder yield per plant (GFYPP). While crude protein (CP) had negative significant genotypic and phenotypic correlation with GFYPP. Leaf: stem ratio had negative significant phenotypic correlation and dry matter content (DM) had positive significant genotypic correlation with GFYPP. The highest correlation of NDF (r_g = 1.209) and stem thickness (r_p = 0.838) with green fodder yield per plant was found at genotypic and phenotypic levels, respectively. The genotypic path coefficient analysis revealed positive direct effects of such yield contributing traits, like days to 50% tasseling, days to 50% silking, Plant height, leaf width and dry matter content and the highest positive direct effect on green fodder yield per plant was observed from leaf width. While, in the phenotypic path, all the traits except leaf: stem ratio, DM and CP. Therefore, selecting the plant with wider leaves and higher plant height will ultimately increase the green fodder yield in forage maize, and the improved forage maize genotypes may lead towards sustainable milk production in developing countries like India.

Key words : Acid Detergent Fiber, Crude Protein, Correlation, Forage Maize, Path Analysis.

Introduction

Maize (*Zea mays* L.) is an important cereal crop belongs to the tribe Maydeae, of the grass family, Poaceae. The plant is native to South America. The genus *Zea* has only one species, *Zea mays*, which has chromosomal number 2n = 20. Maize is gaining importance in India as a feed crop. Its demand is increasing very fast particularly with the expansion of dairy, poultry and maize-based industries (Ahmed *et al.*, 2010). It is increasingly used as an animal feed and fodder crop for both green forage and silage. It has high production potentiality, wide adaptability and multiple uses (Gour *et* *al.*, 2006). It can be grown as a dual crop for grain as well as for fodder in India (Mahdi *et al.*, 2010). Forage maize is quick growing, succulent, sweet palatable, high yielding, nutritious and free from toxicants. It can be safely fed to animals at any stage of crop growth (Devi, 2002). It is utilized in the form of grains, green fodder, silage, stover and pasturage. Green fodder provides adequate energy and proteins for growth of animals and milk production (Takawale *et al.*, 2009). Corn is an important feed for animal and poultry with high net energy content and low fibre content.

Breeders of forage maize face significant difficulty in determining which genetic combinations produce the highest yields of green fodder. The production of green fodder is influenced by multiple metric features and is the outcome of intricate morphological and physiological processes that transpire at distinct growth stages and interact with one another. To choose better genotypes with high yields of green fodder with improved nutrients and quality characteristics, it would be helpful to know, how this economically significant feature is associated with other characters.

The effectiveness of a breeding initiative primarily relies on the direction and extent of the relationship between yield and its components, as well as the significance of each factor to forage output. Generally, correlation assesses the degree and direction (positive or negative) of the relationship among two or more variables. Path analysis is a statistical method that separates correlations into direct and indirect effects. The evaluations of correlation and path coefficients can assist in understanding the roles and relative impacts of various plant characteristics in shaping the growth patterns of crop varieties under specific environmental conditions. (Shahbaz *et al.*, 2007).

Materials and Methods

Experimental Site

The experiment was conducted during *Rabi* 2021-22 at Main Forage Research Station, Anand Agricultural University, Anand (22° 35' N, 72° 55' E), Gujarat, India. The soil texture of the experimental location at Anand centre is sandy loam, with a pH range of 8.1 to 8.5. It has low organic matter, nitrogen and cation exchange capacity, while it has a medium phosphorus content and it is moderately rich in potash.

Experimental Design and Material

Fifty diverse forage maize genotypes were evaluated in a randomized complete block design with three replications. Each genotype was planted in a single row of 5.0 m in length, 30 cm apart, with a 10 cm plant-to-plant spacing. To avoid damage and border effects, the experiment was surrounded by border rows. The recommended agronomical and plant protection practices were followed for the successful raising of the crop.

Observations Recorded and Characters investigated

Observations were recorded on five randomly selected plants from each entry for thirteen different traits *viz.*, days to 50% tasseling, days to 50% silking, number of leaves per plant, plant height (cm), stem thickness (cm), leaf length (cm), leaf width (cm), leaf: stem ratio, dry matter content (%), crude protein content (%) [CP], neutral detergent fibre content (%) [NDF], acid detergent fibre content (%) [ADF] and green fodder yield per plant (g). The sample collected from each genotype was chopped and air-dried for three days followed by oven drying at 100° C till the attainment of constant weight and then dry matter content was calculated from the data. After that, the sample was powdered and scanned with "FOSS NIR System" (Model: 5000 composite) following the standard analytical protocol to estimate all the quality parameters such as CP, NDF and ADF.

Statistical analysis

The data collected were analysed for correlation and path coefficient analysis. Genotypic and phenotypic coefficients of correlation were calculated from genotypic and phenotypic co-variances and variances as described by Singh and Chaudhary (1985); 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. The data were analysed using the "Variability" package (Popat *et al.*, 2020) in the R-studio.

Results and Discussion

The complex character fodder yield is influenced by several different features, each of which has direct and indirect effects on green fodder yield and is either positively or negatively correlated with it. It is crucial to keep in mind that if two attributes are correlated, choosing one would automatically ensure the selection of the other. A better yield of fodder maize would result from selecting the best features in this study that corresponded with yield. To rationally improve fodder yield and its constituent parts, it is necessary to understand the mechanisms of association and causes and effects correlations to choose the best selection techniques for the yield components.

Association between Forage Traits

The genotypic correlation coefficients and phenotypic correlation coefficients for various traits are given in Tables 1 and 2, respectively. Results indicated that all the traits, except LSR and CP, had a positive and significant correlation at the genotypic level with green fodder yield per plant. CP also had a significant, but negative genotypic correlation with green fodder yield. Earlier negative genotypic correlation for CP content in forage maize was found by Kapoor and Batra (2015). While at the phenotypic level, all the traits, except three traits *viz*., LSR, DM and CP; were found positively and significantly correlated with green fodder yield per plant. Thus, selection based on these traits will result in improving the green fodder yield in forage maize genotypes. Here, LSR and CP had significant and negative phenotypic correlations with green fodder yield. These results were in harmony with the findings of Kapoor and Batra (2015) as well as Rathod *et al*. (2021) for number of leaves, plant height, stem girth, leaf length and leaf width. Earlier, similar findings were observed when the same set of genotypes were studied under the *Kharif* season except for LSR and ADF (Borkhatariya *et al*., 2022). Similarly, Parmar *et al*. (2022) studied similar traits in forage bajra and the findings also suggested that such traits like plant height, leaf length, leaf width, NDF and ADF show positive correlation with the green fodder yield per plant, however for CP negative correlation found in most of the cases. Sondarava *et al*. (2023) and Patel *et al*. (2022) while handling the large number of genotypes of maize suggested that days to silking and days to tasseling are highly correlated traits, which supports our findings.

The maximum positive genotypic correlation coefficient was observed between DM and NDF (r_g = 1.881), followed by leaf length and NDF (r_g = 1.619). While, the highest negative and significant correlation coefficient was found between CP and NDF (r_g = -3.809), followed by dry matter content and CP (r_g = -1.767). The highest value of positive and significant phenotypic correlation was observed between days to 50% tasseling and days to 50% silking (r_p = 0.966), followed by stem thickness and green fodder yield per plant (r_p = 0.838). Whereas CP and NDF (r_p = -0.625) exhibited the highest value of negative and significant correlation at the phenotypic level, followed by DM and CP (r_p = -0.348).

The highest correlation of NDF (r_g = 1.209) and stem thickness (r_p = 0.838) with green fodder yield per plant was found at genotypic and phenotypic levels, respectively. While the highest negative correlation of green fodder yield per plant was observed with crude protein content (r_g = -0.604) and leaf: stem ratio (r_p = -0.216) at genotypic and phenotypic levels, respectively. Significant correlations between fodder yield as well as

Table 1 : Genotypic correlation coefficients among various traits of forage maize genotypes.

	DS	NOL	PH	ST	LL	LW	LSR	DM	CP	NDF	ADF	GFYPP
DT	0.979**	0.833**	0.686**	0.904**	0.604**	0.600**	0.072	0.566**	-0.700**	1.103**	0.785**	0.771**
DS		0.846**	0.714**	0.960**	0.651**	0.667**	0.025	0.541**	-0.799**	1.194**	0.837**	0.802**
NOL			0.886**	0.951**	0.607**	0.749**	-0.100	0.378**	-0.702**	0.928**	0.721**	0.846**
PH				1.033**	0.659**	0.854**	-0.106	0.631**	-0.674**	0.619**	1.171**	0.899**
ST					0.645**	0.837**	-0.399**	0.517**	-0.629**	1.554**	1.328**	1.127**
LL						0.908**	-0.690**	0.617**	-0.976**	1.619**	1.524**	0.857**
LW							-0.522**	0.420**	-0.987**	1.425**	1.272**	0.937**
LSR								0.357*	-0.416**	0.088	-0.425**	-0.247
DM									-1.767**	1.881**	0.069	0.430**
CP										-3.809**	-0.160	-0.604**
NDF											0.653**	1.209**
ADF												1.125**

*, **Significant at 5% and 1% level of significance; DT= days to 50% tasseling, DS= days to 50% silking, NOL= number of leaves per plant, PH= plant height (cm), ST= stem thickness (cm), LL= leaf length (cm), LW= leaf width (cm), LSR: leaf: stem ratio, DM= dry matter content (%), CP= crude protein content (%), NDF= neutral detergent fibre content (%), ADF= acid detergent fibre content (%), GFYPP= green fodder yield per plant (g).

Table 2 : Phenotypic correlation coefficients among various traits of forage maize genotypes.

	DS	NOL	PH	ST	LL	LW	LSR	DM	CP	NDF	ADF	GFYPP
DT	0.966 **	0.665 **	0.382 **	0.445**	0.231 **	0.218 **	0.101	0.263 **	-0.216 **	0.183 *	0.293 **	0.625 **
DS		0.667 **	0.399 **	0.461 **	0.231 **	0.207 *	0.080	0.254 **	-0.236 **	0.205 *	0.293 **	0.642 **
NOL			0.527 **	0.629 **	0.257 **	0.308 **	-0.083	0.072	-0.167 *	0.117	0.174 *	0.722 **
PH				0.421 **	0.187 *	0.318 **	-0.142	0.077	-0.134	0.171 *	0.050	0.550 **
ST					0.586 **	0.605 **	-0.168 *	-0.178 *	-0.033	0.002	0.102	0.838 **
LL						0.602 **	-0.265 **	-0.124	-0.004	-0.004	0.168 *	0.536 **
LW							-0.228 **	-0.229 **	0.170*	-0.153	0.098	0.537 **
LSR								0.151	-0.095	0.014	-0.064	-0.216**
DM									-0.348 **	0.446 **	0.151	-0.006
CP										-0.625 **	-0.139	-0.170 *
NDF											0.197 *	0.170 *
ADF												0.274 **

*, **Significant at 5% and 1% level of significance; DT= days to 50% tasseling, DS= days to 50% silking, NOL= number of leaves per plant, PH= plant height (cm), ST= stem thickness (cm), LL = leaf length (cm), LW= leaf width (cm), LSR: leaf: stem ratio, DM= dry matter content (%), CP= crude protein content (%), NDF= neutral detergent fibre content (%), ADF= acid detergent fibre content (%), GFYPP= green fodder yield per plant (g).

Table 3 : Genotypic path coefficient analysis for direct (bold) and indirect effects on green fodder yield per plant (g) in forage maize genotypes.

	DT	DS	NOL	PH	ST	LL	LW	LSR	DM	CP	NDF	ADF	Genotypic correlation with GFYPP
DT	**0.553**	0.816	-0.658	0.521	-0.509	-0.432	0.752	-0.038	0.111	0.020	-0.208	-0.157	0.7714 **
DS	0.542	**0.833**	-0.668	0.541	-0.540	-0.466	0.837	-0.013	0.106	0.023	-0.225	-0.167	0.8029 **
NOL	0.461	0.705	**-0.790**	0.672	-0.535	-0.434	0.939	0.053	0.074	0.020	-0.175	-0.144	0.8464 **
PH	0.380	0.595	-0.700	**0.758**	-0.581	-0.471	1.071	0.056	0.123	0.019	-0.117	-0.234	0.8994 **
ST	0.501	0.800	-0.751	0.783	**-0.562**	-0.462	1.050	0.208	0.101	0.018	-0.292	-0.265	1.1272 **
LL	0.334	0.543	-0.480	0.500	-0.363	**-0.715**	1.140	0.360	0.121	0.028	-0.304	-0.304	0.8575 **
LW	0.332	0.556	-0.592	0.648	-0.471	-0.650	**1.254**	0.272	0.082	0.028	-0.268	-0.254	0.9374 **
LSR	0.040	0.021	0.080	-0.081	0.225	0.494	-0.655	**-0.521**	0.070	0.012	-0.017	0.085	-0.2474
DM	0.313	0.451	-0.299	0.479	-0.291	-0.441	0.527	-0.186	**0.196**	0.050	-0.354	-0.014	0.4300**
CP	-0.388	-0.667	0.556	-0.513	0.354	0.700	-1.242	0.218	-0.347	**-0.028**	0.718	0.032	-0.6049 **
NDF	0.610	0.995	-0.733	0.470	-0.874	-1.158	1.788	-0.046	0.368	0.108	**-0.188**	-0.130	1.2090 **
ADF	0.434	0.697	-0.570	0.888	-0.747	-1.090	1.595	0.221	0.014	0.005	-0.123	**-0.200**	1.1258 **

*, **Significant at 5% and 1% level of significance; DT= days to 50% tasseling, DS= days to 50% silking, NOL= number of leaves per plant, PH= plant height (cm), ST= stem thickness (cm), LL = leaf length (cm), LW= leaf width (cm), LSR: leaf: stem ratio, DM= dry matter content (%), CP= crude protein content (%), NDF= neutral detergent fibre content (%), ADF= acid detergent fibre content (%), GFYPP= green fodder yield per plant (g).

Table 4 : Phenotypic path coefficient analysis for direct (bold) and indirect effects on green fodder yield per plant (g) in forage maize genotypes.

	DT	DS	NOL	PH	ST	LL	LW	LSR	DM	CP	NDF	ADF	Genotypic correlation with GFYPP
DT	**0.072**	0.128	0.078	0.047	0.240	0.011	0.011	-0.009	-0.002	0.014	0.009	0.028	0.6259 **
DS	0.069	**0.132**	0.078	0.049	0.249	0.011	0.010	-0.007	-0.002	0.015	0.010	0.028	0.6428 **
NOL	0.048	0.088	**0.117**	0.064	0.338	0.012	0.015	0.008	-0.001	0.010	0.006	0.017	0.7226 **
PH	0.028	0.053	0.062	**0.122**	0.227	0.009	0.016	0.013	-0.001	0.008	0.008	0.005	0.5503 **
ST	0.032	0.061	0.073	0.052	**0.536**	0.028	0.030	0.015	0.001	0.001	0.000	0.010	0.8381 **
LL	0.017	0.031	0.030	0.023	0.316	**0.048**	0.030	0.024	0.001	0.000	0.001	0.016	0.5360**
LW	0.016	0.028	0.036	0.039	0.327	0.029	**0.050**	0.021	0.002	-0.011	-0.007	0.010	0.5372 **
LSR	0.007	0.011	-0.010	-0.017	-0.090	-0.013	-0.011	**-0.090**	-0.001	0.005	0.001	-0.006	-0.2160 **
DM	0.019	0.034	0.008	0.009	-0.096	-0.006	-0.011	-0.014	**-0.007**	0.022	0.021	0.015	-0.0060
CP	-0.015	-0.031	-0.019	-0.016	0.000	0.000	0.009	0.007	0.003	**-0.063**	-0.030	-0.013	-0.1706 *
NDF	0.013	0.027	0.014	0.021	0.001	0.000	-0.008	-0.001	-0.003	0.039	**0.048**	0.019	0.1704 *
ADF	0.021	0.039	0.020	0.006	0.056	0.008	0.005	0.006	-0.001	0.009	0.009	**0.097**	0.2746 **

*, **Significant at 5% and 1% level of significance; DT= days to 50% tasseling, DS= days to 50% silking, NOL= number of leaves per plant, PH= plant height (cm), ST= stem thickness (cm), LL = leaf length (cm), LW= leaf width (cm), LSR: leaf: stem ratio, DM= dry matter content (%), CP= crude protein content (%), NDF= neutral detergent fibre content (%), ADF= acid detergent fibre content (%), GFYPP= green fodder yield per plant (g).

various yield contributing traits suggest that these characteristics were controlled by genes with pleiotropic effect or controlled by multiple genes that are linked (Chen and Lubberstedt, 2010).

Path Coefficient analysis

The partitioning of the total genotypic correlation coefficient into direct and indirect effects for green fodder yield revealed positive direct effects of many yield-contributing traits, like days to 50% tasseling (0.553), days to 50% silking (0.833), plant height (0.758), leaf width (1.254) and dry matter content (0.196) (Table 3). Similarly, the positive direct effect of days to 50% tasseling and dry matter content was found by Borkhatariya *et al.* (2022) and Rathod *et al.* (2021). Thus, the improvement in yield contributing characteristics such as leaf width and plant height will directly or indirectly help to improve green fodder yield. Parmar *et al.* (2022) also observed the positive direct effect of flowering days and plant height on fodder yield indicating that these traits can be selected as truly correlated traits with the green fodder yield in forage crops.

However, negative direct effects were observed for such traits as number of leaves per plant (-0.790), stem thickness (-0.562), leaf length (-0.715), leaf: stem ratio (-0.521), crude protein content (-0.028), NDF (-0.188) and ADF (-0.200). It ultimately indicated that the positive significant correlation of most of these traits with green fodder yield per plant was due to indirect effects generated through other characters mainly. The negative direct effect of leaf: stem ratio was observed by Borkhatariya *et al*. (2022) and Kapoor (2017); also Kapoor and Batra (2015) reported a negative direct effect of ADF on green fodder yield. Negative direct effects of the number of leaves and other quality parameters like CP and ADF have been observed by Parmar *et al*. (2022), while working with forage crop.

The partitioning of the total phenotypic correlation coefficient into direct and indirect effects for green fodder yield revealed positive direct effects of many yield contributing traits, like days to 50% tasseling (0.072), days to 50% silking (0.132), number of leaves per plant (0.117), plant height (0.122), stem thickness (0.536), leaf length (0.048), leaf width (0.050), NDF (0.048) and ADF (0.097). While negative direct effects were observed for such traits as leaf: stem ratio (-0.090), dry matter content (-0.007) and crude protein content (-0.063) (Table 4).

The highest positive direct effect on green fodder yield per plant was observed from leaf width followed

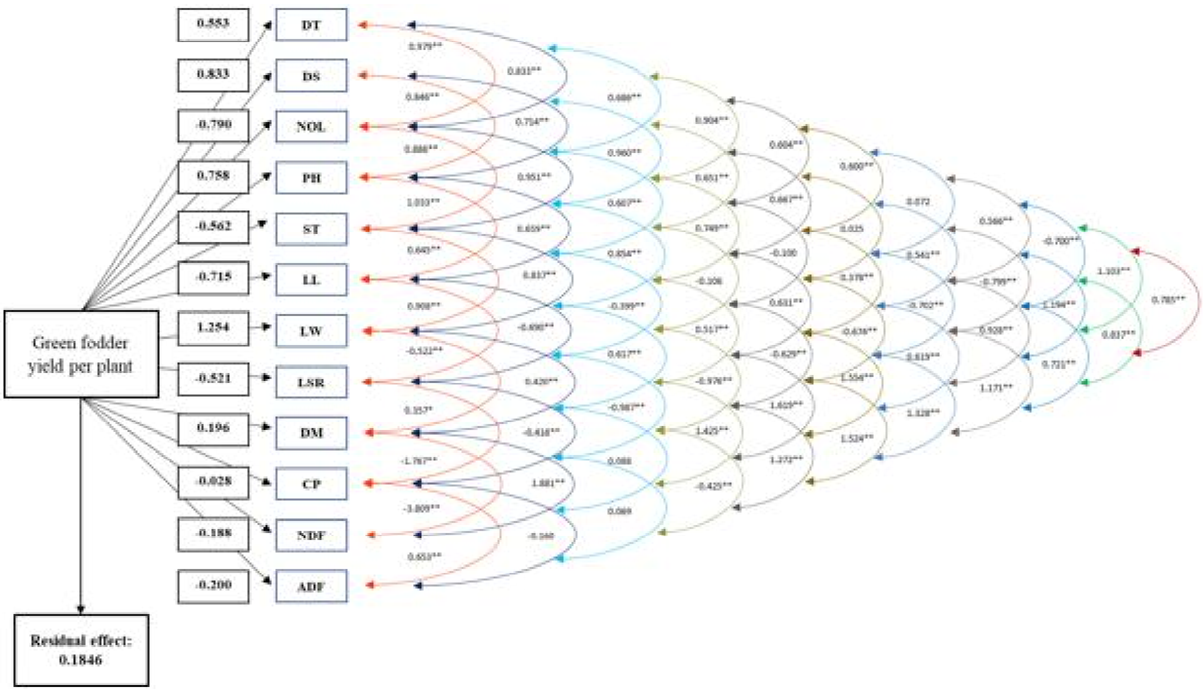

Fig. 1 : Path diagram depicting genotypic correlation and direct effects of yield attributes on green fodder yield per plant in forage maize [*, **Significant at 5% and 1% level of significance; DT= days to 50% tasseling, DS= days to 50% silking, NOL= number of leaves per plant, PH= plant height (cm), ST= stem thickness (cm), LL = leaf length (cm), LW= leaf width (cm), LSR: leaf: stem ratio, DM= dry matter content (%), CP= crude protein content (%), NDF = neutral detergent fibre content (%), ADF= acid detergent fibre content (%), GFYPP= green fodder yield per plant (g)].

by days to 50% silking and plant height. Although, the number of leaves per plant had the highest negative direct effect, the positive correlation with green fodder yield was due to the positive indirect effects *via* leaf width and other important traits.

Further, days to 50% tasseling, days to 50% silking, plant height, leaf width and dry matter content had a true relationship with green fodder yield per plant by establishing a significant positive association and positive direct effect on green fodder yield. Thus, selection for such traits like plant height and leaf width will be more rewarding for the improvement of green fodder yield per plant in forage maize.

Conclusion

The current investigation supports the notion that, selection for positively correlated characteristics such as days to 50% tasseling, days to 50% silking, number of leaves per plant, plant height, stem thickness, leaf length, leaf width, dry matter content, NDF and ADF could increase the yield of green fodder. As per path analysis, selection for the plant with more plant height, leaf width and dry matter content will efficiently increase the green fodder yield. At the same time selection for higher crude protein content can adversely affect the progress in breeding for improving green fodder yield due to the strong negative significant association of this trait with it. However, balancing different quality parameters is also an important task while practising the selection for various quantitative traits to improve green fodder yield in forage maize. Overall, the NDF and ADF in forage maize can be improved simultaneously with higher production of green fodder as they had positive and significant correlation with it.

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