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Exploring the correlated Response and cause-effect Relationship for the Green Fodder Yield and its contributing Traits in Sorghum

Deepak Kaushik[1], Yogesh Jindal[1*], Amit[1], Vikesh Tanwar[1] and Bichhinna Maitri Rout[2]
[1]Department of Genetics and Plant Breeding, CCS HAU, Hisar (Haryana), India.
[2]Department of Vegetable Science, ICAR-IARI (New Delhi), India.

(Corresponding author: Yogesh Jindal)*
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ABSTRACT: The present study was carried out at the CCS Haryana Agricultural University, Hisar to characterize and assess genetic diversity in 49 sorghum genotypes on the basis of fifteen morpho-biochemical parameters. Analysis of variance showed highly significant variation for quantitative parameters in the study. The genotypes GP-236 and IS 49021 had the highest average green (462.8 q/ha) and dry (239.2 q/ha) fodder yields, while G-800 and HC 171 had the lowest amounts of HCN (19.1 µg/g) and tannin (0.32 mg/g). IS 651 and IS 49021, respectively, had the highest levels of crude protein (10.94%) and crude protein yield (23.42 q/ha). Green fodder yield showed significant and positive genotypic correlation with plant height, dry matter percentage, dry fodder yield, crude protein, crude protein yield while significant and negative with 100-grain weight, HCN content. Path analysis studies revealed that the characters *viz.* plant height upto flag leaf base, total plant height, stem diameter, leaf length, 100-grain weight, dry fodder yield *etc*. had positive effect on green fodder yield while negative effect was shown by time of panicle emergence, 100-grain weight, HCN and tannin content. Therefore, choosing this character might lead to an improvement in yield and yield components.

Keywords: Genetic diversity, Green fodder yield, HCN, Tannin content, Sorghum.

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench], also known as great millet, Indian millet, jowar, milo etc. is considered the important cereal crop in *Poaceae* family after wheat, rice, maize, barley and is the source of nourishment for more than 500 million people across 90 countries, substantially in the developing world (Ritter *et al*., 2007). The worldwide production and area under the sorghum cultivation is 58 million tonnes and 40 Mha, respectively with the largest contribution from the Africa (46.8%). In terms of quantity production the largest producers are USA (9 MT), Nigeria (6 MT), Ethiopia (5 MT) and India (4.7 MT), respectively (Anonymous, 2022).

Sorghum has a lot of potential for producing fodder with scarce resources. It is more drought resilient, less input-demanding, and more tolerant of hard conditions than other grains, especially maize. Sorghum is an important silage crop for meat and dairy producers (Mohammed, 2010).

In a population's genetic diversity and the degree to which the targeted traits are heritable have a significant role in the success of a breeding program (Majumder *et al*., 2008). To begin an effective breeding programme, genetic variation evaluation that offers data on estimates such as genotypic coefficient of variation, phenotypic coefficient of variation, heritability estimates, and genetic progress is very much required and of the utmost importance (Atta *et al*., 2008). Estimating heritability provides details on the level of genetic influence over the manifestation of a specific trait as well as the reliability of phenotypic prediction of breeding value (Falconer, 1981). High heritability in a trait is a good indicator of revealing the direction in which it can be further improved. However, broad sense heritability might not be accurate in the absence of genetic advance. Therefore, for a more accurate assessment, estimates of broad sense heritability must be combined with estimates of genetic advance (Najeeb *et al.*, 2009). Correlation coefficient analysis shows the mutual dependence among the various characters under consideration. The insight into the relationship between different simple or complex traits like yield can help in simultaneous improvements (Hussein, 2022). The lone estimation of the correlation coefficient and conclusion can be misleading due to significant indirect effects of the various other traits. So, it is imperative to include the path coefficient analysis for segregating the correlation coefficient into direct and indirect effects (Chavhan *et al.*, 2022). Hence, present investigation was planned to understand genetic variability parameters and their inter-relationship for green fodder yield and its contributing traits in sorghum.

MATERIALS AND METHODS

The forty nine genotypes were grown in randomized block design; with three replication each grown two rows. The plant to plant distance was 10 cm and row to row distance was 30 cm with a row length of 3m. The data was recorded on five randomly selected plants in each genotype for15 morphological and biochemical traits namely: time of panicle emergence (days), height upto flag leaf (cm), total plant height (cm), stem diameter (mm), third leaf length from top (cm), third leaf breadth from top (cm), panicle length without peduncle (cm), dry matter (%), hundred seed weight (g), green fodder yield (q/ha), dry fodder yield (q/ha), HCN content on fresh weight basis (μg/g), protein (%), crude protein yield (q/ha), tannin content on dry weight basis (mg/g).

RESULTS AND DISCUSSION

A. Analysis of variance and mean performance

The ANOVA indicated that all the 49 sorghum genotypes were significantly different for all the traits studied, which indicated the existence of substantial genetic variability among the genotypes under study for further selection and improvement. Results are in agreement with the studies of Sinha and Kumaravadivel (2016); Kisua *et al.* (2015), Kalpande *et al.* (2014) etc. On the basis of mean performance, the highest green fodder yield and dry fodder yield was recorded for the genotypes GP-236 (462.8 q/ha) and IS 49021(239.2 q/ha), respectively. Regarding nutritional quality, lowest amount of HCN and tannin was recorded in G-800 (19.1 μg/g) and HC 171(0.32 mg/g), respectively. The highest amount of crude protein and crude protein yield was recorded for IS 651(10.94%) and IS 49021(23.42 q/ha) respectively. Indicating that these genotypes are useful as genetic source in forage sorghum improvement program. Furthermore, the genotype namely, IS 49021 might prove very useful in the improvement of forage sorghum aimed for both higher dry fodder yield and crude protein yield simultaneously. These results were in agreement with previous findings by Hussein (2022); Chavhan *et al.* (2022) who also found highly significant differences for the means squared of the studied traits.

B. Correlation Studies

Phenotypic and genotypic correlation coefficients among all the observed characters are present in Fig. 1. The phenotypic and genotypic coefficients confirm each other in terms of sign and value in almost every instance. This similarity might be due to the sufficient number of replication and selected plants for observing the characters, which renders the environmental variance and covariance close to zero. And if there are instances of reduced error variance, then the phenotypic and genotypic correlation coefficients start converging and, at last identical. This understanding is vital while considering the correlation between the characters that environmental agencies could influence the association rising false positive and negative associations of the traits hindering the overall breeding improvement of the targeted trait (Patil *et al.*, 2014).

As presented in Fig. 1, time of panicle emergence had a positive and significant correlation with the stem diameter of 0.3294, implying that if there is a delay in the accumulation of stem (diameter), then we can see the increased time for the panicle initiation in the plant. As expected, the character height upto flag leaf is very strongly correlated with the plant height (0.9217), showing that the tall plants certainly have a long flag. Clearly, it can be understood that the increase in the height upto flag leaf/plant height would help increase the green-dry fodder yield and is represented by their correlation coefficients (0.5912, 0.4759 and 0.6183, 0.4807 respectively) that are large and significant. The trait, height upto flag leaf and plant height are negatively correlated with the HCN content, which can be understood by the fact that HCN content is high at early growth stages, subsequently reduced towards maturity while the height was measured at the end of the physiological maturity. Both the characters are strongly and positively correlated with the crude protein yield, but no such association comes out from the crude protein percentage indicating not much significant increase per unit basis despite the overall increase in crude protein yield. Similar results were reported by Jain and Patel (2016); Hussein (2022); Chavhan *et al.* (2022) in sorghum.

Stem diameter was found to be positively correlated with the third leaf breadth, reasoning if there is an increase in the dry matter accumulation in the stem that surely will be translated into the increase in the leaf breadth but no such strong association with the third leaf length was observed. It can be estimated that this will also increase the plant's dry matter percentage, which is supported by its significant and positive correlation with it. Third leaf length and breadth are positively and significantly correlated with the dry matter percentage; also, earlier is twice strongly correlated as the latter. It is observed that breadth (third leaf) is negative – significantly correlated with the panicle length (without peduncle) while remaining largely non-significant with length (third leaf). Length and breadth (third leaf) considerably contribute to the dry fodder and rude protein yield.

Dry matter percentage, shown as DM, is the direct result of dry fodder yield and is strongly affected by the green fodder yield; that can be confirmed by their correlation coefficients which are positive and highly significant: 0.7732 and 0.3109, respectively. It is also strongly associated with the crude protein yield, similar to dry fodder yield. In the case of green fodder yield very strongly positively correlated with the dry fodder yield, as expected. Green fodder yield has a significant negative correlation with the HCN content that can be argued to be similar to height upto flag leaf trait. As in the case of HCN content, phenotypic correlation is found to be significant in the number of cases like plant height, but similarities can't be attributed to the genotypic correlation coefficients. Similarly, tannin content is non-significant for most of the studied traits. The results from the present study are in agreement with the reports by Sood and Ahluwalia (1989); Sanderson *et al*. (1994); Singh *et al.* (2016); Jain and Patel (2016); Chavhan *et al.* (2022) in sorghum genotypes.

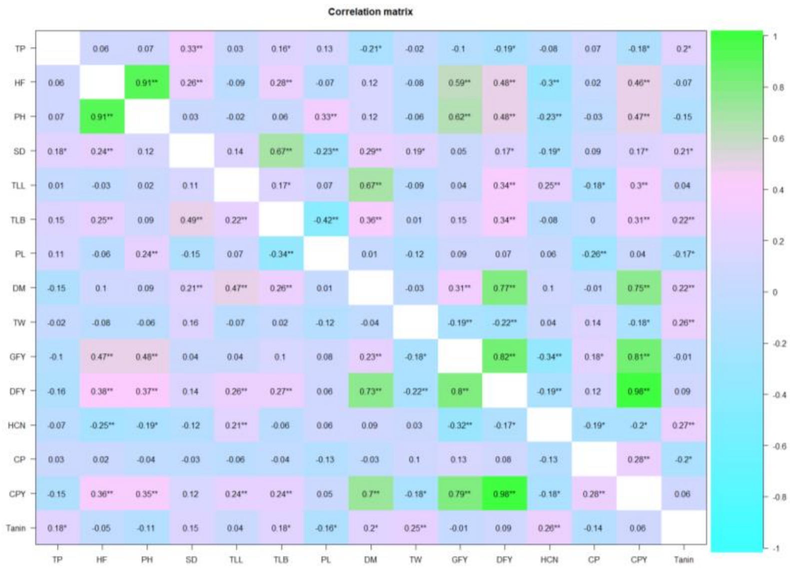

Fig. 1. Genotypic (above diagonal) and phenotypic (below diagonal) correlation matrix between different traits of sorghum.

C. Path Analysis Studies

Path breeders must work with the correlated traits in the crop improvement programmes. Grafius (1959) opined that there might not be genes for yield; in particular, instead could be governed by genes that control the inheritance of component traits. Path analysis is a specialized multivariate analysis dealing with a closed system of linearly related variables. As the number of characters increases, the indirect effects attributed to these become less obvious and more complex. At this juncture, path coefficient analysis could help to differentiate the direct and indirect impact of the relationship of characters. It also helps critically examine factors responsible for the correlation and their relative importance (Dewey and Lu 1959). The path matrix is presented in Table 1.

The results from path coefficient analysis revealed that dry fodder yield (1.882) had very high direct effect on green fodder yield; SD (0.135) and TW (0.118) had low magnitude of direct effect on GFY. DM % (-1.240) showed a highly negative and direct effect on GFY. However, the direct and negative effect of TLB (-0.125) and CPY (-0.197) was low. Furthermore, the effect of TP (-0.093), HF (0.018), PH (-0.0255), PL (0.002), HCN (0.003), protein (0.044) and tannin (0.083) were found to be negligible in either (negative or positive) directions. The most important contributing traits in the green fodder yield was dry fodder yield, third leaf length and height upto flag leaf as these are contributing significantly directly and indirectly. Sorghum, due to its considerable height, tends to slope down or fall, which might result in the loss of the overall gain in grain yield, as expected due to the corresponding large flag leaf that is conferred by the fact we have the non-significant correlation with the 100-seed weight. These results were in conformation with studies by Navneet and Singh (2012); Seetharam and Ganesamurthy (2013); Kalpande *et al.* (2014); Patil *et al*. (2014); Hussein (2022) in sorghum.

Table 1: Direct (diagonal) and indirect (off diagonal) genetic path coefficients on green fodder yield in sorghum.

	TP	HF	PH	SD	TLL	TLB	PL	DM%	TW	DFY	HCN	CP	CPY	Tanin
TP	**-0.0938**	-0.0061	-0.0064	-0.0309	-0.0027	-0.0151	-0.0126	0.0195	0.0015	0.0176	0.0078	-0.0069	0.0165	-0.0186
HF	0.0011	**0.0175**	0.0160	0.0045	-0.0015	0.0050	-0.0012	0.0022	-0.0014	0.0083	-0.0053	0.0003	0.0081	-0.0012
PH	-0.0017	-0.0233	**-0.0255**	-0.0007	0.0005	-0.0014	-0.0084	-0.0031	0.0015	-0.0123	0.0060	0.0008	-0.0119	0.0038
SD	0.0443	0.0343	0.0035	**0.1345**	0.0191	0.0905	-0.0304	0.0384	0.0260	0.0229	-0.0250	0.0115	0.0224	0.0278
TLL	0.0093	-0.0287	-0.0057	0.0462	**0.3248**	0.0552	0.0226	0.2182	-0.0298	0.1091	0.0798	-0.0579	0.0979	0.0119
TLB	-0.0201	-0.0357	-0.0068	-0.0840	-0.0212	**-0.1249**	0.0530	-0.0453	-0.0017	-0.0420	0.0096	0.0005	-0.0391	-0.0272
PL	0.0002	-0.0001	0.0006	-0.0004	0.0001	-0.0007	**0.0018**	0.0000	-0.0002	0.0001	0.0001	-0.0005	0.0001	-0.0003
DM	0.2575	-0.1555	-0.1490	-0.3543	-0.8331	-0.4503	-0.0102	**-1.2403**	0.0409	-0.9590	-0.1204	0.0108	-0.9349	-0.2759
TW	-0.0019	-0.0097	-0.0070	0.0228	-0.0108	0.0016	-0.0147	-0.0039	**0.1177**	-0.0255	0.0045	0.0163	-0.0211	0.0300
DFY	-0.3531	0.8957	0.9047	0.3204	0.6322	0.6325	0.1243	1.4552	-0.4087	**1.8820**	-0.3548	0.2326	1.8524	0.1726
HCN	-0.0003	-0.0010	-0.0008	-0.0006	0.0008	-0.0003	0.0002	0.0003	0.0001	-0.0006	**0.0033**	-0.0006	-0.0007	0.0009
CP	0.0032	0.0007	-0.0014	0.0038	-0.0078	-0.0002	-0.0116	-0.0004	0.0061	0.0054	-0.0085	**0.0440**	0.0124	-0.0086
CPY	0.0346	-0.0912	-0.0916	-0.0329	-0.0594	-0.0617	-0.0089	-0.1485	0.0354	-0.1939	0.0403	-0.0554	**-0.1970**	-0.0123
Tanin	0.0165	-0.0057	-0.0122	0.0172	0.0030	0.0181	-0.0141	0.0185	0.0212	0.0076	0.0222	-0.0163	0.0052	**0.0832**
GFY	**-0.1041**	**0.5912**	**0.6183**	**0.0456**	**0.0440**	**0.1484**	**0.0898**	**0.3109**	**-0.1913**	**0.8198**	**-0.3403**	**0.1792**	**0.8103**	**-0.0139**

R^2 = 0.987; Residual effect = 0.113

TP: Time of Panicle Emergence; HF: Height up to flag leaf (cm); PH: Plant Height (cm); SD: stem diameter (mm); TLL: Third leaf length (cm); TLB: Third leaf breadth (cm); PL: Panicle length without peduncle (cm); DM: Dry matter (%); TW: 100 seed weight (gm); GFY; Green fodder yield (q/ha); DFY: Dry fodder yield (q/ha); HCN: HCN content (µg/g) on fresh weight basis; CP = Crude Protein (%); CPY: Crude protein yield (q/ha); Tanin: tannin (mg/g) on dry weight basis

CONCLUSIONS

The study concluded the presence of significant variability for the studied traits in the sorghum genotypes. Various genetic parameters indicates the presence of additive gene action for the majority of studied traits that can felicitate for direct selection for these traits. From the studied sorghum genotypes; GP-297, IS 49021, PGN 9 and HC 171 can be used for the enhancement green fodder yield and nutritional attributes. So, Subsequent selection of these traits will increase the breeding efficiency of the genotypes. Hence, due consideration should be given for the traits while selecting parental lines. These superior genotypes can be used for further breeding programmes.

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Conflicts of Interest. None.

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