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Delineation of Selection Criterion Using Correlation and Path Analysis in Forage Pearl Millet (*Pennisetum glaucum* (L.) R. Br.) in North Gujarat Condition

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Authors' contributions

This work was carried out in collaboration among all authors. Authors YAV and RS designed the work. Authors RS and PPJ did data collection. Authors RS and ARD performed data analysis. Authors RS and YAV drafted the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Knowledge of genetic and phenotypic association among economic traits helps plant breeders in outlying efficient breeding strategies for development of high yielding forage pearl millet variety. An experiment was conducted at the research farm of Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat to evaluate plant characteristics associated with green forage yield and its attributes in forage pearl millet [*Pennisetum glaucum* (L.) R. Br.] genotypes in north Gujarat condition through correlation and path analyses during 2023. Twelve independent and 1 dependent variables were evaluated for the character association analysis of the 30 forage pearl millet genotypes. The evaluation was performed in a Randomized Complete Block Design with three replications. Data collection was done from 5 randomly selected plants and this data was used for analysis using R Studio. The green forage yield per plant had positive and significant correlation with plant height, number of tiller per plant, stem thickness, leaf length, leaf width, and dry fodder yield per plant at both genotypic and phenotypic level. Path analysis revealed the importance of leaf width and dry fodder yield per plant by showing high and positive direct effects towards green forage yield per plant. These characters also exhibited significant and positive association with green forage yield per plant at the genotypic and phenotypic. Hence, these traits could be considered as the vital component characters for development of high yielding genotypes in forage pearl millet.

Keywords: Forage pearl millet; green forage yield per plant; correlation; path analysis.

1. INTRODUCTION

Pearl millet serves as a dual-purpose drought-tolerant crop, particularly valuable for fodder production. The appeal of pearl millet's green fodder is augmented by its drought resilience and absence of hydrogen cyanide (HCN) content, rendering it safe for cattle consumption at all growth stages [1]. Pearl millet is an annual, tillering and diploid (2n = 2x = 14) crop plant that belongs to the family Poaceae and sub-family Paniceidae. In India, pearl millet is cultivated on 7.55 million hectare area of land with 9.22 million tonnes of production, and 1374 kg/ha productivity in the year 2020-21 [2]. In India, it is mainly grown in Rajasthan, Uttar Pradesh, Gujarat, Haryana and Maharashtra. In Gujarat, the area, production, and productivity of pearl millet are 0.46 million hectares, 1.008 million tonnes, and 2191 kg/ha, respectively in the year 2021- 22 [3]. “Within the total net cropped area, hardly 5 per cent is used to grow fodder crops. That’s why, in recent years India has been facing an acute shortage of feeds and fodder. The demand will reach 1012 million tonnes of green fodder and 631 million tonnes of dry fodder by the year 2050. At the present level of growth in forage resources, there will be an 18.4% deficit in green fodder and a 13.2% deficit in dry fodder within the year 2050. To meet the deficit, green forage has to grow at 1.69% annually” [4]. “There is little or no scope for increasing the cultivation area due to rapid urbanization and industrialization *etc*. Therefore, there is an urgent need to emphasize increasing forage crop production per unit area to meet the fodder requirement by evolving high yielding and improved varieties of forage crops as well as innovative forage production technology. The productivity and growth of livestock are closely linked with the biomass and quality of forages. Analysing the coefficients of correlation between the traits that either directly or indirectly affect yield is important when conducting a selection program” [5]. Correlation estimates between yield and its component characters play a pivotal role in guiding the selection of genotypes and designing effective breeding programs. Correlation coefficients quantify the extent of association, whether influenced by genetic or environmental factors, between two or more characters, thereby serving as a fundamental principle for selection strategies [6,7,8,9]. “This is owing to the fact that most of the characters are inter related, and a changed in one is likely to influence the other, thus the net benefit received by selecting one may be counterbalanced by a simultaneous change in another. Therefore, correlation is helpful in determining the component characters of a complex trait like green forage yield. It does not, however, indicate the relative significance of the direct and indirect effects of these characters” [10]. These may be determined through path analysis, with the unfolding of correlation coefficient for analysed traits. Path coefficient estimation provides information about the direct and indirect effects of yield attributes on yield. It shows how attributing characters influence the yield by their path values, whether they affect yield directly or via influencing other interrelated characters [11].

2. MATERIALS AND METHODS

The experimental materials consist of 30 forage pearl millet genotypes grown during July-October 2023 at research farm of Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat which is located at the 24°-19° North Latitude and 72°-19° East Longitude with an altitude of 154.52 meters above mean sea level situated in the North Gujarat Agro-climatic Zone. The experimental materials were provided by Main Forage Research Station, Anand Agriculture University, Anand. The experimental material consisted of improved genotypes based on diverse performance for various traits along with diverse locations of adaptation. The evaluation was performed in a Randomized Complete Block Design with three replications with row to row spacing of 30 cm and plant to plant spacing of 15 cm. All the recommended package of practices were adapted to raise the healthy crop. Quantitative and qualitative traits, *viz*. days to flowering, days to maturity, plant height (cm), number of tiller per plant, stem thickness (cm), number of leaf per plant, leaf length (cm), leaf width (mm) , leaf: stem ratio, green forage yield per plant (g), dry fodder content %, dry fodder yield per plant (g) and crude protein content % were recorded. Observations were collected on 5 arbitrarily selected pearl millet plants from each line and means were calculated for all the traits excluding days to flowering and days to maturity which were documented on plot basis. Crude protein content (%) was estimated from an oven dried sample following nitrogen estimation by Kjeldahl method [12]. Crude protein content was calculated by multiplying the percentage of nitrogen with a factor of 6.25. The genotypic (r_g) and phenotypic (r_p) correlation coefficient were calculated as under by adopting the procedure explained by Al-Jibouri et al. [13]. The correlation among the different character combinations was utilized to construct the path coefficient analysis suggested by Wright [14] and used by Dewey and Lu [15]. Replicated data were analysed using R package variability v.0.1.0 [16].

3. RESULTS AND DISCUSSION

3.1 Correlation Analysis

As green forage yield per plant is a complex quantitative character which is generally influenced by environment, any direct selection done for yield is not effective. Therefore, correlation studies traits that will be considered for effective choice of increasing green forage yield per plant and quality in terms of crude protein content. Understanding the relationships between various components and their respective contributions is crucial for selection [17,18]. Table 1 and Table 2 represent the findings. In general, the genotypic correlation coefficient was significantly higher than phenotypic correlation coefficient indicating the inherent association among various studied traits and phenotypic value is lessened by the significant interaction of environment. Less significant phenotypic correlation coefficients than genotypic correlation coefficients were also observed in a number of previous study findings [19,20].

The genotypic and phenotypic association of green forage yield per plant was positive and highly significant correlated with plant height (r_g=0.6688, r_p=0.5953), number of tiller per plant (r_g=0.6387, r_p=0.5471), stem thickness (r_g=0.8161, r_p=0.6885), leaf length (r_g=0.6450, r_p=0.4418), leaf width (r_g=0.9244, r_p=0.7269), and dry fodder yield per plant (r_g=0.8567, r_p=0.8045) indicated that these characters are the primary yield determinants. Selection criteria based on these traits would be beneficial for improvement of green forage yield per plant in forage pearl millet. This further helps in simultaneous improvement of both highly correlated traits. According to correlation data from the present study, it is possible that the aforementioned characteristics could be enhanced simultaneously as a result of coinheritance. Similar results also found by Balasaheb [21], Shinde [22] for plant height, leaf length and dry matter yield per plant; Singh et al. [23] for stem thickness; Lokhande [24] for plant height, leaf length, leaf width and dry matter yield per plant; Thomas et al. [25] for plant height and dry matter yield per plant and Shalini [26] for dry matter yield per plant; Aswini et al. [27] for plant height, stem thickness, and dry fodder yield per plant. Green forage yield per plant was negative and significant correlated with days to maturity (r_g= -0.8059, r_p= -0.6236). Days to maturity is inversely proportional to green forage yield per plant. This relation showed that if genotype takes more time for maturity it leads to lower green forage yield per plant. Rani et al. [28] showed negatively significant results with green fodder yield which is contradictory to above result. Non-significant association of green forage yield per

Table 1. Genotypic correlation coefficient for different characters in forage pearl millet

Characters	DF	DM	PH	NTP	ST	NLP	LL	LW	LSR	DFC	DFYP	CPC	GFYP
DF	**1.0000**	-0.3490	0.3915*	0.1461	0.0590	0.2777	0.3912 *	0.1978	0.0979	0.4656**	0.3626*	0.0681	0.1043
DM		**1.0000**	-0.6877**	-0.9542**	-0.8612**	-0.4451*	-0.4577*	-0.8536**	-0.0632	-01836	-0.9386**	-0.0101	-0.8059**
PH			**1.0000**	0.5810**	0.6437**	0.2297	0.5107**	0.7082**	0.2707	0.0764	0.7392**	0.2815	0.6688**
NTP				**1.0000**	0.7969**	0.4437*	0.3676*	0.6643**	0.0937	0.1238	0.7430**	0.0956	0.6387**
ST					**1.0000**	0.2429	0.3858*	0.9259**	0.2472	-0.1121	0.7762**	0.0848	0.8161**
NLP						**1.0000**	0.0178	0.1623	0.0382	0.3176	0.4048*	0.1871	0.1590
LL							**1.0000**	0.5313**	0.2099	-0.1751	0.5689**	-0.1584	0.6450**
LW								**1.0000**	0.3009	-0.2811	0.8452**	-0.0109	0.9244**
LSR									**1.0000**	-0.0126	0.3194	-0.0138	0.3285
DFC										**1.0000**	0.2332	0.2814	-0.2711
DFYP											**1.0000**	0.0942	0.8567**
CPC												**1.0000**	-0.0248
GFYP													**1.0000**

**, ** significant at 5% and 1% level of significance, respectively*

*Where, **DF**= Days to 50% flowering, **DM**= Days to maturity, **PH**= Plant height (cm), **NTP**= Number of tillers per plant, **ST**= Stem Thickness (cm), **NLP**= Number of Leaves per plant, **LL**= Leaf length (cm), **LW**= Leaf width (mm), **LSR**= Leaf: Stem Ratio, **DFC**= Dry Fodder Content (%), **DFYP**= Dry Fodder Yield per Plant (g), **CPC**= Crude Protein content (%), **GFYP**= Green Forage Yield per Plant (g)*

Table 2. Phenotypic correlation coefficient for different characters in forage pearl millet

Characters	DF	DM	PH	NTP	ST	NLP	LL	LW	LSR	DFC	DFYP	CPC	GFYP
DF	**1.0000**	**-**0.2683*	0.3307**	0.1409	0.0657	0.1932	0.2378*	0.1550	0.1163	0.3425**	0.2791**	0.0525	0.0563
DM		**1.0000**	-0.5941**	-0.7676**	-0.6832**	-0.3649**	-0.3087**	-0.6173**	-0.0463	-0.1165	-0.7267**	-0.0657	-0.6236**
PH			**1.0000**	0.5355**	0.5641**	0.1882	0.3853**	0.6285**	0.2343*	0.0267	0.6442**	0.2449*	0.5953**
NTP				**1.0000**	0.7120**	0.3497**	0.2783**	0.5262**	0.0639	0.0795	0.6284**	0.0643	0.5471**
ST					**1.0000**	0.1765	0.2611*	0.7124**	0.1937	-0.0853	0.6592**	0.0517	0.6885**
NLP						**1.0000**	0.0095	0.1435	0.0197	0.2933**	0.2834**	0.1869	0.0489
LL							**1.0000**	0.3531**	0.1142	-0.1155	0.3655**	-0.0990	0.4418**
LW								**1.0000**	0.2413*	-0.1536	0.6748**	-0.0355	0.7269**
LSR									**1.0000**	0.0019	0.2881**	-0.0177	0.2818**
DFC										**1.0000**	0.2516*	0.1812	-0.3416**
DFYP											**1.0000**	0.0686	0.8045**
CPC												**1.0000**	-0.0248
GFYP													**1.0000**

**, ** significant at 5% and 1% level of significance, respectively*

*Where, **DF**= Days to 50% flowering, **DM**= Days to maturity, **PH**= Plant height (cm), **NTP**= Number of tillers per plant, **ST**= Stem Thickness (cm), **NLP**= Number of Leaves per plant, **LL**= Leaf length (cm), **LW**= Leaf width (mm), **LSR**= Leaf: Stem Ratio, **DFC**= Dry Fodder Content (%), **DFYP**= Dry Fodder Yield per Plant (g), **CPC**= Crude Protein content (%), **GFYP**= Green Forage Yield per Plant (g)*

Table 3. Direct and Indirect effects of yield components on green forage yield in forage pearl millet

Sr. No.	Characters	DF	DM	PH	NTP	ST	NLP	LL	LW	LSR	DFC	DFYP	CPC	Genotypic correlation with GFYP
1	**DF**	**-0.1895**	-0.0230	-0.0150	0.0128	-0.0159	-0.0043	0.0672	0.1350	0.0015	-0.0514	0.1846	0.0024	0.1043
2	**DM**	0.0661	**0.0658**	0.0264	-0.0833	0.2321	0.0069	-0.0786	-0.5824	-0.0010	0.0203	-0.4780	-0.0003	-0.8059**
3	**PH**	-0.0742	-0.0453	**-0.0384**	0.0507	-0.1735	-0.0036	0.0877	0.4832	0.0043	-0.0084	0.3765	0.0098	0.6688**
4	**NTP**	-0.0277	-0.0628	-0.0223	**0.0873**	-0.2148	-0.0069	0.0631	0.4533	0.0015	-0.0137	0.3784	0.0033	0.6387**
5	**ST**	-0.0112	-0.0567	-0.0247	0.0696	**-0.2696**	-0.0038	0.0663	0.6317	0.0039	0.0124	0.3952	0.0030	0.8161**
6	**NLP**	-0.0526	-0.0293	-0.0088	0.0387	-0.0655	**-0.0155**	0.0031	0.1108	0.0006	-0.0351	0.2061	0.0065	0.1590
7	**LL**	-0.0742	-0.0301	-0.0196	0.0321	-0.1040	-0.0003	**0.1717**	0.3625	0.0033	0.0193	0.2897	-0.0055	0.6450**
8	**LW**	-0.0375	-0.0562	-0.0272	0.0580	-0.2496	-0.0025	0.0912	**0.6823**	0.0048	0.0310	0.4304	-0.0004	0.9244**
9	**LSR**	-0.0186	-0.0042	-0.0104	0.0082	-0.0666	-0.0006	0.0360	0.2053	**0.0158**	0.0014	0.1625	-0.0005	0.3285
10	**DFC**	-0.0883	-0.0121	-0.0029	0.0108	0.0302	-0.0049	-0.0301	-0.1918	-0.0002	**-0.1104**	0.1187	0.0098	-0.2711
11	**DFYP**	-0.0687	-0.0618	-0.0284	0.0649	-0.2092	-0.0063	0.0977	0.5767	0.0050	-0.0258	**0.5093**	0.0033	0.8567**
12	**CPC**	-0.0129	-0.0007	-0.0108	0.0083	-0.0229	-0.0029	-0.0272	-0.0074	-0.0002	-0.0311	0.0480	**0.0350**	-0.0248

Residual Effect: *0.0532* **, ** Significant at P = 0.05 level and P = 0.01 level respectively*

*Where, **DF**= Days to 50% flowering, **DM**= Days to maturity, **PH**= Plant height (cm), **NTP**= Number of tillers per plant, **ST**= Stem Thickness (cm), **NLP**= Number of Leaves per plant, **LL**= Leaf length (cm), **LW**= Leaf width (mm), **LSR**= Leaf: Stem Ratio, **DFC**= Dry Fodder Content (%), **DFYP**= Dry Fodder Yield per Plant (g), **CPC**= Crude Protein content (%), **GFYP**= Green Forage Yield per Plant (g)*

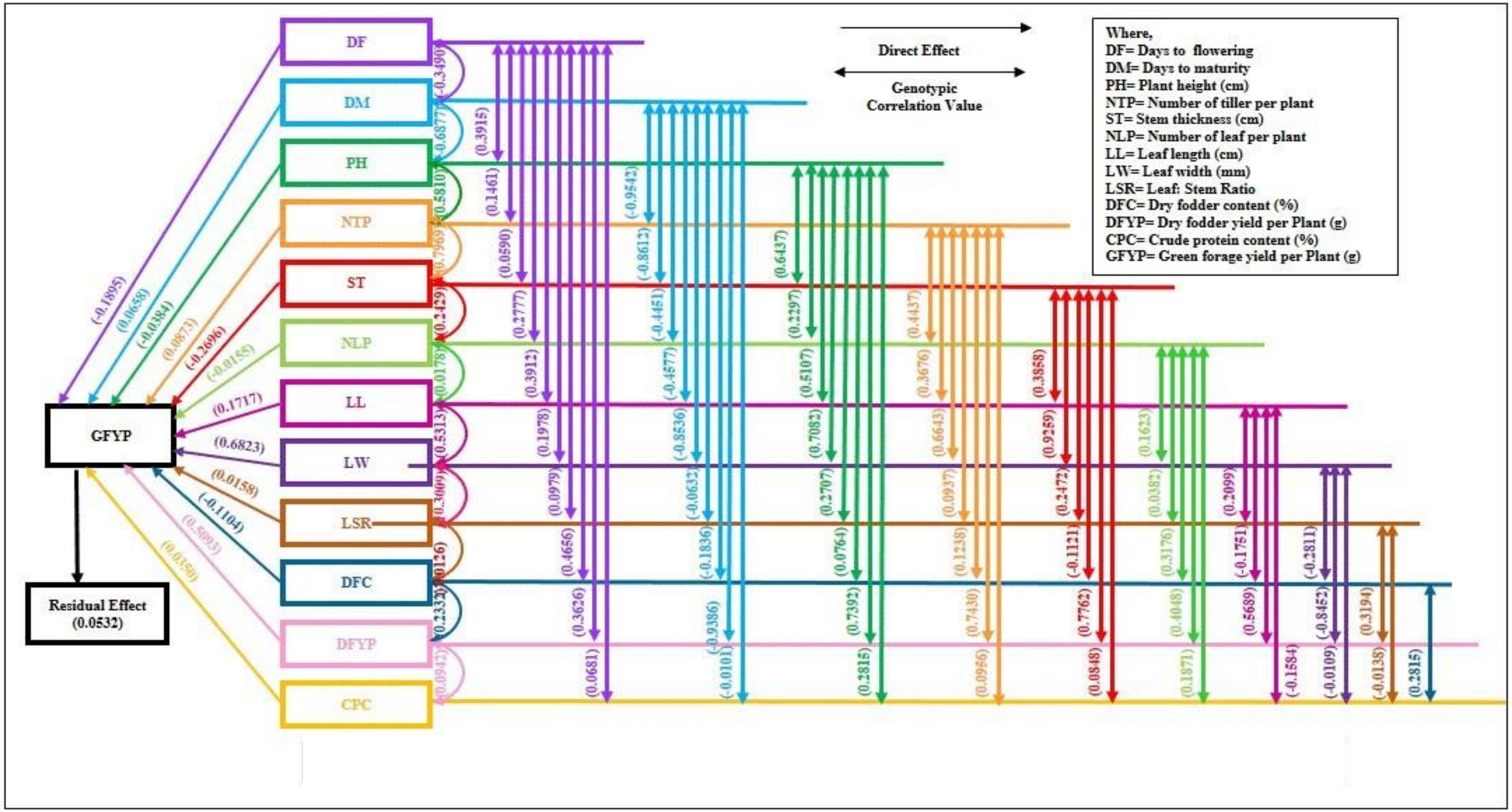

Fig. 1. Diagrammatic representation of genotypic path analysis in forage pearl millet

plant was found with number of leaves per plant and days to flowering and crude protein content at both genotypic and phenotypic level indicating the independence of these character from green forage yield per plant. Extent of crude protein content is the crucial character in forage pearl millet as it is essential nutrition in livestock feed. There was non-significant association of crude protein content with green forage yield per plant which means the improvement of protein content could not affect the yield in the population studied. The underlying reason could be the low genetic variability for the protein content in the population used for the current study. Contradictory results for crude protein content was reported by Shinde [22], Lokhande [24], Parmar et al. [29].

3.2 Path Analysis

Ever since coefficients of correlation merely reveal the interrelationships between the characters deprived of regard to cause and effect, it gains additional significance when divided in components of indirect and direct effects by path coefficient analysis [15]. Green forage yield per plant was deliberated as the dependent variable for analysis, and the other twelve characteristics were employed as the causative factors. Table 3 and Fig. 1 represent the findings. Path analysis revealed the importance of leaf width and dry fodder yield per plant by showing high and positive direct effects towards green forage yield per plant. Balasaheb [21], Shinde [22], Lokhande [24], Shalini [26], Aswini et al. [27], Shinde [30], Govintharaj et al. [31], Narasimhulu and Veeraraghavaiah [32], and Kawadiwale et al. [33] reported similar results as they observed positive and high direct effect of dry matter yield per plant on green forage yield per plant. Leaf length recorded low positive direct effects towards green forage yield per plant. The results are in agreement with the findings of Balasaheb [21] and Lokhande [24] as they reported positive direct effect of leaf length on green forage yield per plant. These characters also exhibited significant and positive association at the genotypic level and phenotypic with green forage yield per plant. So, these traits may be considered as the most important yield contributing traits and due emphasis should be placed on these characters while breeding for high green forage yield per plant. Negligible and positive effect was recorded for days to maturity, number of tiller per plant, leaf: stem ratio and crude protein content. Similar results were found by Rajpoot et al. [34], Andhale et al. [35], Narasimhulu and Veeraraghavaiah [32] and Kumar et al. [36] for days to maturity; Balasaheb [21], Dehinwal et al. [37], Parmar et al. [29], Andhale et al. [35] and Rajpoot et al. [34] for number of tiller per plant. Contradictory results shown by Shinde [22] by showing negative direct effect of crude protein content on green fodder yield per plant. Negative direct effect was shown by days to flowering, plant height, stem thickness, number of leaf per plant and dry fodder content. If the indirectly selected traits have a high heritability as well as correlation with green forage yield, a higher yield can be obtained. In order to indirect selection to be more effective certain combinations of heritability and correlation coefficient values must be present, according to Searle [38]. Plant height, number of tiller per plant and stem thickness showed high indirect effect on green fodder yield per plant thorough leaf width and dry fodder yield per plant; leaf length and dry fodder yield per plant thorough leaf width and leaf width thorough dry fodder yield per plant. The residual effect (0.0532) reported in the present investigation indicated the presence of those independent traits which are associated with green forage yield genotypes were utilized in the study and provided good scope for improvement in green forage yield.

4. CONCLUSION

Results of this study have clarified the significance of leaf width and dry fodder yield per plant which have a high significant positive association and positive direct effects on green forage yield as well as positive indirect effects on all other traits for green forage yield too. Concentrating on these traits in selection process along with other traits such as leaf length and number of tiller per plant will help in crop improvement programme in devising further breeding strategies and selection procedures to evolve high yielding varieties which will benefit the forage pearl millet growing farmers.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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