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Correlation and Path Coefficient Analysis of Biomass Yield and Quality Traits in Forage Type Hybrid Parents of Pearl Millet

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ABSTRACT

One hundred and sixteen forage type hybrid parents (seed and pollinator parents) were investigated at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India, in summer seasons of 2015 and 2016 for estimating inter-relationships between forage quantity and quality traits and their direct and indirect effects. Significant negative correlation but of low value was found between crude protein (CP), In vitro organic matter digestibility (IVOMD) and dry forage yield (DFY). The direct and indirect effect of these forage quantity related traits on the DFY and other forage quality related traits on IVOMD was investigated in pearl millet. Path analysis revealed that total green forage yield (TGFY) had highest positive direct effect on DFY for forage quantity traits followed by plant height (PH). For forage quality traits, metabolizable energy (ME) had highest direct effect on IVOMD in both the cuts. CP and cellulose also had positive direct effects on IVOMD in both the cuts.

Key words: *Dry forage yield (DFY), Green forage yield (GFY), Metabolizable energy (ME), In vitro organic matter digestibility (IVOMD)*

Abbreviations:

PH*-Plant height;* ***NT****-Number of tillers per plant;* ***L/S****-Leaf to stem ratio;* ***GFY****-Green forage yield;* ***DFY****-Dry forage yield;* ***TGFY****-Total green forage yield;* ***DM****-dry matter;* ***Stover N****-Stover Nitrogen;* ***CP****-Crude protein;* ***NDF****-Neutral detergent fibre;* ***HC****-Hemicellulose;* ***ADF****-Acid detergent fibre;* ***ADL****-Acid detergent lignin;* ***ME****-Metabolizable energy;* ***IVOMD****-In vitro organic matter digestibility.*

INTRODUCTION

Pearl millet is an important food and fodder crop, widely grown in semi-arid and arid regions of Africa and Asia. This crop is able to grow under severe drought/salinity condition and low soil fertility. Being a C_4 crop, it has higher biomass production potential, and also possess multiple forage crop traits like quick regeneration capacity, heavy tillering, leafiness and tolerance to multiple pest and disease problems.

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United States of America, Australia and Brazil are already cultivating pearl millet exclusively for forage purpose, and consume it either by grazing, green chopped or harvested as silage for livestock feed. Recently, use of pearl millet crop has increased in north-western India during summer months when most of other forage crops like sorghum or maize are not able to sustain high temperatures[1,13].

Scarcity of fodder is a major limiting factor in the livestock community due to increasing demand on land for food grains, oil seeds and pulses production. At present, India faces net deficit of 35.7% green fodder, 10.9% dry crop residues and 44% concentrate feeds[9]. Hence, there is urgent need to enhance productivity of forage crop to sustain feed for the livestock. Crop improvement program requires information on genetic variation, nature of association among yield and its component traits, and how traits influence each other to finally express the trait of interest. Limited correlation studies have been conducted on forage type pearl millet[3,10], and in majority of path analysis studies in pearl millet, green forage yield (GFY) was considered as dependent variable for investigating direct and indirect effects of forage yield components traits in pearl millet[5,11]; while crude protein (CP) has been considered as dependent variable in case of forage quality traits in grazed and non-grazed pastures[15]. Casler[7], estimated path analysis on dry forage yield (DFY) for biomass linked yield component traits, and *In vitro* organic matter digestibility (IVOMD) as dependent variable for forage quality traits in smooth bromegrass (*Bromus inermis* L.).

Present study was aimed to determine the relationships among forage linked biomass and its quality traits to understand criteria for selection to identify the desirable genotypes with high yielding potential for forage quantity and quality in crop improvement program of pearl millet.

MATERIAL AND METHODS

The study comprised of 116 hybrid parents of pearl millet evaluated in an alpha lattice design with two replications, at ICRISAT, Patancheru (18°N, 78°E, 545 m above sea level) during summer seasons of 2015 and 2016. Experimental plots of each entry consisted of 1 row of 2 m length spaced at 60 cm apart, and plants were spaced 10-15 cm apart. Nitrogen and phosphorous were applied as basal dose in the form of 100 kg ha^{-1} of Diammonium phosphate (18% N and 46% P). Plots were fertilized equally with 100 kg ha^{-1} of urea (46% N) as top dressing, two times before first harvest and also immediately after first harvest. Trial was irrigated at 12 to 15 days' intervals, to prevent moisture stress.

Recording of morphological and biochemical traits

Data were recorded on 5 random plants of each entry for following traits; plant height (PH) in cm**:** measured from base of the stem to the tip of panicle of main tiller at the time of harvest; number of tillers (NT)**:** measured at the time of first harvest; leaf to stem ratio (L/S)**:** stems were separated from leaves, and stems and leaves were weighed separately to determine the ratio. Green forage yield (GFY) and dry forage yield (DFY) were measured on plot basis in t ha^{-1}. Green biomass was first harvested at 50 days (the boot stage of plant development) after planting, 2 m of rows of each entry was harvested manually by cutting at second node from the bottom of the plant. Fresh weight of the green biomass was recorded (kg) and converted into GFY in t ha^{-1}. A sub-sample (10-15 plants) of about 1 kg was collected per entry at the time of harvest and recorded for green biomass weight, oven dried for 8 hours daily for three to four days at 60 ºC in Campbell dryer (Campbell Industries, Inc., 3201 Dean Avenue, Des Moines, Iowa 50317, USA), and weighed again (dry biomass weight in kg). The dry matter concentration was determined by the ratio between dry biomass weight and green biomass weight. Dry biomass on plot basis for each entry was calculated by multiplying the green biomass weight and the dry matter concentration given as percentage and converted into DFY in t ha^{-1}. Second cut was taken after thirty days of first cut. GFY and DFY were again recorded as methodology followed for first cut. Total green forage yield (TGFY) in t ha^{-1} was calculated as sum of both the cuts for each entry in this trial.

For both the cuts, dried sub-samples of each entry were chopped into 10 to 15 mm pieces using a chaff cutter (Model#230, Jyoti Ltd. Vadodara-India) and ground using Thomas Wiley mill (Model # 4, Philadephia, PA, USA) to pass through 1-mm screen for chemical analysis. Ground stover samples (Approximately, 40 g of sample/entry) were analyzed for several forage quality traits [dry matter (DM), ash, stover nitrogen, crude protein (CP), neutral detergent fibre (NDF), hemicellulose (HC), acid detergent fibre (ADF), cellulose, acid detergent lignin (ADL) and *in vitro* organic matter digestibility (IVOMD) are expressed in percent, while metabolizable energy (ME) is expressed in MJ kg^{-1}] using near infrared spectroscopy (NIRS) as described by Bidinger and Blummel[4], and Blummel *et al*[6]. All the above mentioned traits were recorded for both the cuts in both the seasons, except that NT and L/S in summer 2015 and 2016 were recorded only in first cut.

Data analysis

Mean data of traits recorded from each cut over two years were used for Karl Pearson’s correlation coefficients using SAS CORR procedure and path coefficients analysis as suggested by Dewey and Lu[8], using SAS v 9.4[14]. In the present study, path coefficient analysis was conducted considering DFY as dependent variable for morphological traits and IVOMD as dependent variable for forage quality bio-chemical traits in first and second cut, respectively.

RESULTS AND DISCUSSION

The relationships between DFY and key forage quality traits (CP and IVOMD) for both the cuts are presented in Fig.1. DFY and CP had low negative correlation (r = -0.25**, p<0.01) in first cut, but had negative but non-significant correlation in second cut. Similarly, DFY and IVOMD were negatively correlated in second cut (r = -0.31**, p<0.01). Such inverse relationship between desirable forage quantity and quality traits have also been reported earlier in other crops like maize[12,16] and sorghum[2]. Negative significant associations between desirable traits like IVOMD and undesirable traits like NDF (r = -0.47**, p<0.01 and r = -0.02, p>0.01, respectively), ADF (r = -0.28**, p<0.01 and r = -0.48**, p<0.01, respectively) and ADL (r = -0.46**, p<0.01 and r = -0.56**, p<0.01, respectively) were observed at both first and second cuts which suggested that simultaneous improvement of desirable and undesirable forage quality traits is possible in pearl millet breeding (data not shown). Path analysis revealed that TGFY had highest direct effect on DFY (Table 1). PH also had positive direct effect on DFY for both the cuts, indicating that taller plants would have higher DFY in pearl millet. This result was in agreement with the findings of Zhang *et al*[17]., in elephant grass. NT also had positive direct effect on DFY at first cut, while GFY had negative direct effect on DFY at second cut. The indirect effect of the TGFY on DFY via L/S was negative and via PH, NT and GFY were positive. The residual effect was 32.9%, indicating that about 67.1% of the total variation was contributed by the traits included in the path analysis. ME had higher direct effect and exhibited significant positive correlation with IVOMD at first and second cut (Table 2), respectively, indicating strong relationship among these traits. This indicated that direct selection for ME would be effective in increasing IVOMD. Also, three other forage quality traits; CP, cellulose and ash had a positive direct effect on IVOMD in both cuts. Cellulose had significant negative correlation with IVOMD due to negative indirect effects via ash, CP, NDF, ADL and ME. NDF and ADL had negative direct effect on IVOMD in both cuts. ADL had negative direct effect as well as significant negative correlation with IVOMD. Therefore, it is logical to select parents having low ADL for the improvement of IVOMD. ME had negative indirect effects via CP and cellulose; and via DM, hemicelluloses and ADL was positive at both the cuts. The residual effect was 2.2%, indicating that about 98% of the total variation was contributed by these forage quality traits included in the path analysis at first and second cut, respectively.

In conclusion, important forage quality traits like CP and IVOMD had shown low negative correlation with DFY, hence larger breeding populations should be grown in segregating generations to select against these negatively correlated traits and derive new breeding materials with high biomass productivity coupled with high CP and IVOMD. Path analysis revealed that traits like TGFY and PH for forage yield; and ME and CP for forage quality traits could be used as for the improvement of DFY and IVOMD, respectively, in pearl millet.

Table 1: Path analysis for forage quantity traits on dry forage yield (DFY) for two cuts in 116 forage type hybrid parents of pearl millet, evaluated in summer season of 2015 and 2016 at ICRISAT, Patancheru

Traits•	Cutting intervals	PH	NT	L/S	GFY	TGFY	Correlation with DFY
PH	FC†	**0.198**	-0.004	-0.028	0.017	0.107	0.36**
	SC‡	**0.148**	NA	NA	-0.101	0.378	0.50**
NT	FC	-0.004	**0.196**	0.005	-0.007	0.014	0.02
	SC	NA	**NA**	NA	NA	NA	NA
L/S	FC	-0.138	0.023	**0.039**	-0.006	-0.043	-0.20*
	SC	NA	NA	**NA**	NA	NA	NA
GFY	FC	0.063	-0.025	-0.005	**0.054**	0.535	0.79**
	SC	0.097	NA	NA	**-0.153**	0.528	0.63**
TGFY	Combined	0.030	0.004	-0.002	0.040	**0.714**	
Residual Effect^2 = 0.3291							

, * Significant at 0.05 and 0.01 levels of probability, respectively

†FC-First cut; ‡SC-Second cut

•PH-Plant height (cm), NT-Number of tillers/plant, L/S-Leaf to stem ratio, GFY-Green forage yield (t ha^{-1}), TGFY-Total green forage yield (t ha^{-1}), DFY-Dry forage yield (t ha^{-1}).

Table 2: Path analysis for forage quality traits on IVOMD for two cuts in forage type hybrid parents of pearl millet, evaluated in summer season of 2015 and 2016 at ICRISAT, Patancheru

Traits•	Cutting intervals	DM	Ash	CP	NDF	HC	ADF	Cellulose	ADL	ME	Correlation with IVOMD
DM	FC†	**-0.008**	-0.029	-0.106	-0.001	0.001	-0.049	0.092	-0.008	-0.182	-0.29**
	SC‡	**0.038**	-0.005	-0.007	0.054	-0.046	0.001	0.023	0.003	0.269	0.33**
Ash	FC	0.002	**0.138**	0.127	0.001	0.001	0.012	-0.024	0.003	0.091	0.35**
	SC	-0.003	**0.057**	0.060	0.204	-0.176	-0.001	-0.013	-0.001	-0.476	-0.35**
CP	FC	0.003	0.061	**0.288**	0.001	0.000	0.042	-0.065	0.009	-0.027	0.31**
	SC	-0.002	0.019	**0.176**	0.208	-0.103	-0.014	-0.064	0.004	-0.434	-0.21*
NDF	FC	-0.004	-0.078	-0.135	**-0.001**	-0.001	-0.048	0.070	-0.010	-0.264	-0.47**
	SC	-0.005	-0.026	-0.081	**-0.453**	0.264	0.020	0.090	-0.006	0.176	-0.02
HC	FC	0.002	-0.064	0.029	-0.001	**-0.002**	0.028	-0.051	0.003	-0.155	-0.21*
	SC	-0.005	-0.026	-0.047	-0.313	**0.383**	-0.016	-0.103	0.000	0.496	0.37**
ADF	FC	-0.005	-0.022	-0.158	-0.001	0.001	**-0.076**	0.113	-0.013	-0.118	-0.28**
	SC	0.001	-0.001	-0.053	-0.195	-0.130	**0.047**	0.253	-0.009	-0.393	-0.48**
Cellulose	FC	-0.006	-0.028	-0.155	-0.001	0.001	-0.071	**0.121**	-0.010	-0.091	-0.24**
	SC	0.003	-0.003	-0.044	-0.159	-0.153	0.046	**0.258**	-0.007	-0.352	-0.41**
ADL	FC	-0.004	-0.024	-0.161	-0.001	0.000	-0.061	0.079	**-0.016**	-0.273	-0.46**
	SC	-0.008	0.007	-0.061	-0.240	-0.015	0.034	0.150	**-0.012**	-0.414	-0.56**
ME	FC	0.002	0.014	-0.009	0.000	0.000	0.010	-0.012	0.005	**0.910**	0.92**
	SC	0.010	-0.026	-0.074	-0.077	0.184	-0.018	-0.088	0.005	**1.034**	0.95**
Residual Effect^2 = 0.0223											

, * Significant at 0.05 and 0.01 levels of probability, respectively

†FC-First cut; ‡SC-Second cut

•DM-Dry matter (%), Ash-(%), CP-Crude protein (%), NDF-Neutral detergent fibre (%), HC- Hemicellulose (%), Cellulose-(%), ADF-Acid detergent fibre (%), ADL-Acid detergent Lignin (%), ME-Metabolizable energy (MJ kg^{-1}), IVOMD-*In vitro* organic matter digestibility (%).

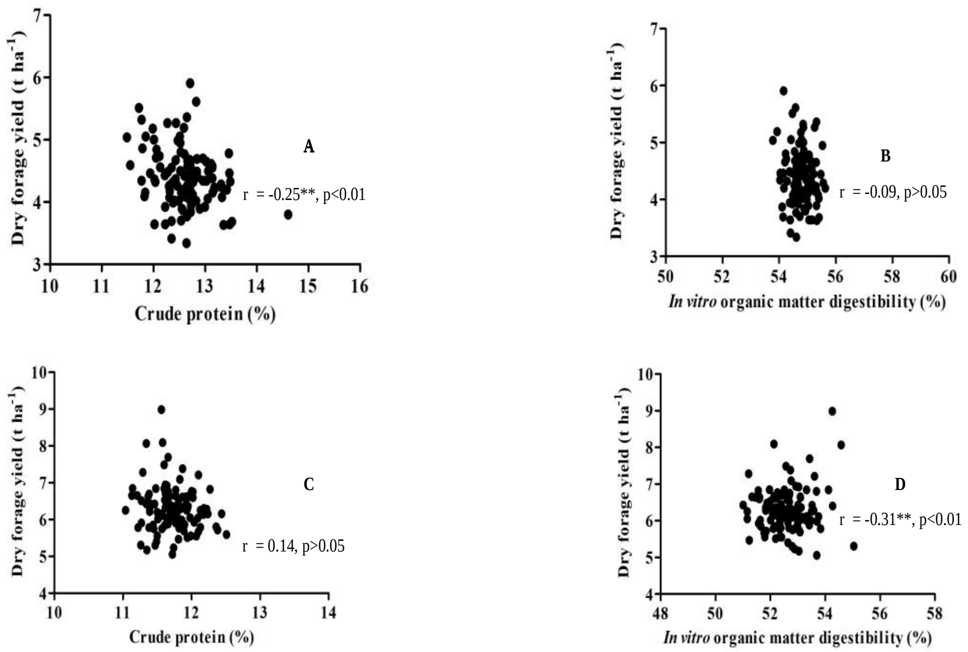

Fig.1: A) Relationship between DFY and CP at first cut; B) between DFY and IVOMD at first cut; C) between DFY and CP at second cut, and D) between DFY and IVOMD at second cut

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