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Genotypic Variation in Forage Linked Morphological and Biochemical Traits in Hybrid Parents of Pearl Millet

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ABSTRACT

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A set of 116 pearl millet hybrid parents was evaluated in two summer seasons for 30 forage specific morphological and quality traits. Green forage yield (GFY) ranged from 15.0 to 29.0 t/ha at first cut and 12.0 to 42.0 t/ha at second cut, while the dry forage yield (DFY) ranged from 3.0 to 6.0 t/ha at first cut and 5.0 to 9.0 t/ha at second cut. Important forage quality traits like stover nitrogen varied from 1.84 to 2.34% at first cut and 1.77 to 2.00% at second cut, while metabolizable energy (ME) ranged from 7.42 to 7.76 MJ/kg at first cut and 6.95 to 7.68 MJ/kg at second cut. *In vitro* organic matter digestibility (IVOMD) varied from 54.0 to 56.0% at first cut and 51.0 to 55.0% at second cut. Pollinator parents showed higher mean values for most of the forage traits than the seed parents. Small but significant negative correlation was found between crude protein (CP), IVOMD and DFY indicating that modifications are needed to breed for higher forage biomass coupled with better forage quality traits. Hierarchical cluster analysis based on forage specific morphological and quality traits delineated 116 pearl millet hybrid parents into 6 distinct clusters. This evaluation identified clusters of hybrid parents having high mean values for specific promising forage quality traits, this information can be used for developing promising forage-type hybrids in pearl millet.

Keywords: Hybrid parents, Dry forage yield, Green forage yield, Forage quality, Pearl millet.

INTRODUCTION

Pearl millet [(*Pennisetum glaucum* (L) R. Br.] is an important food and fodder crop grown in arid and semi-arid regions of Asia and Africa. It is a promising crop for

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green/dry fodder production for feeding livestock especially during the driest season when green fodder/grazing is limited. This crop offers an ideal/potential forage crop due to certain features like: warm season crop with short duration, with tolerance to low soil fertility, having high photosynthetic efficiency and dry matter production ability due to C_4 crop, coupled with other features like fewer pest and disease problems and tolerance to abiotic stresses (drought and salinity). This crop has been used for pasture, silage, hay and grazing in countries like USA (Burton, 1995; Davis *et al.*, 2003; Newman *et al.*, 2010), in New Mexico and West Texas (Marsalis *et al.*, 2012), in summer season in Australia and South America (Hanna, 1996), in South Africa (Hammes, 1972) and Brazil (De Assis *et al.*, 2018). Recently, pearl millet cultivation has increased exclusively for fodder purpose in the dry areas of north-western India (Reddy *et al.*, 2012; Amarender Reddy *et al.*, 2013).

Scarcity of quality fodder is one of the limiting components to improve livestock production (Ullah *et al.*, 2010). At present, India faces net deficit of 35.7% green fodder, 10.9% dry crop residues and 44% concentrate feeds, and it would require 568 million tones of dry fodder, 911 million tones of green fodder by 2030 (IGFRI, 2013). To meet this requirement, high/multi-cut fodder yielding and nutritious varieties of fodder crops need to be identified. Under such circumstances pearl millet fits well for this purpose, as its high tillering potential and quick regenerative ability assures the possibility of multi-cutting which can assure year round supply of green/dry forage.

Investigation on forage quality traits of pearl millet have indicated significant variation among dual-purpose hybrids, populations/OPVs and top cross hybrids (Bidinger and Blummel, 2007; Bidinger *et al.*, 2010; Rai *et al.*, 2012). Significant variability has been observed for biomass traits and also stover nitrogen, ME and IVOMD in new pearl millet germplasm (Gupta *et al.*, 2015). However, very few studies have been conducted to assess genetic diversity in hybrid parents of pearl millet for forage traits. Hence, the present investigation was made to assess the variation for morphological and forage quality traits in a set of 116 forage type hybrid parents of pearl millet.

MATERIALS AND METHODS

Plant materials and experimental design

A set of 116 forage type hybrid parents (98 pollinators and 18 seed parents) was evaluated in this experiment. Pollinator parents were coded as FP01 to FP98, while seed parents were coded as FB01 to FB18 in this study. The trial was planted at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), following partially balanced alpha lattice design with two replications. The plots consisted of one row of 2 m length with rows spaced 60 cm apart. The rows were planted side by side and plants were spaced 10-15 cm apart.

Experimental site and management practices

The experimental trials were conducted during summer growing season (February-June) of 2015 and 2016 on the experimental farm at ICRISAT, Patancheru (latitude

18°N, longitude 78°E, 545m AMSL) on alfisols (red soil). Nitrogen and phosphorous were applied as basal dose in the form of 100 kg/ha of diammonium phosphate (18% N and 46% P). Plots were fertilized equally with 100 kg/ha of urea (46% N) as top dressing, two times before first harvest and also immediately after first harvest. Crop was irrigated at 12 to 15 d intervals, to avoid moisture stress.

Morphological traits

Data was collected on 5 random plants of each entry for following traits; plant height (cm): measured from the base of the stem to the tip of the panicle of main tiller at the time of harvest; number of tillers: measured at the time of first harvest; leaf to stem ratio (%): stems were separated from leaves, and stems and leaves were weighed separately to determine the ratio. The GFY and DFY (t/ha) were measured on plot basis. Green biomass was first harvested at 50d (the boot stage of plant development) after planting, 2m 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 t/ha. 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 8h daily for three to four days at 60°C in Campbell dryer (Campbell Industries, Inc., Des Moines, Iowa, USA), and weighed again (dry biomass weight in kg). The DM content 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 DM content given as percentage and converted into t/ha. Second cut was taken after thirty days of first cut. Green biomass yield and dry biomass yield were recorded as methodology followed for first cut. Total green forage yield of each entry was calculated as sum of the two cuts in this trial.

Forage quality traits

For both the cuts, dried sub-samples of each entry were chopped into 10 to 15 mm pieces using a chaff cutter (Jyoti Ltd. Vadodara, India) and ground using Thomas Wiley mill (Philadelphia, PA, USA) to pass through 1-mm screen for chemical analysis. Ground stover samples (approximately, 40g of sample/entry) were analyzed by Near-Infrared Reflectance Spectroscopic (NIRS) as described by Bidinger and Blummel (2007) and Blummel *et al*. (2007). Dry matter was determined after overnight oven drying at 105°C (AOAC, 1990); ash (%) was estimated after combustion at 600°C for 1h (AOAC, 1990); Nitrogen (N) was determined using Technicon Auto Analyzer, and CP was calculated as N × 6.25 (Henneberg, 1865). The NDF, ADF and ADL were measured as per Van Soest and Robertson (1985). Hemicellulose was determined by NDF-ADF and cellulose was assumed to be difference between ADF and ADL (Van Soest and Robertson, 1980). Metabolizable energy and IVOMD was analyzed according to Menke and Steingass (1988) with the modifications of Blummel and Ørskov (1993). All the above mentioned traits were recorded for both the cuts in both the seasons, except that number of tillers and leaf to stem ratio in summer 2015 and 2016 were recorded only in first cut.

Statistical analysis

Combined analysis of variance was performed using SAS MIXED procedure (SAS Institute Inc., 2017) considered Year, Block, Replication and Treatments are random effects. Individual year residual variances were modeled into combined analysis using REPEATED statement in SAS MIXED procedure. BLUPs (Best Linear Unbiased Predictors) were estimated for treatments across the years from combined analysis.

Based on 30 traits which are characterized at different cutting intervals (first and second cut respectively), 116 treatment means were grouped into different clusters based on Mahalanobis D^2 distance (Mahalanobis *et al.*, 1936) using ward's method in SAS CLUSTER procedure (SAS Institute Inc., 2017). Karl Pearson's correlation coefficients were estimated for all traits using SAS CORR procedure.

RESULTS AND DISCUSSION

Effects of genotypes and year × genotypes interactions

Genotypes had significant differences for most of the important traits like PH, GFY, DFY, stover nitrogen and CP at both the cuts, suggesting existence of substantial genetic variation for forage linked morphological and quality traits in the materials under investigation (ANOVA not presented). Year (environment) × genotypes interactions were found significant for green and dry forage yield for both the cuts suggesting environment had significant effect on biomass traits, though NDF, ADF, hemicellulose, ME and IVOMD at first cut had non-significant G×E interaction. Stover nitrogen and CP had non-significant year (environment) × genotypes interactions for both the cuts, indicating that environment had no significant effect on stover nitrogen and crude protein.

Phenotypic variations among forage type hybrid parents

The GFY across all the hybrid parents in the present set of hybrid parents ranged from 15.0 to 29.0 t/ha and 12.0 to 42.0 t/ha at first and second cut (Figure 1), respectively. Some other studies also reported wide range for green forage yield in pearl millet, like 16.0 to 22.0 t/ha (Byregowda, 1990); 13.0 to 21.0 t/ha (Akmal *et al.*, 1992); 13.0 to 21.0 t/ha (Naeem *et al.*, 1993); 29.0 to 42.0 t/ha (Mohammad *et al.*, 1993). The mean DFY was 4.39 t/ha and 6.30 t/ha at first and second cut, respectively. These values were higher than that reported by Rai *et al.* (2012) of about 3.90 t/ha dry forage yield at first cut in pearl millet.

The mean PH of all the hybrid parents was 88.9 cm and 87.3 cm at first and second cut, respectively. The mean number of tillers per plant was 6.60, which was higher than that reported earlier by Poorani (2009) of about 3.90; and of about 5.20 and 5.40 in rainy and summer seasons, respectively (Babikar *et al.*, 2013). The leaf to stem ratio is a trait that affects animal preference during grazing (Coleman, 1992). In this set of parents, stem thickness was found higher in pollinator parents (123g) than seed parents (120g), which resulted into lower leaf to stem ratio in pollinator parents. The mean leaf to stem ratio across all hybrid parents was 0.76, which was higher than that

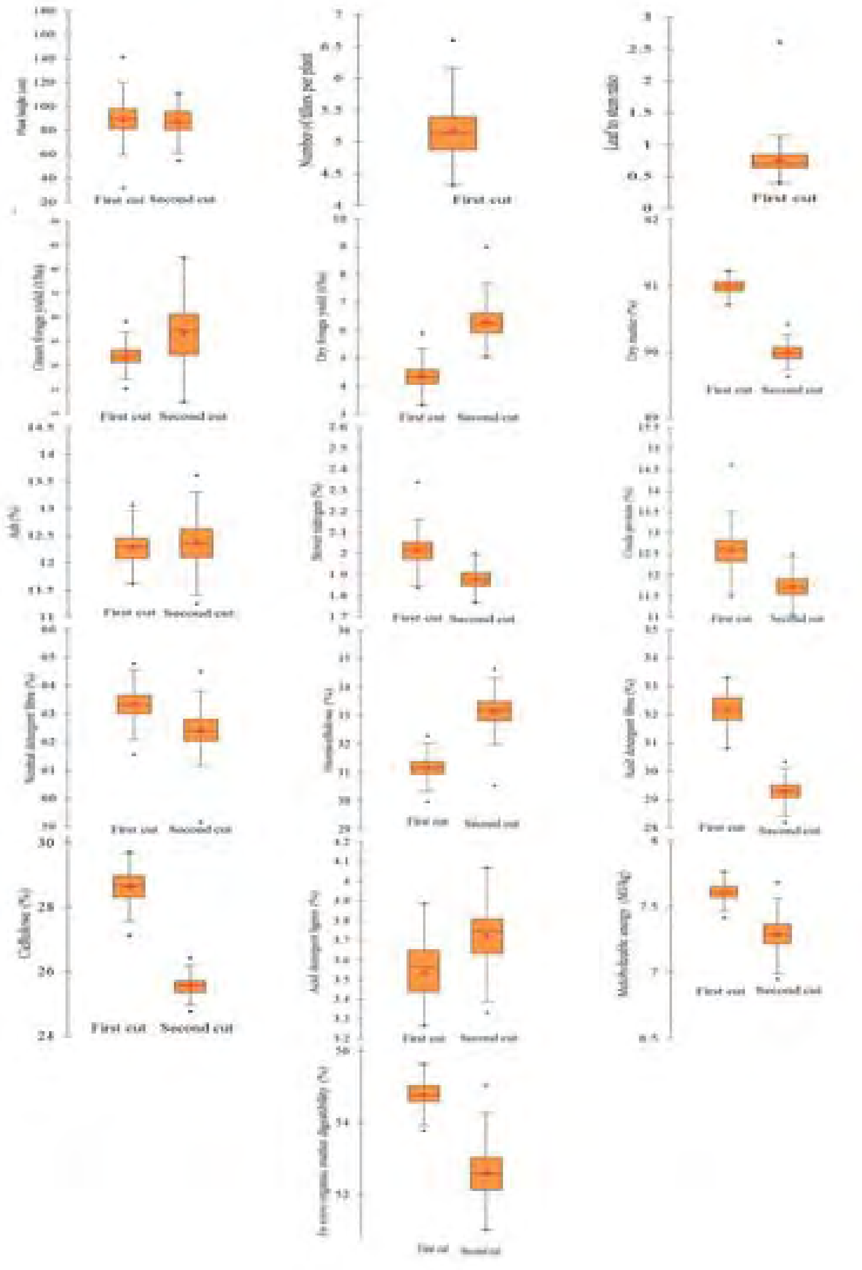

Fig. 1. Box plots, box shows the lower quartile, median (dark line), mean (+ symbol) and upper quartile values, and the whisker's show the range of phenotypic variation for forage yield and quality traits evaluated on 116 forage type hybrid parents at two cuts, combined mean of two season.

reported earlier by Poorani (2009) of about 0.19; and of about 0.34 and 0.35 in rainy and winter seasons, respectively (Babikar *et al.*, 2013).

Nitrogen is an essential nutrient for rumen microbes, and low N (below 1 to 1.2% N in the feed) content is considered as a major limiting factor in cereal straws and stover, unless nitrogen is supplemented by legumes or non-protein N sources such as urea (Sundstol and Owen, 1984). In the present set of hybrid parents, ranges in stover nitrogen were 1.84 to 2.16% and 1.77 to 2.00% in first and second cut, respectively, which is more than the prescribed minimum levels (Van Soest, 1994). This observed genotypic variations in hybrid parents for important forage quality traits can be utilized in pearl millet forage breeding programs to enhance livestock productivity.

The NDF, a measure of fibrous bulk, is negatively associated with amount of forage consumed by animal (Van Soest, 1994). Mean NDF was 63.33 and 62.41% at first and second cut, respectively. ADF, considered as an important negative trait in fodder quality associated with ability of animal to digest the forage (Van Soest, 1994), the average of ADF for all the hybrid parents was 32.2 and 29.3% at first and second cut, respectively. ADL, a measure of lignin which is negatively associated with plant maturity, mean value was 3.54 and 3.72% at first and second cut, respectively. These mean values of negative traits, like NDF, ADF and ADL in this study were found lower than as reported in an earlier study in pearl millet by Bidinger *et al.* (2010) of about 69.7% in NDF, 40.5% in ADF and 5.6% in ADL; and in maize by Eirtiro *et al.* (2013) of about 79.0% in NDF, 45.7% in ADF and 5.6% in ADL.

The ME content, which is an estimate of feed quality is closer to the net energy actually available to the animal than digestible energy (McDonald *et al.*, 1988). The ME content was 7.42 to 7.46 MJ/kg and 6.95 to 7.68 MJ/kg at first and second cut, respectively. Observed mean value of ME was found higher than earlier reported study in pearl millet by Blummel *et al.* (2007) of about 5.12 to 5.87 MJ/kg and Hash *et al.* (2006) of about 5.93 to 6.67 MJ/kg.

The IVOMD is a single measurement that summarizes all desirable and undesirable quality traits and reflects overall stover fodder quality. Vogel and Sleper (1994) reported that 3 to 4 percent unit differences in digestibility in grasses can lead to 17 to 24 percent differences in animal performance. In our study, stover IVOMD varied from 53.8 to 55.6% with a mean of 54.8% and 51.0 to 55.0% with a mean of 52.6% at first and second cut (Fig. 1), respectively. This mean value and variability in IVOMD was found higher in second cut than earlier studies in pearl millet (Blummel and Rai, 2003) of about 39.0 to 47.0%; Hash *et al.* (2006) of about 43.0 to 47.0%; Blummel *et al.* (2007) of about 39.0 to 43.0%; Bidinger *et al.* (2010) of about 41.0 to 46.0%; Rai *et al.* (2012) of about 45.0 to 51.0%). Though, Rai *et al.* (2012) found still higher levels of IVOMD about 56.0 to 61.0% in a study on OPV's in pearl millet at 50 days cut (first cut).

Expression of forage traits in B- and R-lines; and differences in first and second cut B-lines (seed parents) and R-lines (pollinator parents) have been bred following trait-based breeding approach in most of the pearl millet breeding programs, and targeted towards development of diverse hybrid parents with high grain productivity potential. Seed parents have been bred for shorter plant height and larger seed size, while pollinator parents have generally been bred for taller plant height, more tillers, relatively smaller in seed size and profuse pollen production (Rai *et al.*, 2006). Most of these traits are contributing towards grain yield, and very less effort have been made to develop hybrid parents for developing forage cultivars. In the present study, seed parents though primarily developed for higher grain yield but had comparatively higher biomass traits were identified and evaluated for important forage traits. Results indicated that seed parents (B-lines) demonstrated wide range for some of the important forage traits, and showed higher mean of number of tillers per plant, leaf to stem ratio, stover nitrogen, crude protein and hemicellulose at first cut; and had wide range for dry matter, stover nitrogen, CP and IVOMD at second cut (data not shown). Some efforts have been made intentionally to breed forage-type pollinator parents, and pollinator parents under present investigation showed high mean values in comparison to seed parents for most of the forage traits. Pollinator parents showed higher mean values for PH, GFY, DFY, DM, ash, NDF, ADF, cellulose, ADL, ME and IVOMD at first cut, while they had wide range also in second cut for various traits, like for PH, GFY, DFY, ash, NDF, hemicellulose, ADF, cellulose, ADL, ME and TGFY.

Generally, forage quality traits like stover nitrogen, CP, hemicellulose, cellulose, ME and IVOMD are desirable, while ash, NDF, ADF and ADL are undesirable traits for good quality forage. In the present study, traits like GFY and DFY showed significant increase in second cut in comparison to first cut, while hemicellulose and ADL showed slight increase at second cut. Whereas, stover nitrogen, CP and IVOMD showed significant decrease at second cut, while traits like ADF, cellulose and ME showed marginal decrease in values at second cut (Fig. 1).

Association between forage traits

Investigations on associations between forage traits revealed that PH was significantly positively correlated with GFY ($r=0.32^{**}$, $P<0.01$ and $r=0.66^{**}$, $P<0.01$, for first and second cut respectively) and DFY ($r=0.36^{**}$, $P<0.01$ and $r=0.50^{**}$, $P<0.01$, for first and second cut, respectively) (Table 1). Similar correlations between GFY, DFY and PH were also reported by Imran *et al.* (2010) in pearl millet. DFY had significant positive correlation with GFY ($r=0.79^{**}$, $P<0.01$ and $r=0.63^{**}$, $P<0.01$, for first and second cut, respectively) as also earlier reported by Imran *et al.* (2010) in pearl millet and in Napier grass (Pattanshetti *et al.*, 2015). Desirable stover quality traits, such as stover nitrogen and CP had significant negative correlation with GFY ($r=-0.22^{**}$, $P<0.01$) and DFY ($r=-0.21^{**}$, $P<0.01$) at first cut. Similar inverse relationship between stover nitrogen and stover yield has been earlier reported in pearl millet (Bidinger and Blummel, 2007) and in maize (Ertiro *et al.*, 2013). IVOMD had no correlation with GFY ($r=-0.02$, $P>0.05$) and DFY ($r=0.08$, $P>0.05$) at first cut but had small but significant negative correlation with GFY ($r=-0.19^{*}$, $P<0.05$) and DFY ($r=-0.31^{**}$,

Table 1. Correlations among forage related morphological and biochemical traits in a set of 116 hybrid parents

Correlations (r)	Cutting intervals†	NT	LS	GFY	DFY	DM	Ash	Stover N	CP	NDF	HC	ADF	Cellulose	ADL	ME	IVOMD
		Traits‡														
PH	FC	-0.02	-0.70**	0.32**	0.36**	0.27**	-0.40**	-0.53**	-0.53**	0.39**	0.04	0.23*	0.29**	0.24**	0.01	-0.19*
	SC	NA	NA	0.66**	0.50**	-0.14	0.04	-0.35**	-0.35**	0.31**	0.24*	0.08	0.00	0.31**	0.18	0.03
NT	FC		0.12	-0.13	0.02	-0.03	0.04	0.29**	0.29**	-0.01	0.04	-0.06	-0.06	-0.13	-0.11	-0.02
	SC		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
LS	FC			-0.12	-0.20*	-0.29**	0.28**	0.55**	0.55**	-0.26**	0.16	-0.28**	-0.35**	-0.25**	-0.12	0.08
	SC			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GFY	FC				0.79**	-0.02	0.18	-0.22*	-0.21*	0.04	0.04	0.05	0.02	0.12	0.10	0.04
	SC				0.63**	-0.28**	0.28**	-0.14	-0.15	0.16	-0.02	0.16	0.07	0.41**	-0.08	-0.19*
DFY	FC					0.03	0.12	-0.26**	-0.25**	0.08	0.01	0.11	0.09	0.14	-0.02	-0.09
	SC					-0.25**	0.20*	0.14	0.14	0.09	-0.07	0.14	0.09	0.26**	-0.25**	-0.31**
DM	FC						-0.21*	-0.37**	-0.37**	0.44**	-0.28**	0.64**	0.76**	0.49**	-0.20*	-0.29**
	SC						-0.09	-0.03	-0.04	-0.12	-0.12	0.03	0.09	-0.21*	0.26**	0.33**
Ash	FC							0.43**	0.44**	-0.56**	-0.46**	-0.16	-0.2*	-0.17	0.10	0.35**
	SC							0.34**	0.34**	-0.45**	-0.46**	-0.02	-0.05	0.12	-0.46**	-0.35**
Stover N	FC								0.99**	-0.47**	0.09	-0.56**	-0.54**	-0.56**	-0.04	0.30**
	SC								0.99**	-0.48**	-0.28**	-0.32**	-0.26**	-0.37**	-0.42**	-0.20*
CP	FC									-0.47**	0.10	-0.55**	-0.54**	-0.56**	-0.03	0.31**
	SC									-0.46**	-0.27**	-0.3**	-0.25**	-0.35**	-0.42**	-0.21*
NDF	FC										0.36**	0.63**	0.58**	0.64**	-0.29**	-0.47**
	SC										0.69**	0.43**	0.35**	0.53**	0.17	-0.02
HC	FC											-0.37**	-0.42**	-0.16	-0.17	-0.21*
	SC											-0.34**	-0.40**	-0.04	0.48**	0.37**
ADF	FC												0.93**	0.80**	-0.13	-0.28**
	SC												0.98**	0.73**	-0.38**	-0.48**
Cellulose	FC													0.65**	-0.10	-0.24**
	SC													0.58**	-0.34**	-0.41**
ADL	FC														-0.30**	-0.46**
	SC														-0.40**	-0.56**
ME	FC															0.92**
	SC															0.95**

†FC, first cut; SC, second cut.

‡PH, plant height (cm); NTP, number of tillers/plant; LS, leaf to stem ratio; GFY, green forage yield (t/ha); DFY, dry forage yield (t/ha); DM, dry matter (%); Ash (%); Stover N stover nitrogen (%); CP, crude protein (%); NDF, neutral detergent fibre (%); cellulose (%); ADF, acid detergent fibre (%); Hemicellulose (%); ADL, acid detergent lignin (%); ME, metabolizable energy (MJ/kg); IVOMD, *in vitro* organic matter digestibility (%); TGFY, total green forage yield (t/ha).

P < 0.01) at second cut. This indicated that forage quantity can not be improved without affecting important forage quality traits like IVOMD at second cut, such inverse relationship has also been found in other crops like maize (Zaidi *et al.*, 2013 and Ramana Reddy *et al.*, 2013) and Sorghum (Aruna *et al.,* 2015).

Hierarchical clustering pattern among hybrid parents

The 116 (98 pollinator and 18 seed parents) hybrid parents based on both forage related morphological and biochemical traits delineated into six clusters, having 62 hybrid parents in first cluster (designated as C-I), 6 in C-II, 7 in C-III, 24 in C-IV, 4 in C-V and 11 in C-VI. The cluster mean values are given in Table 2 and Fig. 2. Each of these clusters were found to have higher mean values for some specific traits. Cluster II had highest mean value for DFY, along with highest stover nitrogen and CP at first cut. Cluster IV was found to have highest mean values of number of tillers per plant and GFY at first cut; while also had highest mean of stover nitrogen and CP at second cut. Cluster V had highest mean values of PH and IVOMD at first cut, and also had highest mean values for PH, GFY and DFY at second cut; also had highest mean of TGFY. Intercrossing genotypes/hybrid parents from distinct clusters can be identified and crossed to generate larger variability to produce desirable recombinants for forage yield and quality traits with wide genetic base. Zaidi *et al.* (2013), also found six clusters in 60 elite inbred lines for stover quality traits in maize.

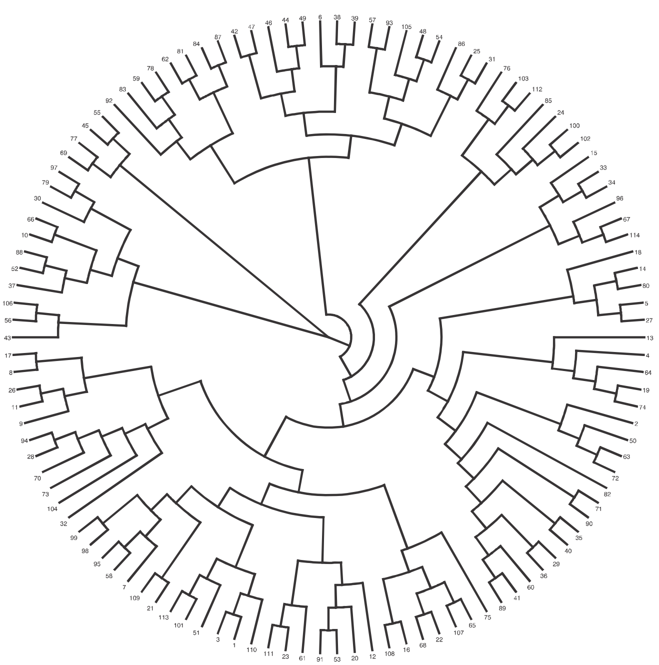

Fig. 2. Dendrogram of 116 hybrid parents of pearl millet based on Ward's method.

Table 2. Cluster mean for forage yield and quality traits of forage type hybrid parents in pearl millet

Traits[†]	Cutting intervals[‡]	Cluster					
		I	II	III	IV	V	VI
PH, cm	FC	86.68	97.96	95.33	90.05	103.97	84.53
	SC	84.21	89.36	91.53	92.16	93.56	87.78
Tillers (Nos)	FC	5.24	5.06	4.96	5.28	5.03	4.94
	SC	NA	NA	NA	NA	NA	NA
LS ratio	FC	0.8	0.7	0.73	0.72	0.59	0.76
	SC	NA	NA	NA	NA	NA	NA
GFY, t/ha	FC	21.35	22.5	22.97	23.14	21.72	21.76
	SC	25.42	25.92	27.35	29.69	30.1	27.43
DFY, t/ha	FC	4.28	4.65	4.53	4.62	4.34	4.35
	SC	6.27	6.11	6.07	6.5	6.95	6.1
DM, %	FC	90.98	91.00	90.97	91.03	91.06	90.99
	SC	89.99	90.08	90.00	89.96	90.08	89.95
Ash, %	FC	12.25	12.25	12.39	12.34	12.41	12.18
	SC	12.28	12.35	12.56	12.56	12.4	12.25
Stover N, %	FC	2.03	2.04	2.01	2.02	1.97	1.98
	SC	1.88	1.87	1.85	1.89	1.85	1.87
CP, %	FC	12.66	12.73	12.55	12.61	12.34	12.36
	SC	11.75	11.71	11.54	11.81	11.56	11.71
NDF, %	FC	63.25	63.82	63.19	63.37	63.34	63.48
	SC	62.33	62.25	62.32	62.49	62.37	62.75
HC, %	FC	31.16	31.38	31.36	31.07	30.97	31.12
	SC	33.06	33.29	33.22	33.16	33.14	33.31
ADF, %	FC	32.1	32.21	31.91	32.38	32.43	32.42
	SC	29.29	29.1	29.17	29.3	29.17	29.33
Cellulose, %	FC	28.55	28.63	28.35	28.85	28.88	28.79
	SC	25.57	25.42	25.45	25.56	25.47	25.58
ADL, %	FC	3.52	3.61	3.53	3.54	3.55	3.58
	SC	3.71	3.67	3.73	3.75	3.69	3.76
ME, MJ/kg	FC	7.6	7.56	7.64	7.62	7.63	7.61
	SC	7.28	7.36	7.38	7.27	7.34	7.28
IVOMD, %	FC	54.75	54.53	54.94	54.89	54.95	54.74
	SC	52.53	52.96	53.07	52.48	52.83	52.49
TGFY, t/ha	Combined	48.14	48.14	49.96	52.16	52.8	48.97

[†]PH, plant height; LS, leaf to stem ratio; GFY, green forage yield; DFY, dry forage yield; TGFY, total green forage yield.

[‡] FC: first cut; SC: second cut.

CONCLUSION

Present set of hybrid parents showed wide variation for forage linked morphological and biochemical traits, with some of parents having higher values for desirable forage traits while some having lower value for undesirable forage traits. Important forage quality traits like CP and IVOMD have shown low negative correlation with GFY and DFY, hence larger breeding populations should be grown in segregating generations to select against these negatively correlated traits and derive breeding lines with high biomass productivity coupled with high CP and IVOMD. Six distinct clusters of forage type hybrid parents were found with each one having breeding lines with desired forage traits. Trait specific hybrid parents can be selected from the identified clusters for utilization in crossing program for enhancing forage yield and quality.

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