Electronic Journal of Plant Breeding, 8(4): 1265-1274 (Dec 2017)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2017.00181.8

Research Article

Genetic variability studies in forage type hybrid parents of pearl millet

***P. Govintharaj*[1,2*], S.K. Gupta[2], M. Maheswaran[1], P. Sumathi[1]**
[1]Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India.
[2]International Crops Research Institute for the Semi-arid Tropics (ICRISAT), Patancheru-502 324, Hyderabad, Telangana, India.
* Email : govinth.tnau@gmail.com

(Received: 13 Nov 2017; Revised: 13 Dec 2017; Accepted: 28 Dec 2017)

Abstract
One hundred and sixteen forage-type hybrid parents of pearl millet were investigated in summer season for two years, the results revealed that the traits like number of tillers and leaf to stem ratio (L/S) at first cut (50 days after planting); and dry forage yield (DFY) at second cut (30 days after first cut) had high phenotypic coefficient of variation (PCV) values than genotypic coefficient of variation (GCV), hence selection will not be effective for these traits. Many of the desirable and undesirable forage quantity and quality linked traits under investigation had GCV almost equivalent to PCV, thus selection to improve those traits might be effective. High to moderate heritability coupled with high genetic advance per cent of mean (GA) was observed for plant height in both the cuts, indicating, this trait to be controlled by additive gene action and thus can be improved through selection, while, moderate heritability and high GA was observed for DFY at first cut; for green forage yield (GFY) at second cut and for total green forage yield (TGFY) from both the cuts, hence improvement in these traits will be possible through selection at later generations.

Keywords: Pearl millet, biomass yield, forage quality, genetic advance, heritability

Introduction

Pear millet (*Pennisetum glaucum* (L.) R. Br.) is an important food and fodder crop grown in the arid and semi-arid regions of the world. In India, it is mainly grown for grain purpose on 7.13 million ha with an average productivity of 8.06 million tonnes during 2015-16 (Directorate of Millet Development, 2017). This crop is a warm season cereal, and being C_4 crop offers higher dry matter production. Also, it is adaptable to drought/saline condition, and has fewer pest and disease problems, thus makes it a valuable fodder crop. Availability of good quality forage is most basic requirement for livestock, green fodder at any stage from pearl millet can be fed to ruminants without any harmful effects (Gupta and Sehgal, 1971). By 2020, India would require 526 million tonnes of dry fodder, 855 million tonnes of green fodder and 56 million tonnes of concentrate feed (Dikshit and Birthal, 2010). Pearl millet has significant variation for forage yield and quality traits, thus offers opportunities for its improvement through breeding efforts.

Knowledge on genetic variability is most basic requirement for the success of any crop breeding program. The parameters like genotypic and phenotypic coefficient of variation are useful to detect the amount of genetic variability in breeding population/lines for desired traits. Heritability alone may not help to identify the traits for imposing selection on a trait; therefore, heritability coupled with genetic advance as percent of mean is more reliable (Johnson *et al.*, 1955). Heritability provides how much variation in the phenotype in a population is due to genetic variation between individuals in that population, while genetic advance as percent of mean is helpful to find actual gain expected under selection (Ogunniyan and Olakojo, 2014). Therefore, this study aimed to assess the magnitude of genetic variability, heritability and genetic advance of morphological and forage quality traits of 116 forage type hybrid parents of pearl millet.

Materials and Methods

A set of 116 forage type hybrid parents of pearl millet (Table 1) were evaluated in alpha lattice design with two replications, at ICRISAT, Patancheru (18°N, 78°E, 545 m above sea level) during summer 2015 and 2016. The plots consisted of one row of two meter length spaced at 60 cm apart. The rows were planted side by side 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 avoid moisture stress.

Data were recorded on five random plants of each entry for plant height (PH) in cm, number of tillers (NT) per plant and leaf to stem ratio (L/S) in each replication and the average was worked out and used for statistical analysis. Green forage yield (GFY) and dry forage yield (DFY) were measured on plot basis in t ha^{-1}. Second cut was taken after thirty days of first cut. Traits were recorded as mentioned in first cut. Total green forage yield

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(TGFY) in t ha^{-1} was calculated as sum of the two 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 by Near-Infrared Reflectance Spectroscopic (NIRS) for 11 forage quality traits (Table 2) as described by Blummel *et al*. (2007). All the above mentioned traits were recorded for both the cuts in both the seasons, except NT and L/S which were recorded only in first cut during summer 2015 and 2016.

Data from two cuts, across the two seasons, were subjected to analysis of variance to estimate the genetic variability parameters (SAS Institute Inc., 2017). Using SAS/Stat module, phenotypic and genotypic coefficient of variation, heritability and genetic advance were estimated for forage quantity and quality traits. The heritability and genetic advance as percent of mean values were categorized as suggested by Johnson *et al*. (1955).

Result and discussion

Analysis of variance indicated, significant differences among the studied hybrid parents for most of the important forage traits like PH, GFY, DFY, stover nitrogen and CP in both the cuts, suggesting existence of considerable genetic variation for biomass quantity and quality traits (Table 3). This finding was in conformity with Bika and Shekhawat, (2015) in pearl millet for PH, GFY and DFY. Year (environment) × genotypes interactions were found significant for GFY and DFY in 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, indicated that environment had no significant effect on stover nitrogen and crude protein. This result was in accordance with those of Ertiro *et al*. (2013) in maize for crude protein.

In the present study, values of PCV were higher than GCV for all the traits in both the cuts (first and second cut, respectively) indicating that the observed variation was not only due to genotype but expression of the traits was influenced by environment (Table 4). Traits like, NT at first cut (16% PCV and 8% GCV), L/S at first cut (40.6% PCV and 30.2% GCV), and DFY (24.54% PCV and 9.39% GCV) at second cut had higher PCV values than GCV indicating large influence of environment on the expression of these traits, hence selection can be misleading for these traits. This finding was in agreement with results reported by Dhedhi *et al*. (2016) for DFY in pearl millet. There were small differences between PCV and GCV for forage traits, like GFY, DFY, stover nitrogen, CP and IVOMD at first cut; and for IVOMD at second cut, indicating very less influence of environments in the expression of these traits, thus selection based on these traits might be effective in future crossing programs. These findings were consistent with those reported in previous studies in pearl millet for GFY and DFY (Bika and Shekhawat, 2015).

PH had high to moderate heritability coupled with high genetic advance at first cut (69%, 31.2%), and also in second cut (57.1%, 18.9%) indicating this trait to be controlled by additive gene action and thus can be improved through selection procedures. Similar result was also reported by Kumar *et al*. (2017) in fodder pearl millet and Pattanshetti *et al*. (2015) in napier grass. Moderate heritability and high GA values were observed for DFY (55% and 20.3%) at first cut, for GFY (48.6% and 27.8%) for second cut and for TGFY (52% and 10.6%) from both the cuts, indicating that selection might be effective for improving these traits in later generations. This result was in agreement with the findings of Bika and Shekhawat, (2015) in pearl millet for DFY.

Forage quality traits like ash (33% and 3.1%), stover nitrogen (52% and 8.1%), CP (52% and 8.1%), NDF (48% and 1.7%), HC (41.00% and 1.91%), ADF (47% and 2.9%), cellulose (48% and 2.5%), ADL (45% and 6.8%), ME (43% and 1.3%) and IVOMD (43% and 1.3%) had moderate heritability together with low GA values at first cut, suggesting that direct selection for these traits would be less effective.

The traits like DFY (15% and 7.4%), stover nitrogen (29% and 4.5%), CP (3.1% and 0.5%), ADF (20.2% and 1.2%), ME (23.3% and 1.1%) and IVOMD (26.1% and 1.1%) under investigation showed low heritability with low GA at second cut, suggesting that direct selection is not possible since most of the observed variation is attributed to environmental effects. Similar results were reported earlier by Pattanshetti *et al*. (2015) for stover nitrogen, ME and IVOMD in napier grass.

Plant height can be improved through selection for multi-cut forage type breeding materials in pearl millet, while selection will still be effective for dry forage yield (DFY) in first cut, for green forage yield (GFY) in second cut and for total green forage yield (TGFY) from both the cuts in later generations. Information generated in the study on components of variance, heritability and genetic advance related to forage traits in pearl millet will help to breed suitable forage type cultivars in pearl millet.

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Table 1. Pedigree details of 116 forage type hybrid parents used in the current study.

SI.No.	Sample ID	Pedigree
1	FB01	(BSECBPT/91-38 × SPF3/S91-529)-10-1-6
2	FB02	(BSECBPT/91-38 × SPF3/S91-529)-2-1-B-2
3	FB03	ICMV87901-175-2-3-2-B-1
4	FB04	9035/S92-B-3
5	FB05	(HTBC-48-B-1-1-1-5 × B-line bulk)-25-1-B-B
6	FB06	[ICMB99555 × {78-7088/3/SER3 AD//B282/(3/4) EB × PBLN/S95-359}-10-2-B-2]-19-2-B-B-B-B
7	FB07	NC D2 S1-1-2-2-2-3-2-B-2
8	FB08	(81B × 4025-3-2-B)-8-1-B
9	FB09	NC D2 S1-17-2-1-1-2-2-B-4
10	FB10	(MC 94 S1-34-1-B × HHVBC)-16-2-1-4-2-B
11	FB11	[ICMB 97444 × (D2BLN/95-98 × EEBC C1-1)-7-B-B]-34-2-4-B-B-5-B-B
12	FB12	[ICMB 99555 × {78-7088/3/SER3 AD//B282/(3/4)EB × PBLN/S95-359}-10-2-B-2]-18-3-B-B-B-B
13	FB13	(SPF3/S91-544 × SPF3/S91-5)-5-1-2-1
14	FB14	(ICMB89111 × 863B)-65-8-B-B
15	FB15	[{(81B × SRL-53-1) × 843 B}-3-5-3 × [(843B × 111B)-10-1-2-2]}-226-B-2-B-B-B
16	FB16	ARD-288-1-10-1-2 (RM)-5
17	FB17	(ICMB89111 × IP9554-9)-4-2-2
18	FB18	(D2BLN95-103 × EEBC C1-3)-6-B-B
19	FP01	{MRC S1-9-2-2-B-B-4-B-B-B-B × (ICMS 7704-S1-127-5-1 × RCB-2 Tall)-B-19-3-3-5-1}-1-3-B
20	FP02	[(((ICMV-IS 94206-15) × B-Lines)-B-6) × (MRC S1-405-1-2-B)]-B-4-1-1-1-6-B × (ICMS 7704-S1-127-5-1 × RCB-2 Tall)-B-19-3-3-5-1]-40-3-B
21	FP03	HHVBC tall (C1) S1-33-3-1-1-1-2-B-B-3-2-3
22	FP04	ICMS 7704-S1-52-3-1-1-3-2-3-3-B-B-11
23	FP05	SOSAT-C 88-S1-60-B-B-1-2-1-3-1-2-1-3-2-1-16
24	FP06	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1-5
25	FP07	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1-5
26	FP08	{(SRC II C3 S1-19-3-2 × HHVBC)-1-5-1}×{[((96111B × 4017-6-1-1)-1-4-4-3) × (IP 19626-4-1-2-1)]-B-6}-B-5-1-1-3
27	FP09	{[((MC 94 S1-34-1-B × HHVBC)-16-2-1) × (IP 19626-4-2-3)]-B-28-3-2-2-2}×{GB 8735-S1-15-3-1-1-3-4-2-2-2-1}-B-4-1-2-4
28	FP10	ICMV 91059 S1-4-2-3-2-1-1-4-B-1-3-B-3
29	FP11	(ICMS 7704-S1-127-5-1 × RCB-2 Tall)-B-19-3-4-5-3
30	FP12	MRC HS-86-1-1-5-B-B-B-B-B-B-2
31	FP13	{MRC S1-9-2-2-B-B-4-B-B-B-B × (ICMS 7704-S1-127-5-1 × RCB-2 Tall)-B-19-3-3-5-1}-11-5-B
32	FP14	{MRC S1-9-2-2-B-B-4-B-B-B-B × (ICMS 7704-S1-127-5-1 × RCB-2 Tall)-B-19-3-3-5-1}-17-1-B
33	FP15	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-1-2-1-1-B
34	FP16	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-1-2-2-1-B
35	FP17	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-1-2-2-2-B

 DOI: 10.5958/0975-928X.2017.00181.8

SI.No.	Sample ID	Pedigree
36	FP18	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-1-2-2-3-B
37	FP19	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-1-3-1-1-B
38	FP20	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-1-3-1-2-B
39	FP21	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-1-3-1-3-B
40	FP22	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-1-3-1-4-B
41	FP23	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-1-3-2-1-B
42	FP24	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-1-3-2-2-B
43	FP25	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-4-1-1-1-B
44	FP26	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-4-1-1-2-B
45	FP27	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-4-1-1-3-B
46	FP28	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-4-1-1-4-B
47	FP29	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-4-1-1-5-B
48	FP30	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-4-1-1-6-B
49	FP31	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-4-1-1-7-B
50	FP32	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-4-1-3-1-B
51	FP33	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-4-1-3-2-B
52	FP34	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-4-1-3-3-B
53	FP35	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-4-1-4-1-B
54	FP36	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-4-2-1-1-B
55	FP37	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-4-2-2-1-B
56	FP38	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-4-2-2-2-B
57	FP39	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-4-2-3-1-B
58	FP40	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-5-3-1-1-B
59	FP41	ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258/K09)-5-5-2-1-B
60	FP42	((IPC 1268 × ICMV 91059 S1-58-2-2-2-1)-7-2-1-B × (E 298 × LCSN 282-4-1-2)-12-2-1-2-B-B-B-B)-4-1-B-B
61	FP43	((IPC 1268 × ICMV 91059 S1-58-2-2-2-1)-7-2-1-B × MRC S1-9-2-2-B-B-4-B-B-B-B)-16-1-B-B
62	FP44	([((MC 94 S1-34-1-B × HHVBC)-16-2-1) × (IP 19626-4-2-3)]-B-1-1-2-3-2-B-1 × 10624-1-1-1-1-3-2-3)-22-1
63	FP45	([(IP 12370-1-3 × B-Lines)-B-9-1-2-1-2-2 × MRC S1-191-2-1-5-B]-B-6 × 10624-1-1-1-1-3-2-3)-2-3
64	FP46	(EERC-HS-23)-22-1-4
65	FP47	(MRC HS-86-1-1-5-B-B-B-B-B × MRC S1-9-2-2-B-B-2-B-B)-18-1-2-B-B
66	FP48	(HHVBC tall (C1) S1-33-3-1-1-1-2-B-B-3-2 × (20252-20258))-11-2-2-2-B
67	FP49	(HHVBC tall (C1) S1-33-3-1-1-1-2-B-B-3-2 × (20252-20258))-11-5-2-3-1
68	FP50	(ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1-1 × 20274 × (20259-20274))-15-3-1-2-3
69	FP51	(ICMS 7704-S1-127-5-1 × RCB-2 Tall)-B-19-3-2-1-4-B-1
70	FP52	(ICMV-IS 94206-7 × (SRC II C3 S1-1-1-2 × HHVBC)-1-3-3))-B-10-1-1-5-4-1-2-14
71	FP53	(MRC HS-130-2-2-1-B-B-1-B-B-B-B-1-B × (20275-20291))-5-3-1-1
72	FP54	(MRC HS-86-1-1-5-B-B-B-B-B × MRC HS-225-3-5-2-B-B-B-B-B)-24-1-3-B-B
73	FP55	(RCB-2-S1-43-3-4 × MRC)-B-2-2-2-B-2-B-B

SI.No.	Sample ID	Pedigree
74	FP56	JBV 3 S1-231-1-2-2-1-3-B-1-B
75	FP57	MRC S1-9-2-2-B-B-2-B-B
76	FP58	{[((MC 94 S1-34-1-B × HHVBC)-16-2-1) × (IP 19626-4-2-3)-B-1-1-2-3-2-B-1 × IP No. 17843-1-1)]}-5-2-1-2-B
77	FP59	{[((MC 94 S1-34-1-B × HHVBC)-16-2-1) × (IP 19626-4-2-3)-B-1-1-2-3-2-B-1 × IP No. 17843-1-1)]}-6-1-1-1-B
78	FP60	{[((MC 94 S1-34-1-B × HHVBC)-16-2-1) × (IP 19626-4-2-3)-B-1-1-2-3-2-B-1 × IP No. 17843-1-1)]}-6-1-4-1-B
79	FP61	{[((MC 94 S1-34-1-B × HHVBC)-16-2-1) × (IP 19626-4-2-3)-B-1-1-2-3-2-B-1 × IP No. 17843-1-1)]}-21-1-2-1-B
80	FP62	{[((MC 94 S1-34-1-B × HHVBC)-16-2-1) × (IP 19626-4-2-3)-B-1-1-2-3-2-B-1 × IP No. 17843-1-1)]}-21-1-2-4-B
81	FP63	{[((MC 94 S1-34-1-B × HHVBC)-16-2-1) × (IP 19626-4-2-3)-B-1-1-2-3-2-B-1 × IP No. 17843-1-1)]}-21-1-2-7-B
82	FP64	{[((MC 94 S1-34-1-B × HHVBC)-16-2-1) × (IP 19626-4-2-3)-B-1-1-2-3-2-B-1 × IP No. 17843-1-1)]}-21-1-3-1-B
83	FP65	{[((MC 94 S1-34-1-B × HHVBC)-16-2-1) × (IP 19626-4-2-3)-B-1-1-2-3-2-B-1 × IP No. 17843-1-1)]}-21-2-3-2-B
84	FP66	{[((MC 94 S1-34-1-B × HHVBC)-16-2-1) × (IP 19626-4-2-3)-B-1-1-2-3-2-B-1 × IP No. 17843-1-1)]}-21-2-3-4-B
85	FP67	{[((MC 94 S1-34-1-B × HHVBC)-16-2-1) × (IP 19626-4-2-3)-B-1-1-2-3-2-B-1 × IP No. 17843-1-1)]}-21-2-3-6-B
86	FP68	{[((MC 94 S1-34-1-B × HHVBC)-16-2-1) × (IP 19626-4-2-3)-B-1-1-2-3-2-B-1 × IP No. 17843-1-1)]}-22-3-1-1-B
87	FP69	{[((MC 94 S1-34-1-B × HHVBC)-16-2-1) × (IP 19626-4-2-3)-B-1-1-2-3-2-B-1 × IP No. 17843-1-1)]}-22-3-4-1-B
88	FP70	{[((MC 94 S1-34-1-B × HHVBC)-16-2-1) × (IP 19626-4-2-3)-B-1-1-2-3-2-B-1 × IP No. 17843-1-1)]}-27-2-2-5-B
89	FP71	((ICMV-IS 94206-7 × (SRC II C3 S1-1-1-2 × HHVBC)-1-3-3))-B-10-1-1-5-4-1-2 × (20252-20258))-1-1-2-1-B
90	FP72	((ICMV-IS 94206-7 × (SRC II C3 S1-1-1-2 × HHVBC)-1-3-3))-B-10-1-1-5-4-1-2 × (20252-20258))-14-1-1-1-B
91	FP73	((ICMV-IS 94206-7 × (SRC II C3 S1-1-1-2 × HHVBC)-1-3-3))-B-10-1-1-5-4-1-2 × (20252-20258))-14-1-1-3-B
92	FP74	((ICMV-IS 94206-7 × (SRC II C3 S1-1-1-2 × HHVBC)-1-3-3))-B-10-1-1-5-4-1-2 × (20252-20258))-16-3-2-3-B
93	FP75	((ICMV-IS 94206-7 × (SRC II C3 S1-1-1-2 × HHVBC)-1-3-3))-B-10-1-1-5-4-1-2 × (20252-20258))-17-4-1-1-B
94	FP76	((ICMV-IS 94206-7 × (SRC II C3 S1-1-1-2 × HHVBC)-1-3-3))-B-10-1-1-5-4-1-2 × (20252-20258))-22-4-3-3-B
95	FP77	(HHVBC tall (C1) S1-33-3-1-1-1-2-B-B-3-2 × (20252-20258))-3-1-2-2-B
96	FP78	(HHVBC tall (C1) S1-33-3-1-1-1-2-B-B-3-2 × (20252-20258))-6-1-2-1-B
97	FP79	(HHVBC tall (C1) S1-33-3-1-1-1-2-B-B-3-2 × (20252-20258))-6-1-2-2-B
98	FP80	(SOSAT-C 88-S1-60-B-B-1-2-1-3-1-2-1-3-2-1× (20252-20258))-16-2-2-2-B
99	FP81	(SOSAT-C 88-S1-60-B-B-1-2-1-3-1-2-1-3-2-1 × (20252-20258))-16-5-3-2-B
100	FP82	(ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258))-5-3-2-2-B
101	FP83	(ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258))-5-4-4-2-3
102	FP84	(ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1× (20252-20258))-5-4-4-3-1
103	FP85	(ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258))-5-5-3-4-4
104	FP86	(ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258))-15-2-2-1-B
105	FP87	(ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258))-15-2-2-2-3
106	FP88	(ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20252-20258))-17-5-1-2-B

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ISSN 0975-928X
DOI: 10.5958/0975-928X.2017.00181.8

SI.No.	Sample ID	Pedigree
107	FP89	(HHVBC tall (C1) S1-33-3-1-1-1-2-B-B-3-2 × (20252-20258))-11-2-1-1-2
108	FP90	(HHVBC tall (C1) S1-33-3-1-1-1-2-B-B-3-2 × (20252-20258))-11-2-1-1-6
109	FP91	(HHVBC tall (C1) S1-33-3-1-1-1-2-B-B-3-2 × (20252-20258))-11-2-2-3-1
110	FP92	(HHVBC tall (C1) S1-33-3-1-1-1-2-B-B-3-2 × (20252-20258))-11-2-2-3-2
111	FP93	(ICMS 8506 S1-4-2-2-2-3-3-1-2-3-3-B-4-1 × ICMS 8506 S1-4-2-2-2-3-3-1-2-3-3-B-4 × (20259-20274))-1-1-1-2-1
112	FP94	(ICMS 8506 S1-4-2-2-2-3-3-1-2-3-3-B-4-1 × ICMS 8506 S1-4-2-2-2-3-3-1-2-3-3-B-4 × (20259-20274))-4-2-1-2-1
113	FP95	(ICMS 8506 S1-4-2-2-2-3-3-1-2-3-3-B-4-1 × ICMS 8506 S1-4-2-2-2-3-3-1-2-3-3-B-4 × (20259-20274))-6-1-1-1-4
114	FP96	(ICMS 8506 S1-4-2-2-2-3-3-1-2-3-3-B-4-1 × ICMS 8506 S1-4-2-2-2-3-3-1-2-3-3-B-4 × (20259-20274))-6-1-1-1-6
115	FP97	(ICMS 8506 S1-4-2-2-2-3-3-1-2-3-3-B-4-1 × ICMS 8506 S1-4-2-2-2-3-3-1-2-3-3-B-4 × (20259-20274))-6-1-1-1-7
116	FP98	(ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1-1 × ICMS 7704-S1-126-5-2-2-5-1-3-B-B-1 × (20259-20274))-17-1-1-1-3

Table 2. List of 11 forage quality traits measured in forage type hybrid parents of pearl millet.

SI. No.	Abbreviation	Unit	Traits Name
1	DM	%	Dry matter
2	Ash	%	Ash
3	Stover N	%	Stover nitrogen
4	CP	%	Crude protein
5	NDF	%	Neutral detergent fibre
6	HC	%	Hemicellulose
7	ADF	%	Acid detergent fibre
8	Cellulose	%	Cellulose
9	ADL	%	Acid detergent lignin
10	ME	MJ/kg	Metabolizable energy
11	IVOMD	%	In vitro organic matter digestibility

Electronic Journal of Plant Breeding, 8(4): 1265-1274 (Dec 2017)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2017.00181.8

Table 3. Analysis of variance for forage related morphological and biochemical traits for two cuts in pearl millet, evaluated in summer seasons of 2015 and 2016 at ICRISAT, Patancheru.

Cutting intervals	Source of variations	DF	PH	NT	L/S	GFY	DFY	DM	Ash	Stover N	CP	NDF	HC	ADF	Cellulose	ADL	ME	IVOMD
First cut	Year	1	0.70	0.65	0.47	0.71	0.71	0.69	0.14	-0.35	-0.35	0.62	0.70	0.71	0.71	0.63	0.59	0.60
	Year × Rep	2	0.79	0.84	0.97	0.53	0.71	0.98	0.90	0.62	0.62	0.56	0.91	0.90	0.93	0.76	0.70	0.77
	Year × Rep × Block	24	2.27**	2.55**	-0.41	1.71	-0.02	1.07	0.86	1.60	1.60	2.54**	2.56**	1.07	1.10	2.18*	2.78***	2.70***
	Geno	115	4.63***	1.52	2.50**	4.76***	5.00***	1.63*	2.09*	3.71***	3.71***	3.50***	2.56**	3.96***	3.28***	4.54***	3.03***	3.01***
	Year × Geno	115	5.34***	2.61**	4.20***	-2.29*	-1.43	1.74*	1.95*	-0.43	-0.43	-0.31	1.18	-0.55	2.05*	-2.01*	1.46	0.26
	Residual	204	86.09	1.24	0.03	28.31	1.10	0.15	0.57	0.17	1.83	2.43	0.97	2.12	0.75	0.17	0.02	1.35
	Total	456	87.58	4.25	1.06	31.26	1.07	2.89	2.47	1.61	3.27	3.30	3.76	4.25	3.49	1.56	2.77	2.98
Second cut	Year	1	0.47			0.69	0.71		0.67	0.65	0.65	-1.67	0.70	0.71	0.71	0.68	0.70	0.70
	Year × Rep	2	0.87			0.94	-1.23	0.76	0.74	0.69	0.69	-0.08	0.19	-0.93	-0.44	0.61	0.60	0.83
	Year × Rep × Block	24	2.26**			1.51	0.85	1.87*	0.88	2.65***	2.66***	-0.25	1.16	1.74	1.74	1.73*	0.38	1.45
	Geno	115	3.61***	NA	NA	2.97**	1.28	1.77*	2.46**	1.89*	1.89*	2.44*	0.27	1.15	1.04	2.84***	1.11	1.48
	Year × Geno	115	5.07***			3.60***	1.61	1.14	2.49**	0.28	0.28	3.42***	3.68***	2.09*	1.77	3.36***	4.54***	4.02***
	Residual	204	76.39			41.48	7.42	0.23	0.75	0.05	1.99	1.46	1.71	1.43	1.10	0.04	0.04	1.42
	Total	456	77.73			44.62	10.63	2.13	3.04	1.67	3.61	-0.54	4.03	4.10	5.92	1.33	2.83	5.88

Note:PH-Plant height (cm), NT-Number of tillers/plant, L/S-Leaf to stem ratio, GFY-Green forage yield (t ha^{-1}), DFY-Dry forage yield (t ha^{-1}), DM-Dry matter (%), Stover N-Stover nitrogen (%), CP-Crude protein (%), NDF-Neutral detergent fibre (%), ADF-Acid detergent fibre (%), HC-Hemicellulose (%), ADL-Acid detergent lignin (%), ME-Metabolizable energy (MJ/kg), IVOMD-In vitro organic matter digestibility (%).

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Table 4. Estimates of variability parameters for forage yield and quality related traits.

Traits*	Cutting intervals	PCV (%)	GCV (%)	Heritability (%)	GA (%)
PH (cm)	FC†	22.02	18.30	69.00	31.25
	SC‡	16.07	12.15	57.13	18.88
NT	FC	16.01	8.03	25.00	8.28
	SC	NA	NA	NA	NA
L/S	FC	40.57	30.20	55.00	46.23
	SC	NA	NA	NA	NA
GFY (t ha^{-1})	FC	1.97	1.47	55.00	2.25
	SC	27.84	19.40	48.57	27.79
TGFY (t ha^{-1})	Combined	20.19	14.61	52.00	21.59
DFY (t ha^{-1})	FC	17.94	13.28	55.00	20.28
	SC	24.54	9.39	15.00	7.42
DM (%)	FC	0.27	0.13	23.00	0.13
	SC	0.35	0.20	30.71	0.22
Ash (%)	FC	4.44	2.57	33.00	3.05
	SC	5.84	3.68	39.81	4.78
Stover N (%)	FC	7.52	5.43	52.00	8.05
	SC	7.53	4.06	29.00	4.49
CP (%)	FC	7.52	5.43	52.00	8.05
	SC	7.33	1.29	3.09	0.47
NDF (%)	FC	1.68	1.16	48.00	1.65
	SC	1.77	1.11	39.26	1.43
HC (%)	FC	2.27	1.45	41.00	1.91
	SC	3.06	0.71	5.44	0.34
ADF (%)	FC	3.02	2.07	47.00	2.91
	SC	2.80	1.25	20.15	1.16
Cellulose (%)	FC	2.51	1.74	48.00	2.47
	SC	2.68	1.15	18.51	1.02

ADL (%)	FC	7.38	4.93	45.00	6.78
	SC	5.38	3.61	45.00	4.97
ME (MJ/kg)	FC	1.45	0.95	43.00	1.28
	SC	2.38	1.15	23.33	1.14
IVOMD (%)	FC	1.43	0.94	43.00	1.26
	SC	2.07	1.06	26.13	1.11

†FC: First; ‡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}), DM-Dry matter (%), Stover N-Stover nitrogen (%), CP-Crude protein (%), NDF-Neutral detergent fibre (%), ADF-Acid detergent fibre (%), HC-Hemicellulose (%), ADL-Acid detergent lignin (%), ME-Metabolizable energy (MJ/Kg), IVOMD-*In vitro* organic matter digestibility (%).