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Research Article

Heterosis and variability studies for yield and yield components traits in pearl millet [*Pennisetum glaucum* (L.) R. Br.]

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Abstract
The experiment was conducted to study the heterosis and variability parameters by using 41 hybrids along with a check during *kharif* 2015. The *per se* performance and standard heterosis revealed that the hybrids *viz*., NHB 999, NPH-5286, AHB-1157 and 86M90 were found to be superior for single plant yield along with days to 50 per cent flowering, days to maturity, plant height, number of productive tillers per plant, earhead length and 1000 seed weight. High level of phenotypic coefficient of variation was observed than the genotypic coefficient of variation for all the studied traits. High heritability along with high genetic advance as per cent of mean was observed in number of productive tillers per plant, 1000 seed weight, seed set per cent and single plant yield. Single plant yield positively and significantly correlated with plant height, 1000 seed weight and seed set per cent. These traits could be used as selection indices for pearl millet yield improvement.

Key words
Pearl millet, heterosis, variability and correlation

Introduction

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is the staple food for majority of the population in arid and semi-arid zones. Pearl millet is a highly cross pollinated crop with protogynous flowering which leads to 85 per cent of outcrossing. In India, pearl millet is the third most widely cultivated food crop after rice and wheat (AICRP on pearl millet, 2017). It is rich in protein (6-13 %), calcium, potassium, magnesium, iron, zinc, manganese and vitamins. Efficient exploitation of heterosis is important for successful hybrid breeding in pearl millet. Many researchers have observed heterosis for yield and other characters in pearl millet. Heterosis breeding recognized as the most suitable breeding methodology for yield improvement in pearl millet. The general expectation of pearl millet farmers is mainly focused on level of yield superiority over the local varities/hybrids, which is grown widely. So there is a compulsory need for the breeder to evaluate the newly developed hybrids with standard hybrids for yield or any other desirable characters. The present study was focused to estimate standard heterosis for yield and yield components among the hybrids.

Materials and methods

The experimental material consists of 41 pearl millet hybrids which were received from the Project Coordinator, AICRP on pearl millet to evaluate at Coimbatore centre. The hybrids along along with a check (86M86) raised in a Randomized Block Design with three replications during *kharif* 2015 at Department of Millets, Tamil Nadu Agricultural University, Coimbatore. The entries were raised in a four metre row length with a row spacing of 50 cm. The observations were recorded on randomly selected five plants in each replication for each entry for the traits *viz*., days to 50 per cent flowering, days to maturity, plant height (cm), number of productive tillers per plant, earhead length (cm), earhead girth (cm), 1000 seed weight (g), seed set (%) and single plant yield (g). Standard heterosis was estimated by using mean values as suggested by Fonseca and Patterson (1968). Phenotypic and genotypic components of traits were worked out based on formula given by Goulden (1952). Heritability in broad sense was worked out as per Allard (1960) and genetic advance as per cent of mean (GAM) according to Johnson *et al*. (1955). Genotypic correlation coefficient was worked out using the formulae suggested by Falconer (1964).

Results and discussion

Analysis of variance exhibited significant differences among the studied traits which revealed that sufficient variability was observed among the hybrids.

The results for *per se* performance of the hybrids were presented in table 1. The mean performance for days to 50 per cent flowering ranged from 40.33 days to 55.67 days and for days to maturity it was varied between 82.33 days to 94 days. The hybrids, GHB 1168, GBH 2015 and BPMH-2 exhibited early flowering and early maturity among the hybrids evaluated. Significant mean performance for plant height was observed in 15 hybrids and tallest nature was exhibited by S 1183 (224.33 cm). For number of productive tillers per plant, five hybrids (ABH 04, NPH-5286, BPMH-1, BPMH-2 and Kaveri S. Boss) expressed significant mean performance than the overall mean (3.26). Regarding earhead length, 10 hybrids found to be significant than the grand mean whereas for

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earhead girth, seven hybrids showed significant performance among the 42 hybrids evaluated.

Maximum 1000 seed weight was observed in HY MH 5 (13.13 g) followed by 86M90 (12.44 g) and JKBH 1531 (12.16 g). For seed set per cent, 16 hybrids exhibited superiority over the grand mean and high seed set was exhibited by PRBH 99 (97.00 %), S 1183 and GK-1200 (92.67 %). High single plant yield was recorded in 86M90 (3.97 g) followed by HY MH 5 (3.53 g) and JKBH 1531 (2.81 g) and lowest yield was recorded by the hybrid HT 415078 (1.07 g).

The standard heterosis was worked out for 41 hybrids with a standard check for nine quantitative traits and the results were furnished in table 2. The traits, days to 50 per cent flowering and days to maturity exhibited significant negative heterosis for some of the hybrids and it will be desirable. The standard heterosis for days to 50 per cent flowering ranged from -21.43 per cent (GBH 2015 and GHB 1168) to 8.44 per cent (MP 7878) while for days to maturity, the value was ranged from -10.18 per cent (BPMH-2) to 2.55 per cent (JKBH 1486 and SUPER 78). Among 41 hybrids, 26 hybrids were negatively significant for days to 50 per cent flowering and days to maturity. Bachkar *et al.* (2014) and Chittora and Patel (2017) also reported negative heterosis for days to 50 per cent flowering and maturity. Early maturing genotypes were preferable in pearl millet growing areas especially in the arid zones.

The range of standard heterosis varied between -4.88 per cent (GBH 2015) and 49.22 per cent (S 1183) and 38 hybrids were found to be positive and significant for plant height. The highest value was observed for the hybrid, S 1183 followed by VNR 3275 and VNR 3255. Salagarkar and Wali (2016) and Patel *et al.* (2016) reported similar results for plant height. Thirty seven hybrids recorded positive and significant standard heterosis for number of productive tillers per plant, and the range was varied from – 2.94 per cent to 105.88 per cent. The highest heterosis was exhibited by ABH 04, NPH-5286, BPMH-2 and BPMH-1. The findings were coincide with the results of Chittora and Patel (2017), Maryam (2015) in pearl millet for productive tillers.

The maximum heterosis was exhibited by S 1183 (28.02 %), ARBH 14090 (24.74%), PRBH 99 (23.70%) and the minimum in GBH 2015 (-21.76 %) for earhead length, whereas for earhead girth, the maximum was observed in NHB 999 (17.20 %) and minimum in GBH 2015 (-19.35 %). Among 41 hybrids, positive and significant heterosis was exhibited by 16 hybrid in earhead length and eight hybrids in earhead girth. Izge *et al.* (2007), Salagarkar and Wali (2016) and Bachkar *et al.* (2014) also observed similar results for earhead length and girth in pearl millet.

Forty hybrids exhibited significant and positive standard heterosis for 1000 seed weight and the value was varied from -0.79 per cent to 106.29 per cent. Maximum heterosis for 1000 seed weight recorded in HY MH 5 followed by 86M90 and JKBH 1531 and minimum in GBH 2014. Concordant result for 1000 seed weight was identified by Salagarkar and Wali (2016) and Bachkar *et al.* (2014). Regarding seed set per cent, the value of standard heterosis ranged from -95.30 per cent to 95.30 per cent. The highest heterosis was exhibited by PRBH 99 (95.30 %) followed by S 1183 and GK-1200 (86.58 %) and lowest in GHB 1168 (-95.30 %).

Among 41 hybrids, 22 hybrids recorded positive and significant heterosis for single plant yield. The highest heterosis was observed in 86M90 (197.26%), HY MH 5 (164.34 %) and JKBH 1531 (110.22 %) and lowest in HT 415078 (-19.70 %). The results were similar with the findings of Bachkar *et al.* (2014), Maryam (2015), Patel *et al.* (2016), Salagarkar and Wali (2016) and Chittora and Patel (2017) in pearl millet.

Based on *per se* performance and standard heterosis, the hybrids NHB 999, NPH-5286, AHB-1157 and 86M90 were found to be superior for single plant yield along with days to 50 per cent flowering, days to maturity, plant height, number of productive tillers per plant, earhead length and 1000 seed weight. These hybrids would be evaluated further in multi-locations to exploit its heterosis before commercialization.

Genetic variability: High level of phenotypic and genotypic coefficient of variation was observed in single plant yield and seed set per cent (Table 3). Sowmiya *et al.* (2016) also observed high PCV and GCV for single plant yield. Number of productive tillers per plant and 1000 seed weight possessed moderate phenotypic and genotypic coefficient of variation while, earhead girth, days to 50 per cent flowering and days to maturity exhibited low level of PCV and GCV. Sumathi *et al.* (2016) reported moderate PCV and GCV for number of tillers per plant and 1000 seed weight.

High heritability along with high genetic advance as per cent of mean was observed in number of productive tillers per plant, 1000 seed weight, seed set per cent and single plant yield. Sowmiya *et al.* (2016), Sumathi *et al.* (2016) and Talawar *et al.* (2017) reported similar results in pearl millet. Therefore, selection should be efficient using these characters for improving the genotypes.

Plant height, 1000 seed weight and seed set per cent were positively and significantly correlated

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with single plant yield (Table 4). Similar findings were observed by Naveen *et al.* (2016) in pearl millet. Days to 50 per cent flowering was positively and significantly correlated with days to maturity, plant height and seed set per cent. Plant height is significantly and positively inter-correlated with earhead length, earhead girth and seed set per cent. Earhead length significantly and positively correlated with earhead girth and seed set per cent.

Based on variability and correlation studies, plant height, number of productive tillers per plant, 1000 seed weight and seed set per cent might be responsible for increasing single plant yield in pearl millet.

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Table 1. Mean performance of hybrids for quantitative traits in pearl millet

Hybrids	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of productive tiller per plant	Earhead length (cm)	Earhead girth (cm)	1000 seed weight (g)	Seed set %	Single plant yield (g)
Hy MH 5	47.67	88.00	187.67	3.33	21.73	3.17	13.13*	89.00*	3.53*
ABH 04	43.67*	85.67*	185.00	4.67*	24.60	3.13	8.97	91.33*	1.16
PRBH 99	47.67	88.00	187.33	3.60	27.67*	3.27	8.96	97.00*	1.37
PB 1744	49.00	88.33	175.67	2.20	22.40	3.10	9.13	55.00	1.16
PB 1779	50.00	89.67	178.67	3.13	21.57	3.10	12.05*	89.00*	1.68
PBH 909	49.00	90.00	184.67	2.67	22.53	3.37*	8.13	24.33	1.78
HT 415078	49.00	90.00	177.00	2.87	21.80	3.47*	10.62*	23.67	1.07
HT 415256	50.33	91.67	205.00*	3.20	22.53	3.60*	11.48*	59.00	2.03
ARBH 11141	45.67	86.67	176.67	3.53	21.20	3.23	8.77	23.33	1.54
ARBH 14090	49.67	90.33	196.00	2.93	27.90*	3.03	8.23	35.00	1.18
NPH-5286	42.33*	84.00*	169.00	3.93*	26.20*	3.33	10.27*	34.67	1.80
NPH-5423	46.00	87.00	183.67	3.27	20.70	3.23	8.97	76.33*	1.92
BPMH-1	42.00*	83.00*	155.33	3.80*	22.43	3.03	10.41*	61.00	1.12
BPMH-2	41.00*	82.33*	211.00*	3.87*	23.23	3.00	10.07*	27.33	1.42
PHB 3144	41.67*	83.33*	196.67*	3.47	22.03	2.83	8.42	12.67	1.50
AHB-1157	43.00*	84.33*	197.00*	3.47	22.83	3.17	9.61	52.67	2.80*
AHB-1199	43.00*	85.67*	199.67*	3.07	24.80	3.37*	9.95*	61.00	1.55
S 1183	52.33	92.00	224.33*	3.07	28.63*	3.23	11.40*	92.67*	2.04
GK-1200	44.67*	85.00*	195.33	2.67	25.27*	2.90	7.36	92.67*	1.91
KBH 5424	49.67	90.33	191.33	3.27	27.23*	3.27	9.06	38.67	2.66*
Bio 8566	48.33	88.67	183.67	3.27	22.53	3.40*	10.45*	85.67*	2.46*
86M90	47.33	88.67	202.33*	3.20	24.17	3.07	12.44*	89.33*	3.97*
JKBH 1531	45.67	86.67	180.33	3.67	26.47*	3.13	12.16*	9.00	2.81*
BLPMH 102	46.67	88.67	199.33*	3.13	22.60	3.23	11.06*	40.00	1.75
MP 7876	53.67	94.00	183.00	3.47	22.80	2.77	7.97	27.67	1.81
MP 7878	55.67	94.00	188.67	3.20	23.97	3.00	11.38*	82.67*	2.33*
GBH 2014	49.00	90.33	186.33	3.13	22.97	3.27	6.31	49.00	1.70
GBH 2015	40.33*	83.33*	143.00	2.40	17.50	2.50	10.07*	16.33	1.44
GHB 1153	43.67*	85.33*	160.33	3.27	22.77	3.00	10.55*	10.33	1.22
GHB 1168	40.33*	82.67*	149.00	2.93	22.07	2.53	8.45	2.33	1.29
Krishna 171	47.00	88.33	179.00	2.73	22.77	2.73	10.42*	20.33	1.68
GK-1207	50.33	90.67	198.33*	3.33	21.50	3.13	6.88	25.00	1.36
JKBH 1486	53.33	94.00	203.00*	3.60	23.63	2.90	8.37	82.00*	1.31
Super 78	54.33	94.00	179.33	3.53	25.03	2.77	7.91	81.00*	1.40
Super 99	48.67	89.33	184.00	3.60	19.90	3.00	7.89	31.00	1.44
VNR 3255	52.33	93.33	221.00*	3.13	27.63*	3.27	10.50*	72.33*	1.75
VNR 3275	49.67	90.33	221.33*	3.40	26.07*	3.47*	8.93	71.67*	1.87
NHB 999	46.00	88.00	186.67	3.27	24.70	3.63*	8.38	63.33*	1.90
NBH 5860	44.67*	86.67	204.00*	3.27	27.57*	3.27	10.95*	50.67	1.80
Kaveri S. Boss	52.33	93.33	202.67*	3.80*	22.40	2.83	7.23	37.00	1.83
86M86	44.00*	85.33*	203.00*	3.33	23.73	3.20	8.37	78.33*	2.52*
NBH 5061 (C)	51.33	91.67	150.33	2.27	22.37	3.10	6.36	49.67	1.34
Grand mean	**47.43**	**88.40**	**187.75**	**3.26**	**23.63**	**3.12**	**9.48**	**52.64**	**1.81**
SE	0.67	0.68	3.08	0.16	0.57	0.08	0.14	3.18	0.13
CD (0.05)	**1.89**	**1.91**	**8.62**	**0.44**	**1.59**	**0.23**	**0.39**	**8.89**	**0.35**

*Significant at 5 per cent level

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Table 2. Standard heterosis for yield and yield attributing traits in pearl millet

Hybrids	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of productive tiller per plant	Earhead length (cm)	Earhead girth (cm)	1000 seed weight (g)	Seed set %	Single plant yield (g)
Hy MH 5	7.14 **	-4.00 **	24.83 **	47.06 **	-2.83 ns	2.15 ns	106.29 **	79.19 **	164.34 **
ABH 04	-14.94 **	-6.55 **	23.06 **	105.88 **	9.99 **	1.08 ns	41.02 **	83.89 **	-13.47 ns
PRBH 99	-7.14 **	-4.00 **	24.61 **	58.82 **	23.70 **	5.38 ns	40.75 **	95.30 **	2.49 ns
PB 1744	-4.55 *	-3.64 **	16.85 **	-2.94 ns	0.15 ns	-0.00 ns	43.53 **	10.74 ns	-13.47 ns
PB 1779	-2.60 ns	-2.18 *	18.85 **	38.24 **	-3.58 ns	0.00 ns	89.42 **	79.19 **	25.69 ns
PBH 909	-4.55 *	-1.82 ns	22.84 **	17.65 ns	0.75 ns	8.60 *	27.76 **	-51.01 **	33.42 *
HT 415078	-4.55 *	-1.82 ns	17.74 **	26.47 **	-2.53 ns	11.83 **	66.84 **	-52.35 **	-19.70 ns
HT 415256	-1.95 ns	0.00 ns	36.36 **	41.18 **	0.75 ns	16.13 **	80.41 **	18.79 *	51.62 **
ARBH 11141	-11.04 **	-5.45 **	17.52 **	55.88 **	-5.22 ns	4.30 ns	37.77 **	-53.02 **	14.96 ns
ARBH 14090	-3.25 ns	-1.45 ns	30.38 **	29.41 **	24.74 **	-2.15 ns	29.28 **	-29.53 **	-11.47 ns
NPH-5286	-17.53 **	-8.36 **	12.42 **	73.53 **	17.14 **	7.53 *	61.34 **	-30.20 **	34.91 *
NPH-5423	-10.39 **	-5.09 **	22.17 **	44.12 **	-7.45 *	4.30 ns	41.02 **	53.69 **	43.89 **
BPMH-1	-18.18 **	-9.45 **	3.33 ns	67.65 **	0.30 ns	-2.15 ns	63.59 **	22.82 *	-15.96 ns
BPMH-2	-20.13 **	-10.18 **	40.35 **	70.59 **	3.87 ns	-3.23 ns	58.30 **	-44.97 **	5.99 ns
PHB 3144	-18.83 **	-9.09 **	30.82 **	52.94 **	-1.49 ns	-8.60 *	32.32 **	-74.50 **	12.22 ns
AHB-1157	-16.23 **	-8.00 **	31.04 **	52.94 **	2.09 ns	2.15 ns	50.97 **	6.04 ns	109.48 **
AHB-1199	-16.23 **	-6.55 **	32.82 **	35.29 **	10.88 **	8.60 *	56.36 **	22.82 *	15.71 ns
S 1183	1.95 ns	0.36 ns	49.22 **	35.29 **	28.02 **	4.30 ns	79.15 **	86.58 **	52.62 **
GK-1200	-12.99 **	-7.27 **	29.93 **	17.65 ns	12.97 **	-6.45 ns	15.72 **	86.58 **	42.89 **
KBH 5424	-3.25 ns	-1.45 ns	27.27 **	44.12 **	21.76 **	5.38 ns	42.43 **	-22.15 *	99.00 **
Bio 8566	-5.84 **	-3.27 **	22.17 **	44.12 **	0.75 ns	9.68 *	64.22 **	72.48 **	84.04 **
86M90	-7.79 **	-3.27 **	34.59 **	41.18 **	8.05 *	-1.08 ns	95.55 **	79.87 **	197.26 **
JKBH 1531	-11.04 **	-5.45 **	19.96 **	61.76 **	18.33 **	1.08 ns	91.15 **	-81.88 **	110.22 **
BLPMH 102	-9.09 **	-3.27 **	32.59 **	38.24 **	1.04 ns	4.30 ns	73.81 **	-19.46 *	31.17 *
MP 7876	4.55 *	2.55 *	21.73 **	52.94 **	1.94 ns	-10.75 **	25.25 **	-44.30 **	35.16 **
MP 7878	8.44 **	2.55 *	25.50 **	41.18 **	7.15 *	-3.23 ns	78.84 **	66.44 **	74.31 **
GBH 2014	-4.55 *	-1.45 ns	23.95 **	38.24 **	2.68 ns	5.38 ns	-0.79 ns	-1.34 ns	27.43 *
GBH 2015	-21.43 **	-9.09 **	-4.88 ns	5.88 ns	-21.76 **	-19.35 **	58.30 **	-67.11 **	7.98 ns
GHB 1153	-14.94 **	-6.91 **	6.65 *	44.12 **	1.79 ns	-3.23 ns	65.74 **	-79.19 **	-8.48 ns
GHB 1168	-21.43 **	-9.82 **	-0.89 ns	29.41 **	-1.34 ns	-18.28 **	32.79 **	-95.30 **	-3.74 ns
Krishna 171	-8.44 **	-3.64 **	19.07 **	20.59 *	1.79 ns	-11.83 **	63.80 **	-59.06 **	25.94 ns
GK-1207	-1.95 ns	-1.09 ns	31.93 **	47.06 **	-3.87 ns	1.08 ns	8.12 *	-49.66 **	2.00 ns
JKBH 1486	3.90 *	2.55 *	35.03 **	58.82 **	5.66 ns	-6.45 ns	31.48 **	65.10 **	-2.24 ns
Super 78	5.84 **	2.55 *	19.29 **	55.88 **	11.92 **	-10.75 **	24.36 **	63.09 **	4.99 ns
Super 99	-5.19 **	-2.55 *	22.39 **	58.82 **	-11.03 **	-3.23 ns	23.99 **	-37.58 **	7.98 ns
VNR 3255	1.95 ns	1.82 ns	47.01 **	38.24 **	23.55 **	5.38 ns	64.96 **	45.64 **	30.92 *
VNR 3275	-3.25 ns	-1.45 ns	47.23 **	50.00 **	16.54 **	11.83 **	40.28 **	44.30 **	39.65 **
NHB 999	-10.39 **	-4.00 **	24.17 **	44.12 **	10.43 **	17.20 **	31.74 **	27.52 **	42.39 **
NBH 5860	-12.99 **	-5.45 **	35.70 **	44.12 **	23.25 **	5.38 ns	72.08 **	2.01 ns	34.91 *
Kaveri S. Boss	1.95 ns	1.82 ns	34.81 **	67.65 **	0.15 ns	-8.60 *	13.67 **	-25.50 **	37.16 **
86M86	-14.29 **	-6.91 **	35.03 **	47.06 **	6.11 ns	3.23 ns	31.48 **	57.72 **	88.53 **

, * Significant at 5 and 1 per cent level

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Table 3. Variability parameters in pearl millet for quantitative traits

Traits	PCV (%)	GCV (%)	h^2 (%)	GA	GAM
Days to 50% flowering	8.72	8.36	92.01	7.84	16.53
Days to maturity	4.02	3.79	88.93	6.51	7.36
Plant height (cm)	10.14	9.73	92.15	36.14	19.25
No. of productive tiller per plant	15.59	13.16	71.26	0.75	22.88
Earhead length (cm)	10.67	9.82	84.81	4.40	18.63
Earhead girth (cm)	8.92	7.65	73.48	0.42	13.51
1000 seed weight (g)	17.72	17.53	97.89	3.39	35.74
Seed set %	54.59	53.58	96.34	57.03	108.33
Single plant yield (g)	36.12	34.06	88.91	1.20	66.15

Table 4. Genotypic correlation of yield component traits on single plant yield in pearl millet

Traits	Days to maturity	Plant height (cm)	No. of productive tillers per plant	Earhead length (cm)	Earhead girth (cm)	1000 seed weight (g)	Seed set %	Single plant yield (g)
Days to 50% flowering	0.984**	0.322*	-0.128	0.206	0.115	-0.117	0.328*	0.065
Days to maturity		0.338*	-0.121	0.200	0.132	-0.137	0.274	0.005
Plant height (cm)			0.235	0.511**	0.394**	0.107	0.385*	0.304*
No. of productive tillers per plant				0.191	0.088	0.062	0.134	0.051
Earhead length (cm)					0.327*	0.111	0.332*	0.139
Earhead girth (cm)						0.185	0.296	0.194
1000 seed weight (g)							0.185	0.476**
Seed set %								0.313*

, * Significant at 5 and 1 per cent level