International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(5): 1406-1409

Received: 19-07-2019
Accepted: 21-08-2019

Patel KN
Department of Genetics and Plant Breeding, College of Agriculture, JAU, Junagadh, Gujarat, India

Dhedhi KK
Assoc. Res. Sci., Main Pearl Millet Research Station, JAU, Junagadh, Gujarat, India

Bamji RC
Department of Genetics and Plant Breeding, College of Agriculture, JAU, Junagadh, Gujarat, India

Correspondence
Patel KN
Department of Genetics and Plant Breeding, College of Agriculture, JAU, Junagadh, Gujarat, India

Heterosis for grain yield and it's component traits in pearl millet [*Pennisetum glaucum* (L.) R. Br.] using line x tester analysis

Patel KN, Dhedhi KK and Bamji RC

Abstract
Four cytoplasmic male sterile lines were crossed with nine restorers to develop 36 hybrids using line x tester design to study extant of standard heterosis in pearl millet for fourteen different characters. The analysis of variance showed highly significant differences among the genotypes for all the traits. Thus, the results quantified the considerable amount of genetic diversity exist among genotypes for the different traits under study. The high magnitudes of standard heterosis was observed for grain yield per plant, length of protogyny, number of nodes on main stem, number of effective tillers per plant and threshing index. Out of 36 crosses studied, nine crosses showed significant standard heterosis in desired direction for grain yield per plant. The range of standard heterosis varied from -64.49% to 27.41%. The highest value of standard heterosis was recorded by cross JMSA$_5$-20175 x J-2598 for grain yield per plant followed by ICMA$_1$-15666 x 92-SB-18, ICMA$_1$-15666 x J-2605 and JMSA$_4$-20172 x J-2591. These crosses also exhibited high heterosis in desired direction for important component traits suggesting that the heterosis for grain yield was associated with heterosis for other yield attributing traits.

Keywords: Line x tester, pearl millet, heterosis

Introduction
Pearl millet is world's sixth important cereal food crop and one of the important staple food crops of India ranking fourth in acreage next to rice, wheat and sorghum. However, it is primarily grown as forage crop in USA, Australia and South Africa. The pearl millet is an annual, tillering diploid (2n=14) crop plant, belongs to family Poaceae and sub family Paniceidae and believed to be originated in Africa. It is a highly nutritious cereal with high levels of metabolized energy, protein (9 to 15%), fat (5%) and mineral matters (2 to 7%). It is also rich in vitamins A and B, thiamin and riboflavin contents and imparts substantial energy to the body with easy digestibility (Pal *et al.* 1996) [11]. The amino acid profile of pearl millet is more balanced than wheat and rice and many other cereals, and low glycemic index (Singh *et al.* 1999 [16] and Sehgal *et al.* 2004 [14]). The cross pollination mechanism due to protogyneous condition in pearl millet permits many breeding techniques to be used ranging from population improvement to strict pedigree selection and heterosis breeding. The phenomenon of heterosis has proved to be the outstanding genetic tool in enhancing the yield of cross pollinated species in general and pearl millet in particular. With the ease of use of functional cytoplasmic genetic male sterility system in pearl millet, exploitation of hybrid vigour on commercial scale has become realistic and economical. In India, truthful revolution in pearl millet production has come with development and release of hybrids for commercial cultivation. Exploitation of hybrid vigour is considered to be one of the outstanding achievements in this crop. Cross pollinated nature and availability of male sterile lines in crop had made of its feasible to exploit hybrid vigour on commercial scale.

Materials and Methods
The experimental material comprising of 13 parents, 36 crosses and one standard check (GHB -732) were evaluated at Main Pearl Millet Research Station, Junagadh Agricultural University, Jamnagar, Gujarat during *kharif* 2018 using line x tester analysis. The crossing material in present investigation involved four cytoplasmic genetic male sterile lines *viz*., JMSA$_4$-20172, JMSA$_5$-20175, JMSA$_1$-20181, ICMA$_1$-15666 and nine restorer pollinators like J-2584, J-2591, J-2598, J-2605, 52-SB-18, 72-SB-18, 92-SB-18, 120-SB-18. The observations were recorded

for fourteen different characters *viz*., days to 50% flowering, length of protogyny (days), number of nodes on main stem, number of effective tillers per plant, ear head length (cm), ear head girth (cm), ear head weight (g), plant height (cm), days to maturity, 1000- grain weight (g), dry fodder yield per plant (g), grain yield per plant (g), Harvest index (%) and threshing index (%).

Result and discussion

The analysis of variance showed highly significant differences among the genotypes for all the traits. Thus, the results quantified the considerable amount of genetic diversity exist among genotypes for the different traits under study (Table 1). In general among all three heterosis, standard heterosis or economic heterosis have more significance and used for commercial exploitation. Hence, in the present investigation, the extent of heterosis over standard check hybrid (GHB-732) for grain yield and thirteen yield component traits is discussed. The range of standard heterosis as well as number of crosses showing significant heterosis in desirable direction is showed in (Table 2). Among fourteen studied characters negative heterosis is desirable for characters viz., days to 50% flowering, length of protogyny condition and days to maturirty which ultimately helps to pearl millet to mature earlier and escaping drought condition in arid region. Out of 36 crosses 17, 7 and 14 crosses showed negative heterosis for days to 50% flowering, length of protogyny condition and days to maturity, respectively. The range of standard heterosis for days to 50% flowering was vary from -8.87% to 8.22%, while for length of protogyny condition it's ranged from -43.56 to 48.03. The range of heterosis for days to maturity is vary from -7.66 to 11.92 per cent. Characters, number of nodes per plant directly effect on plant height, so increasing in number of nodes have positive impact on plant height which is desirable character for increasing fodder yield. The range of heterosis for number of nodes on main stem is varied from -9.38 to 44.46 per cent, whereas for plant height it's ranged from -29.38 to 15.53 per cent. Number of effective tillers per plant, ear head length, ear head girth and ear head weight have positive impact on grain yield per plant. Out of 36 crosses five, four and four crosses showed significant positive heterosis for number of effective tillers per plant, ear head length and ear head girth, respectively. None of the cross showed significant positive heterosis for ear head weight. The range of heterosis for number of effective tillers per plant is vary from -14.94 to 19.98 percent. Whereas, for ear head length it's vary from -14.94 to 19.98 per cent. For ear head girth it's ranged from -19.81 to 7.93 per cent, while for ear head weight it's ranged from - 65.54 to 12.32 per cent. Test weight being important yield attributing character which impact directly on grain yield per plant. The range of standard heterosis for test weight is varied from -30.13 to 23.19 per cent. Most important traits of experiment are dry fodder yield per plant and grain yield per plant. Out of 36 crosses six and nine crosses showed significant and positive hetrosis for dry fodder yield per plant and grain yield per plant, respectively. Range of standard heterosis for dry fodder yield per plant is vary from –40.68 to 20.66 per cent. While for grain yield per plant it's ranged from -64.49 to 27.43 per cent. For harvest index the values of standard heterosis varied from -34.02 to 22.95 per cent. Among 36 crosses only two crosses have significant positive heterosis for this trait. For trait threshing index none of the cross were found significant, but it's range from -29.74 to 27.43.

The high magnitudes of standard heterosis was observed for grain yield per plant, length of protogyny, number of nodes on main stem, number of effective tillers per plant and threshing index, while, moderate for ear head length, ear head weight, plant height, 1000-grain weight, dry fodder yield per plant and harvest index. The low amount economical heterosis was reflected through days to 50% flowering, ear head girth and days to maturity.

A comparative study of crosses for grain yield per plant indicated that none of the cross combination showed desirable significant heterosis for all the studied character. A perusal of Table 3 revealed that the best top five heterotic crosses viz., $JMSA_5$-20175 x J-2598, $ICMA_1$-15666 x 92-SB-18, $ICMA_1$-15666 x J-2605, $JMSA_4$-20172 x J-2591 and $JMSA_4$-20172 x 52-SB-18 had manifested high positive and significant heterosis over standard check GHB 732 for grain yield per plant. The superior cross $JMSA_5$-20175 x J-2598 was also exhibited significant standard heterosis in desired direction for the characters, viz., number of nodes on main stem, number of effective tillers per plant, plant height, 1000-grain weight and dry fodder yield per plant. The second highest heterotic cross $ICMA_1$-15666 x 92-SB-18 was recorded significant and positive heterosis over standard check for number of effective tillers per plant, ear head girth, 1000-grain weight and dry fodder yield per plant. Similarly, the third highest heterotic cross $ICMA_1$-15666 x J-2605 was depicted significant and positive standard heterosis for number of effective tillers per plant, 1000-grain weight and dry fodder yield per plant. On the other hand, the fourth highest heterotic cross $JMSA_4$-20172 x J-2591 had significant standard heterosis in desirable direction for length of protogyny, number of nodes on main stem, number of effective tillers per plant, ear head length, plant height and dry fodder yield per plant. Similarly, the fifth highest heterotic cross $JMSA_4$-20172 x 52-SB-18 was manifested significant standard heterosis in desirable direction for days to 50% flowering, number of nodes on main stem, number of effective tillers per plant, days to maturity, dry fodder yield per plant and harvest index. It is interesting to note that the high heterotic crosses for grain yield did not show high heterosis for all the yield component traits (Table 3). But it was fact from present investigation that the significant and positive heterosis for grain yield was associated with significantly desirable heterosis for two or more yield attributing traits. Similar cumulative heterotic effects of two or more yield components on grain yield of pearl millet was also reported earlier by Bhanderi *et al*. (2007) [3], Kumhar (2007) [8], Chotaliya *et al*. (2009) [4], Dangaria *et al.* (2009) [5], Jethava *et al.* (2012) [6], Bhadalia *et al*. (2013) [2], Mungra (2014) [10], Acharya (2017) [1] and Ladumor *et al*. (2018) [9].

The best three crosses for yield and yield attributing characters have been mentioned in Table 4. The maximum values of standard hetrosis for grain yield per plant recorded in $JMSA_5$-20175 x J-2598 (27.43), while for other yield attributing traits it was -8.87 ($JMSA_4$-20172 x 52-SB-18) for days to 50% flowering and -43.56 ($JMSA_4$-20172 x J-2591) for length of protogyny condition., for number of nodes on main stem $JMSA_4$-20172 x J-2598 (44.46), for number of effective tillers per plant (33.33), for ear head length 19.98 ($JMSA_4$ – 20172 x 72-SB-18),while, for ear head girth $ICMA_1$-15666 x 92-SB-18 (19.98). For plant height highest heterosis in positive direction was recorded by $JMSA_4$-20172 x J-2598 (15.53). As per maturity point of view highest negative heterosis was recorded in $JMSA_1$-20181 x 52-SB-18 (-7.66) for days to maturity and for 1000-grain weight

ICMA$_1$-15666 x J-2605 (23.09), while 20.66 (ICMA$_1$-15666 x J-2605) for dry fodder yield per plant, for harvest index JMSA$_1$-20181 x 52-SB-18 (22.95). High heterosis for grain yield and its several components was also reported by Shah (2009) [15], Jethva *et al.* (2012) [6], Mungra (2014) [10], Patel *et al.* (2016) [12], Salagarkar and Wali (2016) [13], Katba (2017) [7] and Ladumor *et al.* (2018) [9].

Conclusion

The best three promising crosses *viz.*, JMSA$_5$-20175 x J-2598 and ICMA$_1$-15666 x 92-SB-18, ICMA$_1$-15666 x J-2605 had high *per se* performance, considerable magnitude of heterobeltiosis as well as standard heterosis for grain yield per plant and other yield attributing characters. Therefore, these three crosses could be further evaluated over years and locations to exploit for commercial cultivation or utilized in future breeding programme to obtain desirable transgressive segregants for development of superior genotypes or inbreeds.

Table 1: Analysis of variance for experimental design for different characters in pearl millet

Source	d.f.	Days to 50% flowering	Length of protogyny	Number of nodes on main stem	Number of effective tillers/plant	Ear head length (cm)	Ear head girth (cm)	Ear head weight (g)
Replications	2	0.06	0.24	0.04	0.03	10.46*	0.15	15.43
Genotypes	48	20.44**	1.21**	4.57**	0.45**	27.57**	1.40**	1765.28**
Parents (P)	12	34.42**	0.65**	3.93**	0.32**	41.48**	1.66**	367.44**
Crosses (C)	35	15.82**	1.32**	3.74**	0.45**	13.24**	1.01**	686.96**
P. Vs C.	1	14.33**	3.86**	41.48**	2.31**	361.84**	11.74**	56280.72**
Error	96	0.56	0.08	0.30	0.07	2.69	0.09	63.65

Source	d.f.	Plant height (cm)	Day to maturity	1000-grain weight (g)	Dry fodder yield/plant (g)	Grain yield/ plant (g)	Harvest index (%)	Threshing index (%)
Replications	2	97.33	5.19*	3.16*	83.21	59.57	26.03	32.93
Genotypes	48	3307.08**	36.50**	8.39**	1195.71**	1030.04**	84.56**	215.84**
Parents (P)	12	4640.19**	40.48**	7.48**	1083.22**	361.98**	65.76**	383.04**
Crosses (C)	35	1522.01**	34.39**	5.81**	688.47**	515.49**	50.70**	162.85
P. Vs C.	1	49787.59**	62.58**	109.65**	20299.18**	27056.04**	1495.50**	64.36
Error	96	78.19	1.31	1.01	91.57	27.24	15.34	117.38

Table 2: Range of standard heterosis and number of crosses showing significant heterosis in desirable direction in pearl millet

Characters	Standard heterosis (%) over check GHB-732	
	Range	No. of significant crosses in desirable direction
Days to 50% flowering	- 8.87 to 8.22	17
Length of protogyny	- 43.56 to 48.03	7
Number of nodes on main stem	- 9.38 to 44.46	16
Number of effective tillers per plant	- 28.89 to 33.33	5
Ear head length (cm)	- 14.94 to 19.98	4
Ear head girth (cm)	- 19.81 to 7.93	4
Ear head weight (g)	- 65.54 to 12.32	-
Plant height (cm)	- 29.38 to 15.53	6
Days to maturity	- 7.66 to 11.92	14
1000-grain weight (g)	- 30.13 to 23.09	3
Dry fodder yield per plant (g)	- 40.68 to 20.66	6
Grain yield per plant (g)	- 64.49 to 27.43	9
Harvest index (%)	- 34.02 to 22.95	2
Threshing index (%)	- 29.74 to 27.43	-

Table 3: Best five heterotic crosses with per se performance of grain yield per plant and significant desirable standard heterosis for other traits

Heterotic crosses	Grain yield/plant (g)	Significant and desirable heterosis for component traits over Check (GHB 732)
JMSA$_5$-20175 x J-2598	74.17	NONMS, NETP, PH, TGW, DFY
ICMA$_1$-15666 x 92-SB-18	73.93	NETP, EHG, TGW, DFY
ICMA$_1$-15666 x J-2605	72.67	NETP, TGW, DFY
JMSA$_4$-20172 x J-2591	72.20	LOP, NONMS, NETP, EHL, PH, DFYP
JMSA$_4$-20172 x 52-SB-18	72.00	DTF, NONMS, NETP, DM, DFYP, HI

Where,*, ** Significant at 5% and 1% levels, respectively
DTF = Days to 50% flowering, LOP = Length of Protogyny, NONMS = Number of nodes on main stem,
NETP = Number of effective tillers/plant, EHL = Ear head length, EHG = Ear head girth, EHW = Ear head weight, PH= Plant height, DM = Days to maturity, TGW= 1000-Grain weight, DFY = Dry fodder yield per plant, HI = Harvest index, Threshing index

Table 4: The best performing crosses for standard heterosis

Sr. No.	Characters	Crosses		
1	Days to 50% flowering	$JMSA_4$-20172x 52-SB-18	$JMSA_1$-20181 x 72-SB-18	$JMSA_1$-20181 x 52-SB-18
2	Length of protogyny	$JMSA_4$-20172 x J-2591	$ICMA_1$-15666 x J-2591	$JMSA_4$-20172 x 88-SB-18
3	Number of nodes on main stem	$JMSA_4$-20172 x J-2598	$JMSA_4$-20172 x 92-SB-18	$JMSA_4$-20172 x J-2591
4	Number of effective tillers per plant	$ICMA_1$-15666 x 92-SB-18	$JMSA_5$-20175 x J-2598	$ICMA_1$-15666 x J-2605
5	Ear head length (cm)	$JMSA_4$-20172 x 72-SB-18	$JMSA_4$-20172 x J-2591	$JMSA_4$-20172 x J-2598
6	Ear head girth (cm)	$ICMA_1$-15666 x 92-SB-18	$JMSA_1$-20181 x J-2584	$JMSA_1$-20181 x 120-SB-18
7	Ear head weight (g)	-	-	-
8	Plant height (cm)	$JMSA_4$-20172 x J-2598	$JMSA_4$-20172 x J-2591	$JMSA_4$-20172 x 92-SB-18
9	Days to maturity	$JMSA_1$-20181 x 52-SB-18	$JMSA_1$-20181 x 72-SB-18	$JMSA_4$-20172 x 2598
10	1000-grain weight (g)	$ICMA_1$-15666 x J-2605	$JMSA_5$-20175 x J-2598	$ICMA_1$-15666 x 92-SB-18
11	Dry fodder yield per plant (g)	$ICMA_1$-15666 x J-2605	$ICMA_1$-15666 x 92-SB-18	$JMSA_5$-20175 x J-2598
12	Grain yield per plant (g)	$JMSA_5$-20175 x J-2598	$ICMA_1$-15666 x 92-SB-18	$ICMA_1$-15666 x J-2605
13	Harvest index (%)	$JMSA_1$-20181 x 52-SB-18	$JMSA_5$-20175 x 52-SB-18	-
14	Threshing index (%)	-	-	-

Table 5: Crosses have maximum values (%) Standard heterosis for grain yield and its component traits

Characters	Crosses and their maximum values (%) for standard heterosis in desired direction	
	Crosses	Values (%)
Days to 50% flowering	$JMSA_4$-20172x 52-SB-18	-8.87
Length of protogyny	$JMSA_4$-20172 x J-2591	-43.56
Number of nodes on main stem	$JMSA_4$-20172 x J-2598	44.46
Number of effective tillers per plant	$ICMA_1$-15666 x 92-SB-18	33.33
Ear head length (cm)	$JMSA_4$-20172 x 72-SB-18	19.98
Ear head girth (cm)	$ICMA_1$-15666 x 92-SB-18	7.93
Ear head weight (g)	-	12.32
Plant height (cm)	$JMSA_4$-20172 x J-2598	15.53
Days to maturity	$JMSA_1$-20181 x 52-SB-18	-7.66
1000-grain weight (g)	$ICMA_1$-15666 x J-2605	23.09
Dry fodder yield per plant (g)	$ICMA_1$-15666 x J-2605	20.66
Grain yield per plant (g)	$JMSA_5$-20175 x J-2598	27.43
Harvest index (%)	$JMSA_1$-20181 x 52-SB-18	22.95
Threshing index (%)	-	-

References

1. Acharya ZR. Study on heterosis and combining ability analysis using male sterile lines in pearl millet [*Pennisetum glaucum* (L.) R. Br.]. Unpublished M.Sc. (Agri.) thesis submitted to JAU, Junagadh, 2017.
2. Bhadalia AS, Dhedhi KK, Joshi HJ. Heterosis studies in diallel crosses of pearl millet. J Agric. Res. Tech. 2013; 38(3):360-365.
3. Bhanderi SH, Dangaria CJ, Dhedhi KK. Heterosis studies in newly developed restorers of pearl millet. Int. J Biosci. Repo. 2007a; 5(2):563-569.
4. Chotaliya JM, Dangaria CJ, Dhedhi KK. Exploitation of heterosis and selection of superior inbred in pearl millet. Int. J Agric. Sci. 2009; 5(2):531-535.
5. Dangaria CJ, Chotalia JM, Savaliya JJ, Davda BK, Pansuriya AG. Hybrid vigour studies in ten newly developed restorer lines of pearl millet [*Pennisetum glaucum* (L.) R. Br.]. Agric. Sci. Digest. 2009; 29(4):275-278.
6. Jethva AS, Raval L, Madariya RB, Mehta DR, Mandavia C. Heterosis for grain yield and its related characters in pearl millet. Elect. J. Pl. Breed. 2012; 3(3):848-852.
7. Katba PJ. Studies on line x tester analysis over environments in pearl millet [*Pennisetum glaucum* (L.) R. Br.]. Unpublished Ph.D. (Agri.) thesis submitted to AAU, Anand, 2017.
8. Kumhar SR. Combining ability and heterosis in early maturing pearl millet [*Pennisetum glaucum* L. R. Br.]. Crop Research. 2007; 34 (1, 2 & 3):47-52.
9. Ladumor VL, Mungra KD, Parmar SK. Heterosis for grain yield components in pearl millet [*Pennisetum glaucum* (L.) R. Br.]. Trends in Biosciences. 2018; 11(27):3473-3477.
10. Mungra KS. Heterosis and combining ability analysis for grain yield and its components in pearl millet [*Pennisetum glaucum* (L.) R. Br.]. Unpublished M.Sc. (Agri.) thesis submitted to JAU, Junagadh, 2014.
11. Pal M, Deka J, Rai RK. Fundamentals of Cereals Crop Production. Tate McGraw Hill Publishing Company Limited, New Delhi, 1996.
12. Patel BC, Doshi JS, Patel JA. Heterosis for grain yield components in pearl millet [*Pennisetum glaucum* (L.) R. Br.]. Innovare J. Agri. Sci. 2016; 4(3):1-3.
13. Salagarkar S, Wali M. Heterosis for yield and yield related components using diverse restorer lines in pearl millet [*Pennisetum glaucum* (L.) R. Br.]. J. Farm Science. 2016; 29(4):436-438.
14. Sehgal A, Telang S, Passah S, Jyothi M. Maternal and neonatal profile and immediate outcome in extremely low birth weight babies in Delhi. Trop. Doctor. 2004; 34(3):165-168.
15. Shah KA. Genetic analysis of yield and grain quality traits in pearl millet [*Pennisetum glaucum* (L.) R. Br.] Unpublished Ph.D. thesis submitted to Anand Agricultural University, Anand, 2009.
16. Singh F, Nainawatee H, Khairwal I, Rai K, Andrews D, Harinarayana G. Grain quality traits, in pearl millet breeding, EdsKhairwal I.S.; Rai K.N.; Andrews D.J.; Harinarayana G. editors. (New Delhi: Vijay Primlani), 1999.