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Heterosis for grain yield contributing traits in pearl millet (*Pennisetum glaucum*)

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Pearl millet (*Pennisetum glaucum* L.) R. Br., syn. *Cenchrus americanus* (L.) Morrone, is a staple food crop in the semi-arid and arid areas of Africa and Asia. It is a stable diet for the vast majority of poor farmers and also forms an important fodder crop for livestock population in arid and semi-arid region of India. It is a cross pollinated annual C_4 crop species that originated in western Africa and was introduced to eastern Africa and the Indian sub-continent some 2000 years ago. Heterosis breeding has been recognized as the most suitable breeding methodology for augmenting yield in pearl millet. Selection of suitable parents and assessment of degree of heterosis in the resulting crosses forms an important step. An extensive survey of pearl millet literature showed 40% average better parent heterosis for grain yield (Virk 1988, Fu *et al.* 2014, Bhasker *et al.* 2017, Krishnan *et al.* 2019). Previous studies showed high amount of heterosis for grain yield and harvest index (Gupta *et al.* 2020), high magnitude of heterosis for grain yield (Warrier *et al.* 2019) and standard heterosis for grain yield (49.3%), productive tiller (63.3%), ear length (49.3%), ear girth (22.1%), ear weight (76.6%) and 1000 grain weight (86.7%) (Krishnan *et al.* 2019). Heterosis breeding is ideal for increasing yield in pearl millet (Ramamoorthi and Nadarajan 2000, Zakari *et al.* 2019). Therefore, the present investigation was conducted to study the extent of hybrid vigour in F_1 for grain yield and its components.

In the present experiment five male sterile lines and twenty inbreds of pearl millet were chosen for the study. The materials were obtained from CCS HAU, Hisar; JAU, Jamnagar; RARI, Durgapura, Jaipur represented states which collectively cultivate about 90% of pearl millet in India. Among the five male sterile lines used as female parents, ICMA-02333, ICMA-98222, ICMA-00444, ICMA-00111, RMS-7 having A_1 and A_4 cytoplasms from a different source which had been derived line originated from India. The 20 inbreds were used as testers. Crosses were affected by using Line × Tester mating design (Kempthorne 1957). Resultant hybrids along with their parents and standard check (RHB-173, RHB-177 and MPMH-17) received from RARI, Durgapura were raised in Randomized Complete Block Design (RCBD) with three replications during *kharif* 2018. The parents and F_1's with their checks were each planted in a two row of 4 m length, spaced at 15 cm between plants and 50 cm between rows during *kharif*. Recommended well agronomic practices were followed for rising good crop. The off-types were removed before and after flowering. The hybrid performance (%) tested in comparison with mean value of two parents (Relative heterosis) and better parent (heterobeltiosis), and standard check (Standard heterosis) suggested by Fonseca and Patterson (1968) and Meredith and Bridge (1972) respectively.

The analysis of variance for yield and its contributing traits in RCBD revealed that the parents and their hybrids involved in the present study differed significantly for all the traits. Mean values of grain yield contributing traits of parent (line and testers) and their hybrids are presented in Table 1. Heterosis over mid-parent value of grain yield contributing traits are presented in Fig 1.

For days to 50% flowering, 72 hybrids for relative heterosis, 92 hybrids for heterobeltiosis and 92 hybrids for standard heterosis recorded significant negative heterosis. Highest and significant negative relative heterosis, heterobeltiosis and standard heterosis was observed in the cross ICMA 00111 × RIB-494. Similarly, earliness in the flowering was also reported earlier (Ahulwalia and Patnaik 1963, Karad and Harer 2004). With respect to heterosis for early flowering, negative heterosis of hybrids was considered desirable (Arulselvi *et al.* 2006). For plant height, 98 hybrids for relative heterosis, 93 hybrids for heterobeltiosis and 42 hybrids for standard heterosis was observed. Highly significant negative relative heterosis (99.7%), heterobeltiosis (9.09%) and standard heterosis (26.83%) was recorded for plant height by the cross ICMA-00444 × RIB-16296 (Karadand Harer 2004). Highly significant positive

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Table 1 Mean values of grain yield contributing traits of pearl millet among parent (line and tester) and their hybrids

Trait	Line	Tester	Hybrids	SE (m)	CV	CD 5%
Days to 50% flowering	44.87	54.87	45.47	0.85	9.85	3.55
Plant height (cm)	119.07	144.07	203.50	5.13	16.68	14.29
Productive tiller per plant	2.38	1.85	2.28	0.21	21.53	0.58
Panicle length (cm)	20.07	18.70	25.00	1.46	23.16	4.08
Panicle girth (cm)	3.21	3.04	2.99	0.86	12.77	2.41
1000-grain weight (g)	11.79	10.08	11.20	0.32	13.07	0.90
Grain yield per plant (g)	29.59	35.05	36.24	3.37	17.91	9.38
Dry fodder yield per plot (g)	3375.12	3698.86	3218.09	301.44	13.38	839.53
Harvest index (%)	8.64	17.55	21.63	0.67	5.53	1.85

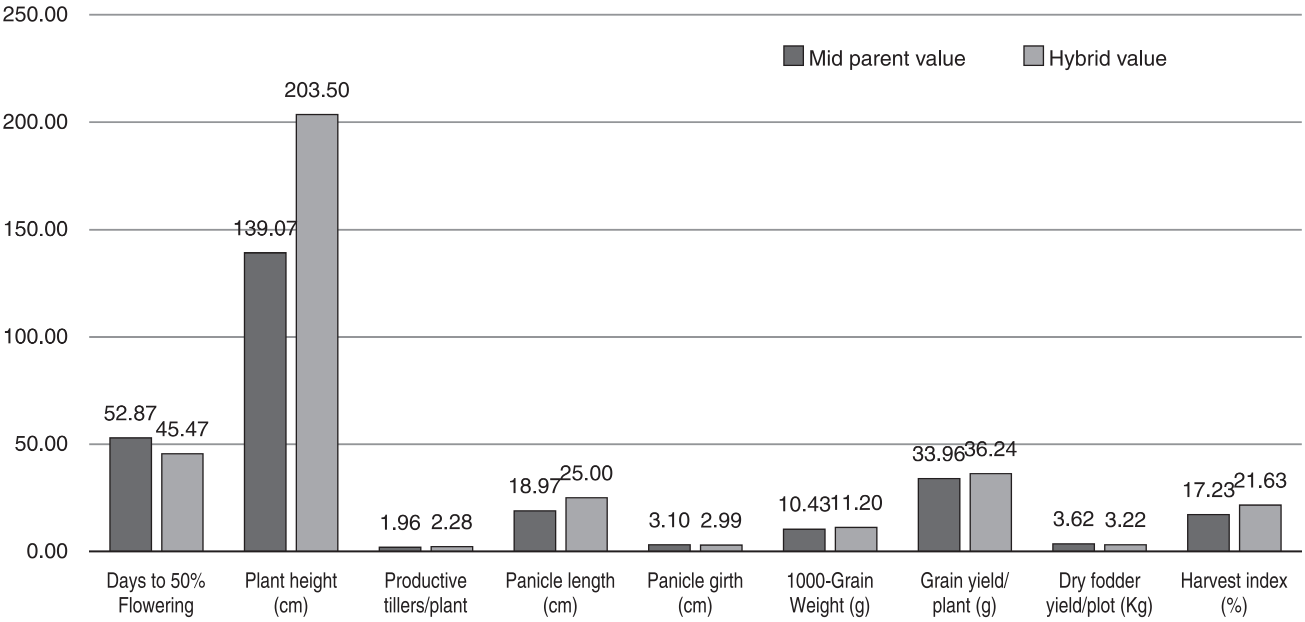

Fig 1 Heterosis over mid-parent value of grain yield contributing traits.
*Mid-parent value and hybrids showing negative heterosis were recorded.

heterosis was observed in ICMA-00111 × RIB-3135-18 (86.50%), ICMA-00111 × RIB-3135-18 (57.74%), ICMA-00444 × RIB-16328 (26.83%) for heterosis, heterobeltiosis, standard heterosis, respectively for number of productive tiller per plant. Out of 69; 64 and 29 hybrids showed significant positive relative heterosis, heterobeltiosis and standard heterosis for panicle length (cm). In which all the traits, hybrid combination ICMA 00111 × RIB-3135-18 (126.26 and 86.67%), showed highest magnitude of positive relative heterosis and heterobeltiosis, respectively in panicle length (cm). Highest significant positive standard heterosis was recorded in ICMA 00444 × RIB-16S/110 (37.50% each) in both panicle length and panicle girth (Krishnan *et al.* 2019). Highest significant positive relative heterosis and heterobeltiosis were recorded in the cross RMS-7 × RIB-15147 (44.33% and 33.22%, respectively) for the trait panicle girth. In total, 4, 1 and 44 hybrids showed positive significant heterosis, heterobeltiosis and standard heterosis for panicle girth (cm). The hybrid ICMA-00444 × RIB-16S/110 (37.50%) recorded highly significant positive standard heterosis (Vetriventhan *et al.* 2008, Krishnan *et al.* 2019). In total 34, 14 and 65 hybrids recorded significant relative heterosis, heterobeltiosis and standard heterosis, respectively for the trait 1000-grain weight.

Highest significant positive standard heterosis for grain yield and dry fodder yield were observed in the cross ICMA-00444 × RIB-17-20S/2017 (15.17%) and RMS-7 × RIB-16296 (74.54%), respectively. Among the crosses, 47, 35 and 1 hybrid exhibited a significant positive relative heterosis, heterobeltiosis and standard heterosis, respectively for the grain yield per plant; while, among the crosses, 5, 5 and 38 hybrids exhibited a significant positive relative heterosis, heterobeltiosis and standard heterosis, respectively for the dry fodder yield per plot (Table 2). Highly significant positive relative heterosis was observed in cross ICMA-00444 × RIB-3135-18 (103.04 and 61.94%) and the same cross also showed highest significant positive heterobeltiosis (78.61 and 52.05%) for grain yield per plant and dry fodder yield per plot, respectively. Similarly, Badhe *et al.* (2018) and Krishnan *et al.* (2019) also observed high magnitude of heterosis for grain and fodder yield. Highest significant positive relative heterosis, heterobeltiosis and

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

Trait	Relative heterosis			Heterobeltiosis			Standard heterosis		
	Highest desirable hybrid		N*	Highest desirable hybrid		N*	Highest desirable hybrid		N*
Days to 50 % flowering**	-23.03	ICMA-00111 × RIB-494	72	-31.18	ICMA-00111 × RIB-494	92	-2.5	ICMA-00111 × RIB-494	92
Plant Height (cm)	99.7	ICMA-00444 × RIB-16328	98	9.09	(ICMA-00111 × RIB-15176	93	26.83	ICMA-00444 × RIB-16296	42
Productive tiller per plant	86.5	ICMA-00111 × RIB-3135-18	26	57.74	ICMA-00111 × RIB-16S/110	13	22.43	ICMA-00444 × RIB-16328	2
Panicle length (cm)	126.26	ICMA-00111 × RIB-3135-18	69	86.67	ICMA-00111 × RIB-3135-18	64	37.5	ICMA-00444 × RIB-16S/110	29
Panicle girth (cm)	44.33	RMS-7 × RIB-15147	4	33.22	RMS-7 × RIB-15147	1	37.5	ICMA-00444 × RIB-16S/110	44
1000-Grain weight (g)	48.26	ICMA-02333 × G.77/107	34	39.33	ICMA-02333 × J-2340	14	35.39	ICMA-00444 × RIB-17-20S/2017	65
Grain yield per plant (g)	103.04	ICMA-00444 × RIB-3135-18	47	78.61	ICMA-00444 × RIB-3135-18	35	15.17	RMS-7 × RIB-3135-18	1
Dry fodder yield per plot (g)	61.94	ICMA-00444 × RIB-3135-18	5	52.08	ICMA-00444 × RIB-3135-18	5	74.54	RMS-7 × RIB-16296	38
Harvest index (%)	112.96	ICMA-02333 × RIB-192	79	103.82	ICMA-02333 × J-2340	51	3.19	ICMA-02333 × RIB-15176	0

*No. of crosses; **Hybrids showing negative heterosis was recorded for days to 50% flowering.

standard heterosis were recorded in the cross ICMA-02333 × RIB-192 (112.96%), ICMA-02333 × J-2340 (103.82%) and ICMA 02333 × RIB-15176 (3.19%), respectively for the harvest index. In total, 79 and 51 hybrids exhibited a significant positive relative heterosis and heterobeltiosis for harvest index while none of hybrids showed significant positive standard heterosis for this trait.

In nutshell, hybrid, viz. RMS-7 × RIB-3135-18 and RMS-7 × RIB-16296 showed positive and highest significant standard heterotic value for grain yield and dry fodder yield, respectively and another four cross combination, viz. ICMA-00444 × RIB-16S/110, ICMA-00111 × RIB-494, ICMA-00444 × RIB-16296 and ICMA-00444 × RIB-16328 were also showed positive and high significant standard heterotic values for other specific studied traits.

SUMMARY

The general expectation of the pearl millet farmers is mainly focused on level of superiority of newly released hybrids than the local standard hybrids, which is grown widely. Hence, the standard check RHB-173, RHB-177 and MPMH-17 were used as standard hybrid. The hybrid namely RMS-7 × RIB-3135-18 expressed highest significant standard heterotic value for grain yield per plant and four associated traits out of nine studied traits including dry fodder yield per plot also showed positive significant standard heterosis. Similarly, another hybrid namely RMS-7 × RIB-16296 showed highest significant standard heterosis for dry fodder yield per plot. The showed cross combination, viz. ICMA-00444 × RIB-16S/110, ICMA-00111 × RIB-494, ICMA-00444 × RIB-16296 and ICMA-00444 × RIB-16328 were good for other studied traits.

At the end, among 100 hybrids studied, one hybrid, viz. RMS-7 × RIB-3135-18 was selected as best cross since, it expressed high significant standard heterosis over best check for many of the traits including grain yield and dry fodder yield and may have potential to replace old cultivar in the future.

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