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Combining ability and heterosis studies in fodder pearl millet [*Pennisetum glaucum* (L.) R. Br.]

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Abstract
An investigation was undertaken with 54 hybrids obtained by crossing nine lines and six testers in L x T mating design to analyse heterosis and combining ability. Sixteen biometric traits were measured. The SCA variance was observed to be more than GCA variance for all the traits except for days to 50% flowering and days to green fodder harvest indicating the preponderance of non-additive gene action governing the traits studied. Results of *gca* effects and the mean performance of parents revealed that the genotypes *viz*., IP 17424, IP 17435, CO 8, GP 15074 and PT 5588 were identified as good combiners for green fodder yield and its component traits. Based on the standard heterosis over the standard check TNAU pearl millet hybrid CO 9, the hybrids *viz*., PT 5701 x GP 18219, CO 8 x PT 5588, CO 8 x GP 16026, IP 17424 x GP 15074, IP 17424 x PT 5682, IP 17424 x PT5365, IP 17424 x PT 5588 and IP 17424 x GP 18219 recorded superior heterosis for green fodder yield. Considering *sca* effects, mean performance and standard heterosis, the hybrids *viz*., IP 17424 x GP 15074, IP 17424 x PT 5682 and CO 8 x PT 5588 were identified as the superior performing hybrids for green fodder yield. Similarly, for high crude protein, the hybrid PT 5652 x PT 5588 was identified as the superior one. The above hybrids could be exploited further to improve green fodder yield with quality traits in pearl millet.

Key words: Combining ability, Gene action, Green fodder yield, Heterosis, Line x Tester

INTRODUCTION

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] commonly known as bajra is an important food and fodder crop of India. Pearl millet contributes approximately 50 per cent of total millet production globally. Thirty-one million hectares of land is devoted to this crop worldwide for grain as well as fodder production (ICRISAT, 2020). Farmers in North India choose to produce pearl millet as a fodder crop rather than a grain crop because of its drought tolerance, fast growth with remarkable fodder producing capability in a very short period of time, low prussic acid, high protein and mineral content, and palatable to animals (Kapoor *et al*., 2017). It's a hardy rainy-season grass with lots of tillers and leaves. Pearl millet has high crude protein content (9.9 to 14 %) and is considered as any time forage crop (Kumawat *et al*., 2017).

One of the primary constraints in obtaining the appropriate level of livestock production has been recognised as a lack of feed and fodder (Kumar *et al.,* 2012). India is contemplating the white revolution which can only be accomplished with high-quality feed and fodder (Mungra *et al*., 2011). The availability of feed and fodder remains a major source of concern since there is the supply-demand gap in the country. According to the Indian Council for Agricultural Research (ICAR)-affiliated National Institute of Animal Nutrition and Physiology (NIANP), the deficit in the requirement and availability of dry fodder and green fodder in 2025 are expected to rise to 23% and 40% respectively. Hence, it is mandatory to develop new fodder crop hybrids and varieties with high green fodder yield coupled with quality parameters.

The exploitation of heterosis in agriculture has been hailed as a game-changer, resulting in a significant rise in crop production across the globe. Although substantial improvements have been made in boosting the grain yield in many crops such as rice, maize and pearl millet through the exploitation of heterosis, the potentiality of exploitation of green fodder yield in crops such as pearl millet remains untapped. In any breeding program, the choice of parents based on the trait of interest is found to be the critical step. Even though plant breeders use various genetic statistical tools in their breeding materials, the concept of combining ability proposed by Griffing (1956) provides information on best parental performance and hybrid combinations along with the nature of gene action and its magnitude in controlling its biometric traits (Monpara and Sanghi, 1982). Information on the nature and magnitude of gene action (both additive and non-additive components of variation) of a character is essential for making a breeding programme effective for its genetic improvement (Mitra *et al*, 2001). The line x tester analysis method is one of the most powerful mating patterns for assessing the combining ability effects which assists the breeder in selecting optimal parents for hybridisation for heterosis breeding. With the above background, to exploit heterosis for enhancing the green fodder yield as well as quality in pearl millet, the present investigation was taken up.

MATERIALS AND METHODS

The experiment was conducted at the new area farm in the Department of Forage crops, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore. Hybridisation was carried out during *Rabi*, 2020 subsequently hybrids were evaluated during *Kharif*, 2021 season. Fifty-four hybrids of fodder pearl millet were obtained through line x tester mating system (Kempthorne, 1957) by using nine lines *viz*., GP 15988, PT 5652, TNFB 9901, TNFB 9902, PT 5701, CGP/PT 4685, CO 8, IP 17424, IP 17435 and six testers, GP 15074, PT 5682, PT 5365, PT 5588, GP 18219 and GP 16026 obtained from ICRISAT gene-pool as well as the gene pool of Department of Forage Crops, Tamil Nadu Agricultural University, Coimbatore. Sowing was done in two rows per entry of 4 m length and 3 m breadth with a spacing of 60 x 15 cm and all the recommended packages of practices were followed to raise the crop. The experimental trial was laid out in randomized block design with two replications under irrigated conditions. Data on five randomly selected plants per entry was recorded. Sixteen quantitative and quality traits *viz*., days to green fodder harvest, the number of tillers per plant (cm), plant height (cm), the number of leaves per plant (cm), internode length (cm), stem girth (cm), leaf length (cm), leaf breadth (cm), leaf–stem ratio, dry matter percentage (%), dry fodder yield per plant (g) and green fodder yield per plant (g), crude protein (%), crude fibre (g/100g), crude fat (g/100g) and ash content (%) were recorded in all the experimental hybrids and parents. TNAU pearl millet hybrid CO 9 was included as a standard check for calculating the standard heterosis. Data were analysed using TNAUSTAT Software and GENRES 7.01 software package for heterosis and combining ability. For selecting the superior hybrids for green fodder yield and quality traits, the mean performance, *sca* effects and standard heterosis were considered.

Table 1. Analysis of Variance (ANOVA) for combining ability

S.No.	Traits	Lines	Testers	Line x Testers	Error
1	Days to green fodder harvest	347.79**	0.54	0.93	1.88
2	Number of tillers per plant	7.73**	0.4	0.45	0.11
3	Plant height	2409.79**	461.36**	349.90**	16.98
4	Number of leaves per plant	8.61**	2.39*	1.11	0.89
5	Internode length	13.90**	4.13**	2.62**	1.29
6	Stem girth	1.58	0.66	0.32	0.1
7	Leaf length	43.98**	16.88**	18.51**	4.21
8	Leaf breadth	1.15	0.1	0.36	0.04
9	Leaf-stem ratio	0.05	0	0	0
10	Crude protein	21.42**	0.23	1.37	0.75
11	Crude fibre	0.11	0.01	0.01	0
12	Crude fat	2.99**	6.56**	2.34**	0.3
13	Ash content	8.57**	2.35	2.58**	0.18
14	Dry matter percentage	18.73**	14.75**	14.59**	0.55
15	Dry fodder yield per plant	10241.68**	1778.95**	2911.37**	80.25
16	Green fodder yield per plant	350180.56**	23264.61**	38331.03**	378.47
	Degrees of freedom	8	5	40	53

**- Significance at 1 % level

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RESULTS AND DISCUSSION

The analysis of variance for combining ability revealed that the mean sum of squares due to lines, testers and line x testers were highly significant for green fodder yield per plant followed by dry fodder yield per plant, plant height, dry matter content, leaf length, internode length and crude fat content **(Table 1)**.

The variance components due to GCA ranged from 0.001 (crude fibre and leaf stem ratio) to 1000.606 (green fodder yield/plant) and the variance components due to SCA ranged from -0.471 (days to green fodder harvest) to 8976.276 (green fodder yield per plant). The ratio of GCA to SCA variance was less than unity for all the traits studied indicating the prevalence of non additive gene action **(Table 2).**

The estimates of general combining ability or *gca* effects of 15 parents for sixteen traits are tabulated in **Table 3a and 3b.** The lines, IP 17424, IP 17435, GP 15988, CO 8 and tester GP 15074 were found to exhibit positive and significant *gca* effects for the number of tillers per plant. While, considering plant height, the highest positive significant *gca* effects were observed in the lines *viz*., PT 5652, TNFB 9901, IP 17424 and IP 17435 and *viz.,* testers GP 18219 and GP 16026. As for as leaves per plant is concerned, only two lines *viz*., IP 17424 and IP 17435 and the tester, GP 18219 were observed to show positive significant *gca* effects. However, the genotypes IP 17424 and GP 16026 recorded positive significant *gca* effects for the trait internode length. For leaf length, the lines TNFB 9901, IP 17424, IP 17435 and TNFB 9902 and a tester PT 5588 showed positive significant values of *gca* effects.

The lines IP 17424 and IP 17435 were found to register positive significant *gca* effects for other traits such as leaf-stem ratio, crude protein content, crude fibre, crude fat, dry matter content, dry fodder yield/plant and green fodder yield/ plant. IP 17424 and 1P 17435 were identified as the parents expressed high *gca* effects for crude protein content. For dry fodder yield per plant and green fodder yield per plant the lines *viz*., CO 8, IP 17424, IP 17435 and testers GP 15074, PT 5588 recorded highly significant *gca* effects. Hence, these parents can be considered as the best parents for synthesising hybrids with enhanced green fodder yield.

Among 54 hybrids evaluated, only seventeen hybrids exhibited highly significant *sca* value for green fodder yield per plant **(Table 4).** The hybrids CGP/PT 4685 x GP 16026 and PT 5652 x PT5588 exhibited significant *sca* effects for high crude protein content even though the performance for green fodder yield is less. The hybrid IP 17424 x PT 5682 showed highly significant *sca* effects for most of the traits including the number of tillers per plant, plant height, leaf breadth, leaf-stem ratio, ash content, dry matter content, dry fodder yield per plant and green fodder yield per plant. Even though the parent CGP/PT 4685 was not genetically worthy based on *gca* effects, when crossed with a tester with good *gca* effects, PT 5682, the performance of the hybrid was found to be significant and positive and might be attributed to non-additive gene action. Similarly, positive *sca* effects in crosses with good x poor combiners and poor x poor combiners can be ascribed to better complementation between favourable alleles (Mungra *et a,l*, 2011, Bhandari *et al*., 2007, Khandagale *et al*., 2014).

Table 2. Magnitude of GCA and SCA variances for sixteen different traits

S.No.	Characters	GCA variance	SCA variance	GCA /SCA
1	Days to Green fodder harvest	1.147	-0.471	-2.436
2	No. of tillers per plant	0.024	0.170	0.142
3	Plant height	7.046	166.461	0.042
4	Number of leaves per plant	0.027	0.110	0.248
5	Internode length	0.041	0.663	0.061
6	Stem girth	0.005	0.108	0.045
7	Leaf length	0.081	7.145	0.011
8	Leaf breadth	0.002	0.162	0.012
9	Leaf- stem ratio	0.001	0.009	0.113
10	Crude protein	0.064	0.311	0.206
11	Crude fibre	0.001	0.009	0.105
12	Crude fat	0.011	1.019	0.011
13	Ash	0.019	1.199	0.016
14	Dry matter percentage	0.014	7.022	0.002
15	Dry fodder yield per plant	21.911	1415.557	0.015
16	Green fodder yield per plant	1000.606	8976.276	0.111

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Table 3a. The estimates of general combining ability effects for various traits in fodder pearl millet

S.No.	Parents	Days to green fodder harvest	Number of tillers per plant	Plant height	Number of leaves per plant	Internode length	Stem girth	Leaf length
				Lines				
1	GP 15988	-4.40 **	0.24 *	1.28	-0.31	-2.23 **	-0.39 **	-1.13
2	PT 5652	-4.06 **	-0.21 *	5.68 **	0.05	0.29	-0.38 **	-0.52
3	TNFB 9901	-3.23 **	0.03	11.11 **	-0.09s	0.21	-0.03	1.65 **
4	TNFB 9902	-2.90 **	-0.39 **	-10.10 **	0.05	-0.76 *	0.14	1.23 *
5	PT 5701	-2.73 **	-0.49 **	-16.35 **	-0.35	-0.03	0.31 **	-1.80 **
6	CGP/PT 4685	-0.15	-1.54 **	-19.66 **	-1.60 **	0.14	0.38 **	-3.66 **
7	CO 8	-0.90 *	0.26 **	-5.07 **	-0.17	0.38	0.45 **	0.66
8	IP 17424	9.44 **	1.10 **	24.28 **	1.19 **	1.84 **	0.06	2.03 **
9	IP 17435	8.94 **	1.01 **	8.82 **	1.23 **	0.16	-0.54 **	1.53 *
				Testers				
10	GP 15074	-0.12	0.21 *	-0.81	-0.17	-0.31	0.13	-0.76
11	PT 5682	0.27	-0.23 **	-4.69 **	-0.54 *	-0.46	0.20 **	0.03
12	PT 5365	0.10	-0.06	-6.65 **	-0.18	-0.50	0.12	-1.27 *
13	PT 5588	-0.23	0.11	1.77	0.17	0.30	0.02	1.55 **
14	GP 18219	-0.01	0.02	3.76 **	0.47 *	0.34	-0.26 **	0.22
15	GP 16026	-0.01	-0.05	6.63 **	0.26	0.62 *	-0.21 **	0.24
	SE (lines)	0.40	0.10	1.19	0.27	0.33	0.91	0.59
	SE (testers)	0.32	0.08	0.97	0.22	0.27	0.07	0.48

*** Significant at 5% level ** Significant at 1% level**

Table 3b. The estimates of general combining ability effects for various traits in fodder pearl millet

S. No.	Parents	Leaf breadth	Leaf-stem ratio	Crude protein	Crude fibre	Crude fat	Ash content	Dry matter content	Dry fodder yield/ plant	Green fodder yield/ plant
					Lines					
1	GP 15988	-0.07	-0.07 **	0.50 *	-0.01	-0.14	1.13 **	0.89 **	-30.46 **	-153.30 **
2	PT 5652	-0.46 **	-0.06 **	0.43	0.04 **	-0.33 *	0.40 **	0.24	-20.50 **	-116.68 **
3	TNFB 9901	-0.24 **	0.01 *	0.29	0.10 **	-0.08	0.05	0.50 *	-12.75 **	-70.00 **
4	TNFB 9902	-0.18 **	-0.05 **	-1.08 **	-0.10 **	-0.48 **	0.12	0.08	-22.56 **	-100.49 **
5	PT 5701	-0.14 *	0.04 **	-0.33	-0.08 **	-0.34 *	0.03	0.01	-7.36 **	-10.69
6	CGP/PT 4685	0.07	-0.09 **	-2.72 **	-0.17 **	-0.53 **	0.66 **	2.33 **	-8.97 **	-89.21 **
7	CO 8	0.11	0.06 **	-0.22	0.08 **	0.53 **	0.06	1.53 **	27.94 **	85.68 **
8	IP 17424	0.52 **	0.09 **	1.39 **	0.07 **	0.61 **	1.95 **	1.74 **	60.84 **	404.20 **
9	IP 17435	0.39 **	0.07 **	1.76 **	0.08 **	0.76 **	0.13	0.77 **	13.83 **	50.48 **
					Testers					
10	GP 15074	0.02	-0.01	0.20	0.00	0.60 **	0.14	0.93 **	5.43 *	23.01 **
11	PT 5682	-0.03	-0.02 **	0.00	0.03 **	-0.60 **	0.56 **	0.77 **	2.24	-34.74 **
12	PT 5365	0.02	0.03 **	-0.12	-0.00	-0.05	0.30 **	0.55 **	1.86 **	-37.42 **
13	PT 5588	0.12 **	-0.00	-0.07	0.00	-0.83 **	0.36 **	1.50 **	7.43 **	53.96 **
14	GP 18219	-0.08	0.00	0.04	-0.01	0.55 **	0.06	0.27	1.48	-16.58 **
15	GP 16026	-0.06	-0.01	-0.06	-0.03 **	0.33 *	0.31 **	0.08	3.60	11.77 *
	SE (lines)	0.06	0.01	0.25	0.01	0.16	0.12	0.21	0.26	5.62
	SE (testers)	0.05	0.01	0.20	0.01	0.13	0.10	0.17	0.21	4.59

Table 4. The estimates of specific combining ability effects for sixteen trsits in fodder pearl millet hybrids

S. No	Hybrids	DGFH	NTPP	PH	NLPP	INL	SG	LL	LB
1	GP15988 x GP 15074	0.12	0.35	-4.88	0.39	-0.25	-0.17	-1.63	0.21
2	GP15988 x PT 5682	-0.77	-0.25	-1.60	-0.41	1.65 *	-0.21	-5.58 **	-0.59 **
3	GP15988 x PT5365	0.40	-0.38	-0.81	-0.77	0.36	-0.03	-3.94 **	-0.05
4	GP15988 x PT 5588	0.23	-0.05	-0.73	-0.28	-0.47	-0.33	2.06	0.37 **
5	GP15988 x GP 18219	-0.49	0.11	4.28	0.25	-0.43	0.34	5.06 **	0.52 **
6	GP15988 x GP 16026	0.51	0.22	3.74	0.80	-0.86	0.40	4.03 **	-0.46 **
7	PT5652 x GP 15074	-0.71	-0.54 *	5.45	-0.13	-0.01	-0.02	-0.24	-0.12
8	PT5652 x PT5365	0.40	0.56 *	-6.65 *	0.90	-2.31 **	0.58 *	2.14	0.60 **
9	PT5652 x PT 5682	-0.44	0.06	10.79 **	1.54 *	-0.33	0.36	0.27	0.49 **
10	PT5652 x PT 5588	0.90	-0.11	-2.46	-0.98	-0.29	0.01	0.62	-0.19
11	PT5652 x GP 18219	-0.32	-0.02	3.38	0.06	1.74 *	-0.19	-4.88 **	-0.66 **
12	PT5652 x GP 16026	0.18	0.05	-10.51 **	-1.40 *	1.20	-0.74 **	2.09	-0.12
13	TNFB 9901 x GP 15074	-0.05	0.22	5.41	-0.49	0.79	0.41	0.76	0.39 **
14	TNFB 9901 x PT5365	-0.44	0.23	-0.60	0.04	-1.62 *	-0.53 *	-5.03 **	-0.52 **
15	TNFB 9901 x PT 5682	0.23	0.33	8.75 **	-0.32	0.25	0.44 *	3.10 *	0.52 **
16	TNFB 9901 x PT 5588	0.06	0.16	4.66	0.83	0.87	-0.32	0.79	0.42 **
17	TNFB 9901 x GP 18219	0.34	-0.25	-12.88 **	-0.47	0.08	-0.10	1.45	-0.39 **
18	TNFB 9901 x GP 16026	-0.16	-0.68 **	-5.33	0.41	-0.37	0.11	-1.08	-0.43 **
19	TNFB 9902 x GP 15074	-0.38	-0.35	-4.95	0.03	-1.78 *	-0.06	1.34	-0.07
20	TNFB 9902 x PT5365	0.23	-0.25	-19.89 **	-1.43 *	-0.65	0.25	-0.61	0.24
21	TNFB 9902 x PT 5682	-0.10	0.25	10.74 **	0.54	1.80 *	-0.44	0.52	0.07
22	TNFB 9902 x PT 5588	-0.27	0.46	3.65	0.69	-1.24	0.04	-2.30	-0.74 **
23	TNFB 9902 x GP 18219	0.01	-0.33	2.49	-0.27	0.53	0.1	-0.63	0.03
24	TNFB 9902 x GP 16026	0.51	0.24	7.96 **	0.44	1.3	0.09	1.68	0.46 **
25	PT 5701 x GP 15074	0.45	0.33	7.14 *	-0.40	-0.20	0.01	1.04	0.02
26	PT 5701 x PT 5682	0.06	-0.99 **	-7.14 *	0.31	-0.20	-0.10	-0.58	-0.01
27	PT 5701 x PT5365	-0.27	0.68 **	-12.01 **	0.28	-0.13	-0.26	1.05	-0.52 **
28	PT 5701 x PT 5588	0.06	-0.66 **	-21.76 **	-0.24	0.02	-0.02	-0.93	0.17 ns
29	PT 5701 x GP 18219	-0.16	0.98 **	31.41 **	0.89	1.41	0.30	2.73	0.67 **
30	PT 5701 x GP 16026	-0.16	-0.34	2.37	-0.82	-0.90	0.06	-3.30 *	-0.33 *
31	CGP/PT 4685 x GP 15074	-2.13 *	0.46	3.40	-0.48	0.21	-0.26	-1.60	-0.02
32	CGP/PT 4685 x PT 5682	-0.02	-0.11	11.68 **	0.39 s	1.10	-0.00	5.61 **	-0.04
33	CGP/PT 4685 x PT5365	0.65	-0.77 **	-5.93 *	-0.47	-0.92	-0.10	0.41	-0.42 **
34	CGP/PT 4685 x PT 5588	0.48	-0.11	-7.76 **	-0.41	-0.48	0.06	0.59	0.08
35	CGP/PT 4685 x GP 18219	0.76	0.31	-6.73 *	1.05	-0.21	0.27	-1.74	-0.00
36	CGP/PT 4685 x GP 16026	0.26 s	0.22	5.35	-0.08	0.29	0.03	-3.27 *	0.41 **
37	CO 8 x GP 15074	0.12	-0.17	-20.42 **	0.09	0.23	-0.37	-4.43 **	-0.35 *
38	CO 8 x PT 5682	0.23	-0.05	13.76 **	-0.88	-0.59	-0.40	2.72	-0.24
39	CO 8 x PT5365	0.40	-0.41	-18.12 **	-0.74	-0.92	-0.15	-4.25 **	-0.15 s
40	CO 8 x PT 5588	-0.27	0.46	19.81 **	0.64	0.68	0.28	0.95	0.10
41	CO 8 x GP 18219	0.51	-0.49 *	-13.37 **	-0.05	-0.18	0.50 *	2.40	0.22
42	CO 8 x GP 16026	-0.99	0.66 **	18.34 **	0.92	0.79	0.14	2.60	0.41 **
43	IP 17424 x GP 15074	1.79	0.30	16.86 **	0.95	1.32	0.47 *	3.04 *	0.57 **
44	IP 17424 x PT 5682	-0.10	0.58 *	14.56 **	0.86	1.27	0.38	2.24	0.35 *
45	IP 17424 x PT5365	0.06	0.20	8.36 **	0.07	0.87	0.20	2.80	-0.03
46	IP 17424 x PT 5588	-0.60	-0.08	4.50	-0.11	0.07	0.48 *	-0.02	-0.07
47	IP 17424 x GP 18219	-0.32	-0.41	-16.79 **	-1.24	-1.63 *	-0.69 **	-4.44 **	-0.44 **
48	IP 17424 x GP 16026	-0.82	-0.59 *	-27.50 **	-0.53	-1.90 *	-0.85 **	-3.63 *	-0.37 **
49	IP 17435 x GP 15074	0.79	-0.59 *	-8.01 **	0.03	-0.31	-0.02	1.70	-0.64 **
50	IP 17435 x PT 5682	0.40	0.28	-4.12	0.22	1.35	0.03	-0.91	0.22
51	IP 17435 x PT5365	-0.94	0.04	-1.76	-0.13	-0.97	-0.04	0.05	0.08
52	IP 17435 x PT 5588	-0.60	-0.06	0.09	-0.15	0.84	-0.20	-1.77	-0.14
53	IP 17435 x GP 18219	-0.32	0.10	8.23 **	-0.23	-1.31	-0.55 *	0.06	0.04
54	IP 17435 x GP 16026	0.68	0.22	5.57	0.26	0.40	0.78 **	0.87	0.44 **
Standard error (sca effects of hybrids)		0.97	0.24	2.91	0.67	0.80	0.22	1.45	0.14

*5% significance level ** 1% significance level

DGFH- Days to green fodder harvest, NTPP- Number of tillers per plant, PH- Plant height, NLPP- Number of leaves per plant, IL-Internode length, SG-Stem girth, LL- Leaf length, LB- Leaf breadth, LSR- Leaf-stem ratio, CP-Crude protein, CFR- Crude fibre, CF-Crude fat, ASH-Ash content ,DMP-Dry matter percentage, DFYPP-Dry fodder yield per plant, GFYPP-Green fodder yield per plant.

Table 4. Continued

S. No	Hybrids	LSR	C.P	CFIB	CF	ASH	DMP	DFYPP	GFYPP
1	GP15988 x GP 15074	-0.01	0.75	-0.03	-0.74	0.60 *	1.67 **	7.08	-37.24 **
2	GP15988 x PT 5682	0.03	0.01	-0.00	-0.38	-0.79 **	1.89 **	-4.51	-28.44 *
3	GP15988 x PT5365	0.09 **	-0.50	0.04	0.58	-1.01 **	-3.35 **	-12.84 *	-31.76 *
4	GP15988 x PT 5588	-0.05 **	0.08	-0.05 *	-0.47	0.09	-2.87 **	-17.33 **	-17.89
5	GP15988 x GP 18219	-0.04 *	-0.16	0.01	-0.18	0.08	1.63 **	23.90 **	115.15 **
6	GP15988 x GP 16026	-0.02	-0.19	0.04	1.20 **	1.03 **	1.04	3.71	0.18
7	PT5652 x GP 15074	-0.03	-1.06	0.03	0.26	-1.82 **	-5.33 **	-42.30 **	-137.06 **
8	PT5652 x PT5365	-0.03	0.39	0.02	0.31	0.21	-1.07 *	-18.20 **	10.14
9	PT5652 x PT 5682	-0.02	0.20	0.01	-0.58	0.97 **	1.50 **	40.73 **	108.37 **
10	PT5652 x PT 5588	0.03	1.53 *	-0.04	0.19	0.48	1.16 *	11.26	10.59
11	PT5652 x GP 18219	-0.04 *	1.00	-0.00	0.43	0.36	2.74 **	10.88	38.28 **
12	PT5652 x GP 16026	0.09 **	-2.05 **	-0.03	-0.62	-0.19	1.01	-2.36	-30.32 *
13	TNFB 9901 x GP 15074	0.05 **	-0.23	0.01	1.36 **	0.92 **	3.08 **	61.14 **	206.26 **
14	TNFB 9901 x PT5365	-0.05 **	-0.10	-0.02	0.89 *	-0.79 **	-4.66 **	-52.15 **	-133.99 **
15	TNFB 9901 x PT 5682	-0.09 **	0.65	0.03	-1.49 **	0.32	2.96 **	25.67 **	26.95
16	TNFB 9901 x PT 5588	0.02	-1.27 *	-0.09 **	-0.29	-0.51	-0.37	-24.29 **	-126.44 **
17	TNFB 9901 x GP 18219	0.05 **	0.49	0.04	-1.60 **	-0.79 **	-1.99 **	-25.96 **	-75.29 **
18	TNFB 9901 x GP 16026	0.03	0.46	0.03	1.13 **	0.86 **	0.99	15.59 *	102.50 **
19	TNFB 9902 x GP 15074	-0.04 *	0.45	0.16 **	-2.24 **	0.15	-2.56 **	-28.09 **	-103.75 **
20	TNFB 9902 x PT5365	-0.02	-0.45	0.02	0.12	-0.94 **	-2.67 **	-31.79 **	-99.50 **
21	TNFB 9902 x PT 5682	0.09 **	-0.79	-0.06 **	0.25	-0.31	3.05 **	3.92	30.23 *
22	TNFB 9902 x PT 5588	0.01	0.72	-0.07 **	-0.14	-0.71 *	0.95	11.58	-21.16
23	TNFB 9902 x GP 18219	-0.02	-0.64	-0.09 **	1.48 **	1.13 **	0.42	-6.16	10.84
24	TNFB 9902 x GP 16026	-0.01	0.71	0.05 *	0.53	0.69 *	0.81	50.55 **	183.34 **
25	PT 5701 x GP 15074	0.01	0.95	0.04	0.29	-1.74 **	-3.87 **	-53.75 **	-209.55 **
26	PT 5701 x PT 5682	0.03	0.52	0.03	-0.51	-0.16	-0.67	-16.34 *	-65.70 **
27	PT 5701 x PT5365	-0.00	0.02 ns	-0.03	1.10 **	0.07	1.29 *	5.52	27.08
28	PT 5701 x PT 5588	0.00	-0.34	-0.00	-0.78 *	0.29	-0.91	-13.04 *	81.99 **
29	PT 5701 x GP 18219	0.04 *	0.16	0.05	1.84 **	1.96 **	3.04 **	87.42 **	292.44 **
30	PT 5701 x GP 16026	-0.08 **	-1.30 *	-0.09 **	-1.94 **	-0.41	1.12 *	-9.81	-126.26 **
31	CGP/PT 4685 x GP 15074	0.03	0.53	-0.03	-0.19	1.27 **	4.64 **	15.78 *	67.72 **
32	CGP/PT 4685 x PT 5682	0.01	-0.84	-0.05	1.52 **	2.64 **	3.11 **	39.63 **	226.22 **
33	CGP/PT 4685 x PT5365	-0.01	-0.71	-0.07 **	-1.87 **	-0.33	-3.03 **	-3.22	-35.24 *
34	CGP/PT 4685 x PT 5588	0.00	-1.08	0.13 **	-0.09	0.07	3.62 **	2.81	-27.48 *
35	CGP/PT 4685 x GP 18219	-0.04 *	0.69	0.00	-0.63	-1.79 **	-5.96 **	-9.10	-139.68 **
36	CGP/PT 4685 x GP 16026	0.01 ns	1.41 *	0.01	1.25 **	-1.86 **	-2.38 **	-45.90 **	-91.54 **
37	CO 8 x GP 15074	-0.04 **	-0.72	0.01	0.58	-0.71 *	0.63	7.41	-56.92 **
38	CO 8 x PT 5682	-0.03	0.41	0.02	-0.88 *	-1.04 **	0.59	-10.55	-53.22 **
39	CO 8 x PT5365	-0.02	-0.40	0.08 **	-0.26	-0.20	-1.82 **	-19.13 **	-127.58 **
40	CO 8 x PT 5588	0.02	0.49	0.05 *	0.69	1.32 **	-0.86	23.52 **	118.13 **
41	CO 8 x GP 18219	0.03 ns	-0.25	-0.05 *	-0.48	-1.28 **	0.98	-45.57 **	-102.02 **
42	CO 8 x GP 16026	0.04 *	0.47	-0.10 **	0.36	1.91 **	0.47	44.31 **	221.62 **
43	IP 17424 x GP 15074	0.03 *	-0.46	-0.13 **	0.84 *	0.98 **	1.96 **	39.62 **	236.16 **
44	IP 17424 x PT 5682	0.04 *	0.05	-0.08 **	-0.46	0.99 **	1.78 **	95.00 **	183.49 **
45	IP 17424 x PT5365	-0.01	0.80	-0.02	1.49 **	-0.04	-0.97	-49.68 **	-21.68
46	IP 17424 x PT 5588	0.01	-0.50	0.04	0.28	-0.14 ns	0.78	20.79 **	67.63 **
47	IP 17424 x GP 18219	-0.01	-0.62	0.09 **	-0.77 *	-0.35	-1.43 **	-46.38 **	-153.55 **
48	IP 17424 x GP 16026	-0.06 **	0.73	0.10 **	-1.38 **	-1.44 **	-2.12 **	-59.34 **	-312.05 **
49	IP 17435 x GP 15074	0.01	-0.20	-0.06 *	-0.15	0.35	-0.21	-6.90	34.38 *
50	IP 17435 x PT 5682	0.01	-0.00	0.06 *	-0.61	-0.10	1.72 **	-1.08	-38.98 **
51	IP 17435 x PT5365	-0.02	0.74	0.02	0.78 *	0.53	0.37	9.04	23.62
52	IP 17435 x PT 5588	-0.04 *	0.38	0.03	0.62	-0.87 **	-1.50 **	-15.28 *	-85.37 **
53	IP 17435 x GP 18219	0.03	-0.67	-0.04	-0.10	0.67 *	0.57	10.97	13.83
54	IP 17435 x GP 16026	0.01	-0.26	-0.01	-0.54	-0.58	-0.94	3.24	52.52 **
	Standard error (sca effects of hybrids)	0.02	0.61	0.02	0.39	0.30	0.52	6.33	13.76

Tablle 5. The estimates of standard heterosis (%) over standard check (TNAU Cumbu hybrid CO 9) for sixteen traits (per cent)

S.No	Hybrids	DGFH	NTPP	PH	NLPP	INL	SG	LL	LB
1	GP15988 x GP 15074	-1.96	39.11 **	2.46	-10.13	-19.26 **	3.43	-9.88 **	1.05
2	GP15988 x PT 5682	-2.94	13.16	2.14	-19.11 **	-11.30 *	4.17	-14.25 **	-16.84 **
3	GP15988 x PT5365	-0.98	13.92	1.51	-19.11 **	-17.38 **	6.62	-13.77 **	-4.21
4	GP15988 x PT 5588	-1.96	26.71 **	6.06 **	-12.67	-17.51 **	-3.19	-1.61	6.63
5	GP15988 x GP 18219	-2.94	28.35 **	9.80 **	-6.28	-17.13 **	6.25	0.69	5.58
6	GP15988 x GP 16026	-0.98	29.49 **	11.04 **	-3.70	-17.83 **	9.07	-0.69	-14.74 **
7	PT5652 x GP 15074	-2.94	5.44	10.33 **	-11.40	-6.69	7.35	-7.13 *	-14.00 **
8	PT5652 x PT5365	0.00	22.41 **	1.79	-6.24	-17.83 **	23.77 **	-2.76	0.00
9	PT5652 x PT 5682	-1.96	13.92	10.06 **	1.43	-9.03	16.42 *	-7.13 *	-1.05
10	PT5652 x PT 5588	0.01	13.92	7.48 **	-15.25 *	-5.23	5.39	-2.76	-13.37 **
11	PT5652 x GP 18219	-1.96	13.92	11.67 **	-4.97	4.23	-6.50	-12.19 **	-27.37 **
12	PT5652 x GP 16026	-0.98	13.92	5.78 **	-17.84 *	3.02	-18.63 *	-2.53	-15.79 **
13	TNFB 9901 x GP 15074	0.01	30.51 **	13.21 **	-15.25 *	-3.48	26.23 **	-2.76	1.37
14	TNFB 9901 x PT5365	0.01	19.87 *	7.93 **	-13.98	-15.10 **	5.02	-9.66 **	-18.95 **
15	TNFB 9901 x PT 5682	0.98	26.58 **	11.87 **	-13.98	-6.75	26.96 **	-0.23	4.21
16	TNFB 9901 x PT 5588	0.00	26.58 **	14.19 **	-2.43	-0.32	5.88	0.46	4.21
17	TNFB 9901 x GP 18219	0.98	13.92	5.88 **	-10.13	-3.73	4.17	-0.46	-17.16 **
18	TNFB 9901 x GP 16026	0.01	1.27	11.45 **	-5.01	-4.48	10.78	-3.91	-17.58 **
19	TNFB 9902 x GP 15074	0.00	5.44	-3.65	-10.13	-19.56 **	18.87 *	-2.53	-7.05
20	TNFB 9902 x PT5365	1.96	-2.91	-13.71 **	-24.23 **	-15.08 **	28.31 **	-4.14	-1.47
21	TNFB 9902 x PT 5682	0.98	13.92	1.61	-6.28	-4.12	9.44	-4.37	-3.89
22	TNFB 9902 x PT 5588	0.00	23.67 **	2.32	-2.43	-14.33 **	18.87 *	-4.37	-18.95 **
23	TNFB 9902 x GP 18219	0.98	1.27	2.76	-7.55	-6.07	13.97	-3.91	-7.05
24	TNFB 9902 x GP 16026	1.96	13.92	7.22 **	-3.70	-1.07	14.34	-0.69	2.53
25	PT 5701 x GP 15074	1.96	20.25 *	-0.53	-16.56 *	-9.03	25.00 **	-7.13 *	-4.21
26	PT 5701 x PT 5682	1.96	-24.05 **	-10.24 **	-13.94	-9.71	24.14 **	-8.28 **	-6.00
27	PT 5701 x PT5365	0.98	22.41 **	-13.89 **	-11.40	-9.55	18.14 *	-7.81 **	-15.47 **
28	PT 5701 x PT 5588	0.98	-7.22	-14.60 **	-12.71	-5.25	21.69 **	-6.66 *	1.05
29	PT 5701 x GP 18219	0.98	32.03 **	14.87 **	-1.73	1.30	22.55 **	-3.45	7.37
30	PT 5701 x GP 16026	0.98	-3.04	0.89	-16.53 *	-7.96	18.01 *	-11.72 **	-13.37 **
31	CGP/PT 4685 x GP 15074	1.96	-2.91	-4.31 *	-26.81 **	-6.37	20.10 *	-13.33 **	-0.74
32	CGP/PT 4685 x PT 5682	6.86 *	-28.35 **	-1.96	-22.96 **	-3.02	28.19 **	-2.30	-2.11
33	CGP/PT 4685 x PT5365	7.84 **	-40.89 **	-12.41 **	-26.81 **	-12.37 *	23.77 **	-11.26 **	-9.05
34	CGP/PT 4685 x PT 5588	6.86 *	-19.87 *	-8.89 **	-23.61 **	-6.75	25.37 **	-7.12 *	3.47
35	CGP/PT 4685 x GP 18219	7.84 **	-11.39	-7.27 **	-10.09	-5.32	23.41 **	-12.18 **	-2.42
36	CGP/PT 4685 x GP 16026	6.86 *	-15.57	0.71	-20.42 **	-1.77	18.87 *	-14.26 **	6.63
37	CO 8 x GP 15074	4.90	26.58 **	-9.23 **	-11.40	-5.23	19.00 *	-11.27 **	-6.74
38	CO 8 x PT 5682	5.88 *	18.73 *	6.95 **	-21.69 **	-9.64	20.10 *	-0.32	-5.58
39	CO 8 x PT5365	5.88 *	13.92	-11.13 **	-17.84 *	-11.30 *	24.14 **	-11.72 **	-2.53
40	CO 8 x PT 5588	3.92	40.38 **	13.64 **	-4.55	-0.39	32.35 **	-0.66	4.84
41	CO 8 x GP 18219	5.88 *	13.92	-3.03	-7.55	-4.12	30.64 **	-0.50	3.16
42	CO 8 x GP 16026	2.94	41.27 **	15.45 **	-1.73	1.57	23.16 **	-0.19	7.47
43	IP 17424 x GP 15074	28.43 **	59.75 **	26.37 **	5.66	6.39	29.90 **	0.92	21.16 **
44	IP 17424 x PT 5682	25.49 **	56.08 **	23.07 **	2.16	5.48	29.53 **	0.90	15.37 **
45	IP 17424 x PT5365	25.49 **	50.38 **	18.70 **	-1.12	3.48	23.16 **	-0.11	8.53
46	IP 17424 x PT 5588	23.53 **	47.85 **	21.14 **	0.15	3.48	27.70 **	-0.11	9.79 *
47	IP 17424 x GP 18219	24.51 **	37.09 **	10.83 **	-6.28	-4.07	-8.09	-8.05 **	-2.11
48	IP 17424 x GP 16026	23.53 **	30.89 **	6.64 **	-2.39	-4.03	-10.54	-6.90 *	-0.42
49	IP 17435 x GP 15074	25.49 **	34.94 **	4.82 *	-1.12	-8.64	3.43	-1.61	-7.05
50	IP 17435 x PT 5682	25.49 **	45.95 **	4.82 *	-2.43	-1.77	6.37	-4.14	9.89 *
51	IP 17435 x PT5365	22.55 **	44.05 **	5.04 *	-2.39	-12.51 *	2.57	-4.60	8.11
52	IP 17435 x PT 5588	22.55 **	45.95 **	10.52 **	0.15	-0.68	-3.55	-3.22	5.58
53	IP 17435 x GP 18219	23.53 **	47.72 **	15.94 **	1.81	-10.23	-19.12 *	-2.53	5.26
54	IP 17435 x GP 16026	25.49 **	48.99 **	16.05 **	4.01	-1.21	14.71	-1.38	14.00 **

Table 5. continued

S.No	Hybrids	LSR	CP	CFIB	CF	ASH	DMP	DFYPP	GFYPP
1	GP15988 x GP 15074	-33.80 **	18.31 *	-34.88 **	-3.34	-33.59 **	-6.43 *	-43.53 **	-39.61 **
2	GP15988 x PT 5682	-25.35 **	10.08	-32.20 **	-21.96	-66.41 **	-4.74	-48.30 **	-45.77 **
3	GP15988 x PT5365	4.23	4.53	-31.95 **	11.48	-65.62 **	-22.40 **	-58.48 **	-46.53 **
4	GP15988 x PT 5588	-42.25 **	10.08	-36.10 **	-29.32 *	-38.28 **	-15.92 **	-44.41 **	-33.28 **
5	GP15988 x GP 18219	-38.03 **	8.98	-33.66 **	7.80	-42.97 **	-3.63	-31.74 **	-25.42 **
6	GP15988 x GP 16026	-35.21 **	7.83	-33.41 **	33.78 **	-24.22 **	-5.46	-40.32 **	-36.32 **
7	PT5652 x GP 15074	-38.03 **	1.80	-29.27 **	14.83	-60.16 **	-35.05 **	-65.90 **	-47.56 **
8	PT5652 x PT5365	-40.85 **	12.81	-28.29 **	-10.81	-39.45 **	-15.16 **	-50.41 **	-36.31 **
9	PT5652 x PT 5682	-26.76 **	10.04	-30.49 **	-18.28	-23.44 **	2.44	-22.43 **	-24.29 **
10	PT5652 x PT 5588	-21.13 **	22.18 **	-32.93 **	-18.62	-20.86 **	5.19	-22.53 **	-25.09 **
11	PT5652 x GP 18219	-38.03 **	18.57 *	-31.71 **	17.50	-27.34 **	4.29	-33.48 **	-30.48 **
12	PT5652 x GP 16026	-4.23	-9.20	-34.15 **	-10.81	-32.03 **	-2.66	-38.11 **	-35.55 **
13	TNFB 9901 x GP 15074	5.63	7.88	-27.32 **	44.93 **	-11.80	1.69	-2.80	1.51
14	TNFB 9901 x PT5365	-23.94 **	7.31	-27.07 **	7.80	-49.61 **	-32.52 **	-65.28 **	-48.57 **
15	TNFB 9901 x PT 5682	-23.94 **	12.81	-26.59 **	-33.11 **	-28.13 **	7.83 *	-26.58 **	-28.66 **
16	TNFB 9901 x PT 5588	-1.41	-3.70	-32.20 **	-23.86	-30.86 **	-2.93	-38.31 **	-36.46 **
17	TNFB 9901 x GP 18219	8.45	12.81	-26.59 **	-22.41	-39.84 **	-18.22 **	-49.99 **	-38.90 **
18	TNFB 9901 x GP 16026	-0.00	11.71	-28.29 **	33.78 **	-10.16	-3.92	-23.52 **	-12.96 **
19	TNFB 9902 x GP 15074	-38.03 **	1.80	-29.76 **	-44.26 **	-21.09 **	-21.83 **	-59.00 **	-41.33 **
20	TNFB 9902 x PT5365	-36.62 **	-7.83	-35.37 **	-18.28	-49.22 **	-21.65 **	-59.30 **	-48.07 **
21	TNFB 9902 x PT 5682	8.45	-11.93	-40.98 **	-3.34	-35.16 **	10.17 **	-44.49 **	-32.08 **
22	TNFB 9902 x PT 5588	-22.54 **	1.80	-41.22 **	-29.43 *	-31.25 **	4.94	-23.52 **	-27.05 **
23	TNFB 9902 x GP 18219	-30.99 **	-9.20	-42.68 **	37.46 **	-7.03	-5.44	-44.32 **	-31.90 **
24	TNFB 9902 x GP 16026	-30.99 **	1.80	-37.07 **	11.48	-10.08	-2.80	-9.25	-6.63 **
25	PT 5701 x GP 15074	2.82	12.81	-35.12 **	15.27	-53.13 **	-27.36 **	-64.94 **	-43.35 **
26	PT 5701 x PT 5682	4.23	7.31	-34.15 **	-29.43 *	-39.45 **	-12.22 **	-41.90 **	-32.51 **
27	PT 5701 x PT5365	8.45	1.80	-38.54 **	18.84	-31.64 **	2.59	-34.95 **	-21.18 **
28	PT 5701 x PT 5588	1.41	-0.92	-37.07 **	-40.58 **	-17.97 **	-3.04	-28.86 **	-2.77
29	PT 5701 x GP 18219	14.08 *	4.53	-35.37 **	48.61 **	3.52	6.77 *	17.42 **	14.83 **
30	PT 5701 x GP 16026	-23.94 **	-9.20	-42.93 **	-40.58 **	-29.69 **	-1.01	-34.88 **	-34.28 **
31	CGP/PT 4685 x GP 15074	-28.17 **	-11.97	-42.93 **	0.33	-15.78 *	0.50	-26.39 **	-18.34 **
32	CGP/PT 4685 x PT 5682	-38.03 **	-25.70 **	-41.95 **	11.48	-5.47	-5.71	-11.04 *	-5.66 *
33	CGP/PT 4685 x PT5365	-29.58 **	-25.70 **	-44.63 **	-51.73 **	-47.66 **	-27.42 **	-40.82 **	-38.90 **
34	CGP/PT 4685 x PT 5588	-33.80 **	-28.48 **	-34.88 **	-29.43 *	-31.25 **	6.86 *	-20.78 **	-26.42 **
35	CGP/PT 4685 x GP 18219	-43.66 **	-11.93	-41.71 **	-10.81	-64.84 **	-44.38 **	-38.27 **	-49.42 **
36	CGP/PT 4685 x GP 16026	-33.80 **	-6.47	-42.44 **	26.31 *	-62.11 **	-27.36 **	-56.27 **	-39.79 **
37	CO 8 x GP 15074	-7.04	-0.92	-28.78 **	41.25 **	-35.55 **	-0.16	-10.20	-12.02 **
38	CO 8 x PT 5682	-5.63	7.31	-26.83 **	-18.28	-51.56 **	0.32	-18.58 **	-18.82 **
39	CO 8 x PT5365	9.86	-0.97	-25.61 **	7.80	-34.38 **	-4.53	-28.91 **	-28.51 **
40	CO 8 x PT 5588	12.68	7.31	-26.83 **	11.48	-0.39	4.06	11.92 *	13.90 **
41	CO 8 x GP 18219	16.90 *	1.80	-32.44 **	16.28	-45.70 **	4.38	-38.02 **	-22.68 **
42	CO 8 x GP 16026	15.49 *	7.31	-35.85 **	29.99 *	8.20	2.93	15.87 **	21.61 **
43	IP 17424 x GP 15074	22.54 **	15.54 *	-35.85 **	48.61 **	20.31 **	6.74 *	26.76 **	64.94 **
44	IP 17424 x PT 5682	21.13 **	18.31 *	-31.71 **	-7.13	9.53	6.61 *	60.00 **	51.04 **
45	IP 17424 x PT5365	18.31 **	23.81 **	-30.73 **	48.61 **	-2.34	0.20	-27.58 **	24.89 **
46	IP 17424 x PT 5588	18.31 **	12.81	-27.56 **	4.01	6.25	12.38 **	29.04 **	47.63 **
47	IP 17424 x GP 18219	12.68	12.81	-25.37 **	11.48	-1.56	-5.59	-19.81 **	10.92 **
48	IP 17424 x GP 16026	-5.63	23.81 **	-26.10 **	-7.02	-14.77 *	-7.85 *	-24.28 **	-5.46 *
49	IP 17435 x GP 15074	8.45	21.08 **	-31.95 **	30.10 *	-17.97 **	-7.42 *	-26.32 **	-4.96 *
50	IP 17435 x PT 5682	7.04	21.08 **	-24.88 **	-7.02	-35.94 **	1.96	-21.21 **	-21.46 **
51	IP 17435 x PT5365	11.27	26.54 **	-28.29 **	36.34 **	-21.88 **	1.89	-20.93 **	-13.92 **
52	IP 17435 x PT 5588	-2.82	23.81 **	-27.56 **	15.16	-33.59 **	-2.30	-18.10 **	-16.13 **
53	IP 17435 x GP 18219	18.31 **	15.58 *	-31.46 **	29.99 *	-14.06 *	-0.95	-13.94 **	-12.53 **
54	IP 17435 x GP 16026	9.86	18.31 *	-31.46 **	15.16	-29.69 **	-6.90 *	-15.44 **	-4.09

*5% significance level ** 1% significance level

DGFH- Days to green fodder harvest, NTPP- Number of tillers per plant, PH- Plant height, NLPP- Number of leaves per plant, IL-Internode length, SG-Stem girth, LL- Leaf length, LB- Leaf breadth, LSR- Leaf-stem ratio, CP-Crude protein, CFR- Crude fibre, CF-Crude fat, ASH-Ash content ,DMP-Dry matter percentage, DFYPP-Dry fodder yield per plant, GFYPP-Green fodder yield per plant.

Hence, it is noted that the superior hybrids derived from lines IP 17424, CO 8 and testers GP 15074 and PT 5588 with highly significant *gca* effects values might be attributed to additive gene action. Line IP 17424 can be considered as the outstanding combiner which can give consistent green fodder yield when crossed with testers of even less *gca* effects values. The performance of hybrids *viz*., IP17424 x PT5682, IP17424 x GP18219, IP17424 x PT 5365 were the examples for the combination of good x poor combining ability parents. Therefore, when considering green fodder yield improvement, involvement of both additive and non-additive gene action should be taken into account (Gavali *et al*., 2018). At least one or both parents are required to be a good general combiner to get desirable transgressive segregants for green fodder yield in later generations (Shinde and Mehetre, 2014).

A hybrid is commercially viable only when it exhibits significant higher heterosis over its better parent or locally adopted variety/hybrid or check (Subbulakshmi *et al*., 2018). Therefore, in addition, to mean performance and *sca* effects, standard heterosis was estimated for all the hybrids evaluated. Based on the standard heterosis value over the standard check TNAU pearl millet hybrid CO 9, the hybrids *viz*.,, IP 17424 x GP 15074 (64.94), IP 17424 x PT 5682 (51.04%), IP 17424 x PT 5588 (47.63%), CO 8 x GP 16026 (26.61%) IP 17424 x PT5365 (24.89%), PT 5701 x GP 18219 (14.83%), CO 8 x PT 5588 (13.90%) and IP 17424 x GP 18219 (10.92%) recorded significant positive heterosis for green fodder yield **(Table 5)**. Similarly, the hybrids PT 5652 x PT 5588, PT 5652 x GP 18219, IP 17424 x GP 16026 and IP 17424 x GP 15074 recorded significant positive standard heterosis for crude protein content. Among the 15 parents utilised for heterosis breeding programme, high mean performance coupled with general combining ability was recorded in IP 17424, IP 17435, CO 8, GP 15074 and PT 5588 **(Table 6).** Among the 54 hybrids studied, IP 17424 x GP 15074, IP 17424 x PT 5682 and CO 8 x PT 5588 were the hybrids that exhibited high mean performance along with significant positive *sca* effects and positive standard heterosis over TNAU pearl millet hybrid CO 9 for green fodder yield **(Table 7).** Based on standard heterosis, the hybrid PT 5652 x PT 5588 excelled for crude protein content (13.88 %).

The superior hybrids identified *viz.,* IP 17424 x GP 15074 and CO 8 x PT 5588 involved the combination of parents with high mean, significantly positive *gca* effects for green fodder yield, dry fodder yield, dry matter percentage which indicates that there is the possibility of the appearance of superior segregants in later generations which would enable the breeder to develop new inbreds or open pollinated variety with enhanced green fodder yield. Besides, the superior performing parents identified with high mean and positive *gca* effects for the green fodder yield and related traits *viz.,* IP 17424, IP 17435, CO 8, GP 15074, and PT 5588 could be exploited for developing superior synthetics for green fodder yielding after testing their combining ability.

Table 6. Mean performance and *gca* effects values of superior parents for various traits

S. No.	Superior parents	DGFH	NTPP	PH (cm)	NLPP	SG (cm)	LSR	CP (g/100g)	CFR (g/100g)	DMP (%)	GFYPP (g)
						Mean performance					
1	IP 17424	62.00	5.84	214.72	14.50	5.58	0.45	13.65	2.00	23.55	973.05
2	CO 8	52.00	5.00	209.50	12.84	4.71	0.36	13.68	4.00	21.94	862.10
3	GP 15074	53.00	4.00	211.33	13.00	4.20	0.26	11.39	3.50	25.16	533.63
4	PT 5588	51.50	4.16	209.94	15.59	4.98	0.28	12.79	1.50	23.69	602.30
5	IP 17435	65.00	6.21	212.83	13.84	5.22	0.42	13.66	3.50	24.63	960.95
						***gca* effects values**					
1	IP 17424	9.44 **	1.10 **	24.28 **	1.19 **	0.06	0.09 **	1.39 **	0.07 **	1.74 **	404.20 **
2	CO 8	-0.90 *	0.26 **	-5.07 **	-0.17	0.45 **	0.06 **	-0.22	0.08 **	1.53 **	85.68 **
3	GP 15074	-0.12	0.21 *	-0.81	-0.17	0.13	-0.01	0.20	0.01	0.93 **	23.01 **
4	PT 5588	-0.23	0.11	1.77	0.17	0.02	-0.00	-0.07	0.001	1.50 **	53.96 **
5	IP 17435	8.94 **	1.01 **	8.82 **	1.23 **	-0.54 **	0.07 **	1.76 **	0.08 **	0.77 **	50.48 **

*5% significance level ** 1% significance level

DGFH- Days to green fodder harvest, NTPP- Number of tillers per plant, PH- Plant height, NLPP- Number of leaves per plant, SG- Stem girth, , LSR- Leaf-stem ratio, CP-Crude protein, CFR- Crude fibre, DMP-Dry matter percentage, GFYPP-Green fodder yield per plant.

Table 7. Mean performance, *sca* effects values and standard heterosis of identified superior fodder pearl millet hybrids for various traits

Superior hybrids	DGFH	NTPP	PH (cm)	NLPP	SG (cm)	LSR	CP (g/100g)	CFR (g/100g)	DMP (%)	GFYPP (g)
					Mean performance					
IP 17424 x GP 15074	64.00	5.33	196.19	12.84	4.22	0.38	13.76	1.39	20.53	755.35
CO 8 x PT 5588	53.00	5.55	212.69	12.39	5.40	0.40	12.19	1.50	23.07	905.25
IP 17424 x PT 5682	64.00	6.16	230.33	13.26	5.28	0.43	13.44	1.40	23.63	1200.43
PT 5652 x PT 5588	51.00	4.50	201.17	11.00	4.30	0.28	13.88	1.38	23.32	595.35
					***sca* effects values**					
IP 17424 x GP 15074	1.79	0.30	16.86 **	0.95	0.47 *	0.03 *	-0.46	-0.13 **	1.96 **	236.16 **
CO 8 x PT 5588	-0.27	0.46	19.81 **	0.64	0.28	0.02	0.49	0.05 *	-0.86	118.13 **
IP 17424 x PT 5682	-0.10	0.58 *	14.56 **	0.86	0.38	0.04 *	0.05	-0.08 **	1.78 **	183.49 **
PT 5652 x PT 5588	0.90	-0.11	-2.46	-0.98	0.01	0.03	1.53 *	-0.04	1.16 *	10.59
					Standard heterosis					
IP 17424 x GP 15074	28.43 **	59.75 **	26.37 **	5.66	29.90 **	22.54 **	15.54 *	-35.85 **	6.74 *	64.94 **
CO 8 x PT 5588	3.92	40.38 **	13.64 **	-4.55	32.35 **	12.68	7.31	-26.83 **	4.06	13.90 **
IP 17424 x PT 5682	25.49 **	56.08 **	23.07 **	2.16	29.53 **	21.13 **	18.31 *	-31.71 **	6.61 *	51.04 **
PT 5652 x PT 5588	0.01	13.92	7.48 **	-15.25 *	5.39	-21.13 **	22.18 **	-32.93 **	5.19	-25.09 **

*5% significance level ** 1% significance level

DGFH- Days to green fodder harvest, NTPP- Number of tillers per plant, PH- Plant height, NLPP- Number of leaves per plant, SG- Stem girth, , LSR- Leaf-stem ratio, CP-Crude protein, CFR- Crude fibre, DMP-Dry matter percentage, GFYPP-Green fodder yield per plant.

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