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STUDIES ON COMBINING ABILITY OVER ENVIRONMENTS FOR GRAIN YIELD, MORPHO-PHYSIOLOGICAL, NUTRITIONAL TRAITS IN PEARL MILLET (*Pennisetum glaucum* (L.) R. Br.)

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ABSTRACT

The experiment was conducted with 50 hybrids and fifteen parents which were developed through Line × Tester mating design using five male sterile lines and ten restorers as parental material evaluated over four seasons and pooled over seasons at Agricultural Research Station, Podalakur. Significant differences were observed for all the fifteen characters studied. Among fifteen parental inbred lines studied in pooled over seasons, the superior inbred lines *viz*., ICMR 13999, ICMR 100556 and ICMB 98222 identified based on mean performance, general combining ability effects may be utilized in the development of high yielding hybrids possessing earliness and enriched nutritional parameters and also that can fit well in different cropping windows. Among 50 hybrids studied in pooled over seasons, the superior hybrids ICMB 04999 × ICMR 100549 and ICMB 08666 × ICMR 13999 identified based on *per se* performance, *sca* and standard heterosis for grain yield and yield components over seasons could be recommended for commercial cultivation after extensive testing under MLT's / on-farm trials.

KEYWORDS: *Pennisetum glaucum*, Line × Tester mating design

INTRODUCTION

Pearl millet (*Pennisetum glaucum* (L.) R. Br.), is the fourth most important food grain crop after rice, wheat and sorghum in India. The contribution of pearl millet to the total Fe and Zn intake from all food sources has been reported to very widely vary across rural India. For instance, it was observed to be contributing 19-63 per cent of the total Fe intake and 16-56 per cent of the total Zn intake in parts of Rajasthan, Maharashtra and Gujarat states (Parthasarathy *et al.,* 2006). Constant efforts have been made to improve grain yield and its contributing characters through hybridization in pearl millet. Proper selection of parents is very crucial in planned hybridization programme. Combining ability provides useful information regarding the selection of suitable parents for effective hybridization programme and at the same time elucidates the nature and magnitude of different types of gene action. Since, the nature of gene action varies with genetic architecture of population involved in hybridization, it is necessary to evaluate the parents for their combining ability. This information enables the breeder to evaluate and classify selected parental material for their utility in development of high yielding F_1 hybrids in pearl millet, where hybrids are being cultivated on commercial scale. The current experiment was laid out comprising of fifty hybrids and fifteen parents of pearl millet to determine the combining ability for grain yield, Morpho-physiological and Nutritional traits.

MATERIAL AND METHODS

This trial was conducted with 50 hybrids, 5 lines and 10 testers in over pooled seasons at ARS, Podalakur in RBD replicated thrice. Every genotype was sown in one row of four meters length with 45 × 15 cm spacing. All management practices were followed as and when required to establish a good crop. Observations were recorded on 15 economically important characters viz., Days to 50% flowering, Days to maturity, productive tillers plant^{-1}, Plant height (cm), Panicle length (cm), Panicle girth (cm), 1000 grain weight (g), Grain yield (t ha^{-1}), Green fodder yield (t ha^{-1}), Dry fodder yield (t ha^{-1}), SPAD chlorophyll meter readings (60 DAS), Relative water content (%), Harvest index (%), Grain Fe content (ppm), Grain Zn content (ppm). Data from all the characters studied were exposed to analysis of variance technique on the basis of model proposed by Panse and Sukhatme (1967). The analysis of variance (ANOVA)

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method, as described by Singh and Chowdary (1985), was used. The combining ability analysis was carried out according to the method suggested by Kempthorne (1957).

RESULTS AND DISCUSSION

Combining ability analysis is of vital importance in crops like pearl millet as it helps in identification of potential parents with good *gca* effects and hybrids with good *sca* effects (Sprague and Tatum, 1942). As a general rule, general combining ability (GCA) is the result of additive gene effects and additive × additive interaction which are fixable, while the specific combining ability (SCA) is the result of non- additive gene effects that includes dominance, epistasis and other interactions which are non-fixable (Jinks, 1954). Parents with desirable *gca* effects for the targeted characters can be used to accumulate favourable alleles by recombination and selection in evolving productive hybrids. Knowledge on the nature and magnitude of gene actions involved in the inheritance of various quantitative characters is important in developing an effective and sound breeding programme. The present investigation was carried out with an objective of identifying potential parents and specific cross combinations for yield and yield components under four seasons and pooled over seasons through combining ability.

Analysis of Variance for Combining Ability

Combining ability analysis was carried out utilising the mean data recorded on replication wise for all the 15 characters in 50 hybrids using L × T mating design separately for all the four seasons *viz., kharif* 2020 (E_1), late *kharif* 2020 (E_2), *rabi* 2020-21 (E_3) and *summer* (E_4) and pooled data over seasons. ANOVA for combining ability analysis for all the characters studied is presented in Table 1. Combining ability analysis indicated that mean sum of squares due to GCA, SCA and seasons were significant for all the characters studied in all four seasons.

Pooled analysis of variance for combining ability over four seasons is presented in Table 1. The variance components due to GCA, SCA and seasons showed the highly significant differences for all the characters. Mean sum of squares due to GCA × Seasons and the interaction of SCA × Seasons also exhibited significant differences for all characters. Significant mean sum squares due to seasons and GCA × Seasons and SCA × Seasons for yield and yield components indicate that both additive and non-additive genetic variances are greatly influenced by environments (Seasons).

The detailed results of combining ability effects and variances for all characters under consideration are presented here under season wise and pooled over seasons.

General Combining Ability (*gca*) Effects

A perusal of estimates of *gca* effects in pooled data analysis revealed that none of the parents tested were found to be the good general combiners for all the characters. However, a few parents showed desirable *gca* effects for most of the characters under study. ICMR 100549 is best suitable cultivar for number of productive tillers plant^{-1}, ICMR 08666 for plant height(cm) and green fodder yield (t ha^{-1}), ICMR 13999 for panicle length (cm), grain yield (t ha^{-1}) and Relative water content (%), ICMR 100549 for panicle girth (cm) and dry fodder yield (t ha^{-1}), ICMR 13999 for 1000 grain weight (g), days to 50% flowering and days to maturity, ICMB 98222 for SPAD chlorophyll meter readings (60 DAS), ICMR 100087 for harvest index (%) ICMR 12555 for Grain Fe content (ppm) and Grain Zn content (ppm).

Among the testers ICMR 100556 was identified as the best general combiner as it registered significant *gca* effects in desired direction for number of productive tillers plant^{-1}, plant height (cm), panicle girth (cm), 1000 grain weight (g), grain yield (t ha^{-1}), green fodder yield (t ha^{-1}), days to 50% flowering, days to maturity, SPAD chlorophyll meter reading (SCMR), relative water content (%), harvest index (%) and nutritional parameters grain Fe content (ppm) and grain Zn content (ppm). The tester parent ICMR 13999 registered significant *gca* effects in desired direction for number of productive tillers plant^{-1}, plant height (cm), panicle length (cm), panicle girth (cm), 1000 grain weight (g), grain yield (t ha^{-1}), green fodder yield (t ha^{-1}), dry fodder yield (t ha^{-1}), days to 50% flowering, days to maturity, SPAD chlorophyll meter reading (SCMR) and relative water content (%). Crosses involving these parents might produce heterotic hybrids with high mean performance for the respective traits (Table 2).

Among the lines, ICMB 98222 exhibited desirable significant *gca* effects for nine characters *viz*., number of productive tillers plant^{-1}, plant height (cm), panicle girth

Table 1. Pooled analysis of variance for combining ability for grain yield, morpho-physiological and nutritional traits over four seasons

Source of variation	df	Mean sum of squares							
		DF	DM	PT	PH	PL	PG	TGW	GY
Replications	2	10.82	0.07	0.02	16.00	7.34	0.01	0.21	0.04
Seasons	3	997.08**	1434.75**	39.46**	13431.80**	674.07**	10.78**	166.86**	76.63**
Replications × Seasons	6	4.51	2.97	0.01	5.65	1.62	0.02	0.53	0.04
Hybrids	49	60.67**	73.64**	1.14**	1580.40**	45.67**	0.83**	21.33**	2.99**
Line effect	4	110.53**	58.72**	0.50**	2080.69**	65.22**	1.84**	52.42**	3.63**
Tester effect	9	134.76**	115.67**	0.72**	2290.07**	71.09**	1.78**	17.54**	0.45**
Line × Tester effect	36	36.59**	64.79**	1.31**	1347.39**	37.15**	0.49**	18.82**	2.66**
Seasons × Hybrids	147	8.08**	11.58**	0.43**	163.47**	12.71**	0.07**	2.39**	0.56**
Seasons × Line effect	12	19.24**	11.62**	0.35**	455.13**	36.20**	0.05*	3.44**	0.79**
Seasons × Tester effect	27	6.87**	12.62**	0.55**	121.31**	15.81**	0.09**	2.38**	0.62**
Seasons × LT effect	108	7.14**	11.32**	0.41**	141.57**	9.32**	0.07**	2.28**	0.52**
Error	392	1.22	1.93	0.02	33.58	1.41	0.02	0.40	0.04
Total	599	12.82	17.35	0.41	258.75	11.20	0.15	3.43	0.77

* : Significant at 5% level; ** : Significant at 1% level

DF : Days to 50% flowering; PT : Productive tiller plant^{-1}; PL : Panicle length; TGW : 1000 grain weight
DM : Days to maturity; PH : Plant height; PG : Panicle girth; GY : Grain yield

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Table 1. Cont...

Source of variation	df	Mean sum of squares						
		GFY	DFY	SCMR	RWC	HI	Fe	Zn
Replications	2	29.82	0.20	16.26	46.79	5.48	0.60	1.90
Seasons	3	4292.67**	172.83**	666.12**	6681.23**	9016.71**	4488.23**	343.42**
Replications × Seasons	6	6.72	0.06	6.19	26.88	2.96	1.87	1.79
Hybrids	49	256.97**	20.97**	103.95**	749.58**	390.38**	994.78**	490.21**
Line effect	4	1104.94**	31.18**	191.45**	330.44**	477.19**	4416.95**	643.92**
Tester effect	9	434.50**	28.99**	70.52**	884.02**	337.09**	2669.49**	1335.62**
Line × Tester effect	36	118.37**	17.83**	102.58**	762.54**	394.06**	195.86**	261.78**
Seasons × Hybrids	147	29.40**	5.80**	18.68**	50.05**	128.51**	23.11**	24.68**
Seasons × Line effect	12	104.48**	12.80**	30.33**	55.96**	320.35**	38.68	41.44**
Seasons × Tester effect	27	21.45**	4.74	15.12**	32.70**	90.56**	33.13*	19.37**
Seasons × LT effect	108	23.04**	5.29**	18.28**	53.73**	116.69**	18.88**	24.14**
Error	392	3.25	0.45	3.00	9.92	9.36	2.07	1.28
Total	599	52.03	4.30	18.50	113.98	114.81	110.90	48.74

* : Significant at 5% level; ** : Significant at 1% level

GFY : Green fodder yield; SCMR : SPAD chlorophyll meter reading; HI : Harvest index; Zn : Grain Zn content
DFY : Dry fodder yield; RWC : Relative water content; Fe : Grain Fe content

(cm), 1000 grain weight (g), grain yield (t ha^{-1}), SPAD chlorophyll meter reading (SCMR), harvest index (%) and nutritional parameters grain Fe content (ppm) and grain Zn content (ppm). However, the parent ICMR 1809 registered as poor general combing ability effects in desirable direction for all the characters except harvest index (%) (Table 2).

Based on the above discussion, it could be concluded that among the tested 15 parents. The parent *viz*., ICMR 100556 was found to be good general combiner for grain yield and most of the yield characters, earliness and nutritional parameters grain Fe content (ppm) and grain Zn content (ppm). The parent ICMR 13999 was found be the good general combiner for grain yield and most of the yield characters and earliness. As *gca* effects are attributed to additive gene effects, the parents ICMR 100556 and ICMR 13999 might be considered as potential parents for pearl millet improvement programme aimed at yield, earliness and nutritional parameters grain Fe content (ppm) and grain Zn content (ppm).

Specific Combining Ability (*sca*) Effects

Based on the g*ca* effects of the parents involved in specific cross combinations, the hybrids may be grouped into three categories *viz*., good × good, good × poor or poor × good and poor × poor combinations. Most of the hybrids with high and significant *sca* effects did not involve both the parents with good *gca* effects. Contrary to this, hybrids involving parents possessing good *gca* effects did not result in significant *sca* effects in desired direction. The cross combinations with high and significant *sca* effects for more than one yield contributing characters would yield better hybrids. These types of hybrids could be better utilised in population improvement programme *via* recurrent selection so as to isolate superior parents.

Perusal of *sca* effects recorded in the present investigation for 50 hybrids in pooled analysis suggested that none of the cross combinations registered significant *sca* effects in desired direction for all the 15 characters studied. Hence, to decide the *sca* status of a cross, it is necessary to consider the *sca* effects for different characters. ICMB 98222 × ICMR 100584 is best suitable cross for Number of productive tillers $plant^{-1}$, ICMB 99222 × ICMR 08444 for plant height (cm), ICMB 08666 × ICMR 12555 for panicle length (cm), panicle girth (cm) and grain yield (t ha^{-1}), ICMB 04999 × ICMR 100089 for 1000 grain weight (g), ICMB 04999 × ICMR 100584 for green fodder yield (t ha^{-1}), ICMB 99222 × ICMR 100556 for dry fodder $yield^{-1}$ (t ha^{-1}), ICMB 04999 × ICMR 100549 for days to 50% flowering, ICMB 04999 × ICMR 100549 for days to maturity, ICMB 06111 × ICMR 100556 for SPAD chlorophyll meter readings (60 DAS), ICMB 04999 × ICMR 12555 for Relative water content, ICMB 08666 × ICMR 13999 for Harvest index (%), ICMB 08666 × ICMR 12555 for Grain Fe content (ppm), ICMB 06111 × ICMR 08444 for Grain Zn content (ppm). The top five hybrids in pooled over seasons, *viz*., ICMB 08666 × ICMR 12555, ICMB 99222 × ICMR 100587, ICMB 06111 × ICMR 08444, ICMB 04999 × ICMR 100549 and ICMB 98222 × ICMR 100584 recorded significant positive *sca* effects for grain yield. Among them, the hybrid ICMB 08666 × ICMR 12555 (good × poor) registered desirable and significant *sca* effects in all the four seasons *kharif, late kharif, rabi* and *summer* and pooled over seasons for number of productive tillers $plant^{-1}$, plant height (cm), panicle length (cm), panicle girth (cm), 1000 grain weight (g), grain yield (t ha^{-1}), days to 50% flowering, days to maturity, SPAD chlorophyll meter reading (SCMR), harvest index and nutritional parameters grain Fe content (ppm) and grain Zn content (ppm); The hybrid ICMB 06111 × ICMR 08444 (poor × poor) recorded significant positive *sca* effects in three seasons *kharif, late kharif* and *summer* for Number of productive tillers $plant^{-1}$, panicle length (cm), panicle girth (cm), 1000 grain weight (g), grain yield (t ha^{-1}), green fodder yield (t ha^{-1}), dry fodder yield (t ha^{-1}), days to 50% flowering, days to maturity, relative water content (%) and nutritional parameters grain Fe content (ppm) and grain Zn content (ppm) (Table 3).

Hence, these hybrids ICMB 08666 × ICMR 12555 (good × poor) and ICMB 06111 × ICMR 08444 (poor × poor) registered desirable and significant *sca* effects for most of yield components, earliness, SPAD chlorophyll meter reading (SCMR) and nutritional parameters grain Fe content (ppm) and grain Zn content (ppm). Hence these hybrids may be utilized in breeding high yielding hybrids coupled with earliness, drought and nutritional parameters grain Fe content (ppm) and grain Zn content (ppm). The importance of non-additive gene action as documented in this present study is in agreement with the findings of Mungra *et al.* (2015), Badurkar *et al.* (2018), Barathi *et al.* (2020), Anuradha *et al*., (2020), Anusha *et al*., (2021).

Table 2. Estimates of general combining ability effects (*gca*) of lines and testers for grain yield, morpho-physiological and nutritional traits in pooled over seasons

Parent(s)	Days to 50% flowering	Days to maturity	Number of Productive tillers plant^{-1}	Plant height (cm)	Panicle length (cm)	Panicle girth (cm)	1000 grain weight (g)	Grain yield (t ha^{-1})	Green fodder yield (t ha^{-1})	Dry fodder yield (t ha^{-1})	SPAD chlorophyll meter readings (60 DAS)	Relative water content (%)	Harvest index (%)	Grain Fe content (ppm)	Grain Zn content (ppm)
Lines															
ICMB 98222	-0.97**	-0.43**	0.10**	-1.71**	-0.43**	0.15**	0.59**	0.23**	-1.39**	-0.14*	2.11**	-0.67*	2.49**	5.23**	2.28**
ICMB 99222	0.89**	0.35**	-0.05**	-3.56**	-0.17	0.02	0.25**	-0.08**	-1.85**	0.37**	-1.31**	-1.69**	-2.31**	7.70**	0.94**
ICMB 08666	1.08**	0.42**	0.05**	7.20**	-0.83**	-0.04**	-0.09	0.09**	3.62**	0.56**	-0.25	2.33**	-1.77**	-2.80**	-0.73**
ICMB 04999	-0.13	0.67**	0.01	-0.97	0.38**	-0.18**	0.341**	-0.01	2.83**	-0.02	-0.28	1.08**	0.77**	-5.89**	-3.67**
ICMB 06111	-0.82**	-1.01**	-0.01	-0.97	1.06**	0.05**	-1.10**	-0.23**	-3.22**	-0.76**	-0.26	-1.05**	0.82**	-4.24**	1.18**
Testers															
ICMR 08444	0.02	0.32	0.03	3.85**	1.49**	-0.30**	-0.70**	-0.24**	-0.71**	0.38**	-1.65**	1.88**	-3.67**	-6.61**	-0.50**
ICMR 13999	1.59**	1.01**	0.04*	5.70**	1.96**	0.09**	1.04**	0.39**	3.02**	0.80**	0.57*	3.94**	0.65	-8.09**	-5.67**
ICMR 12555	-3.49**	-3.32**	0.10**	-3.52**	0.38*	-0.05**	-0.41**	-0.34**	-1.18**	-0.86**	0.21	-8.47**	-0.55	8.64**	6.59**
ICMR 100087	-0.56**	-0.88**	-0.04*	-10.90**	-0.33*	-0.12**	0.10	0.09**	-5.43**	-0.66**	0.60**	2.97**	2.83**	-6.23**	-0.22
ICMR 1809	-0.36*	-0.09	-0.02	-6.75**	-1.14**	-0.05**	0.10	-0.05*	-1.62**	-0.72**	-1.00**	0.38	2.82**	-3.17**	-8.95**
ICMR 100089	-0.56**	-0.20	-0.17**	-5.75**	-1.63**	-0.14**	-0.18	0.30**	1.89**	0.19*	1.65**	-0.10*	1.94**	-6.06**	-2.67**
ICMR 100549	-0.04	0.25	0.12**	2.23**	0.16	0.25**	0.59**	0.03	1.22**	1.02**	-0.26	0.92*	-2.20**	2.91**	2.23**
ICMR 100556	0.97**	1.25**	0.10**	5.93**	-0.06	0.24**	0.20	0.22**	1.86**	-0.10	1.31**	1.48**	2.00**	4.56**	3.38**
ICMR 100584	0.57**	0.01	0.04*	3.25**	-0.46**	0.05**	-0.70**	-0.35**	-2.08**	-0.65**	-1.25**	2.58**	-1.46**	8.20**	1.48**
ICMR 100587	1.86**	1.65**	-0.19**	5.96**	-0.37*	0.04*	-0.51**	-0.04	3.03**	0.60**	-0.18	-4.70**	-2.35**	5.86**	4.32**
S.E (g_i) Lines	**0.10**	**0.13**	**0.01**	**0.53**	**0.11**	**0.01**	**0.06**	**0.02**	**0.16**	**0.06**	**0.16**	**0.29**	**0.28**	**0.13**	**0.10**
S.E(g_i) Testers	**0.14**	**0.18**	**0.02**	**0.75**	**0.15**	**0.02**	**0.08**	**0.02**	**0.23**	**0.09**	**0.22**	**0.41**	**0.40**	**0.19**	**0.14**

* : Significant at 5% level; ** : Significant at 1% level

Table 3. Estimates of specific combining ability effects of 50 hybrids for grain yield, morpho-physiological and nutritional traits in pooled over seasons

Hybrid (s)	Days to maturity	Days to 50% flowering	Number of productive tillers $plant^{-1}$	Plant height (cm)	Panicle length (cm)	Panicle girth (cm)	1000 grain weight (g)	Grain yield (t ha^{-1})
ICMB 98222 × ICMR 08444	2.02**	0.72*	-0.05	4.07*	-0.13	-0.04	-0.17	0.23**
ICMB 98222 × ICMR 13999	-0.55	-1.10**	0.11 *	-8.38**	0.94**	0.19**	0.63**	0.22**
ICMB 98222 × ICMR 12555	0.47	0.48	-0.18 **	-16.64**	-3.18**	-0.226**	-1.87**	-0.33**
ICMB 98222 × ICMR 100087	-3.91**	-3.11**	-0.21**	-2.42	0.08	0.13**	0.34	-0.29**
ICMB 98222 × ICMR 1809	-3.43**	-2.23**	-0.42**	-10.72**	-0.74*	0.02	-1.13**	0.16**
ICMB 98222 × ICMR 100089	0.06	-0.45	0.03	4.63**	1.07**	-0.07	0.49**	-0.27**
ICMB 98222 × ICMR 100549	3.45**	1.20**	-0.29**	1.50	-2.11**	-0.18**	-0.89**	-0.20**
ICMB 98222 × ICMR 100556	0.32	0.18	0.32**	0.78	2.15**	0.07	1.45**	0.27**
ICMB 98222 × ICMR 100584	-1.31**	1.58**	0.68**	10.70**	2.71**	0.02	1.86**	0.60**
ICMB 98222 × ICMR 100587	2.88**	2.72**	0.02	16.48**	-0.79*	0.09*	-0.69**	-0.38**
ICMB 99222 × ICMR 08444	2.13**	0.36	0.22**	19.70**	0.76*	-0.12**	0.21	0.01
ICMB 99222 × ICMR 13999	-0.52	0.13	-0.21**	14.59**	-0.13	0.28**	-1.21**	-0.82**
ICMB 99222 × ICMR 12555	-1.16**	-0.29	0.11*	4.52**	-1.61**	-0.17**	-0.81**	-0.69**
ICMB 99222 × ICMR 100087	-0.41	-0.56	0.16**	3.25	0.80*	0.10*	0.52**	0.22**
ICMB 99222× ICMR 1809	-0.04	0.41	-0.12**	3.35*	0.30	0.05	0.36*	-0.23**
ICMB 99222 × ICMR 100089	-0.09	2.28**	0.30**	-13.48**	-0.65	-0.13**	-0.60**	0.11*
ICMB 99222 × ICMR 100549	2.26**	1.68**	0.31**	-10.02**	1.38**	-0.04	0.77**	0.55**
ICMB 99222 × ICMR 100556	-1.51**	-1.76**	-0.48**	-8.35**	-1.71**	0.04	-0.95**	0.11*
ICMB 99222 × ICMR 100584	-0.11	-0.69*	-0.32**	-6.26**	-1.55**	-0.16**	-0.21	-0.01
ICMB 99222 × ICMR 100587	-0.53	-1.56**	0.02	-7.28**	2.40**	0.15**	1.92**	0.74**
ICMB 08666 × ICMR 08444	-2.13**	-0.16	0.02	-8.10**	-0.57	0.08*	1.01**	-0.39**
ICMB 08666 × ICMR 13999	0.76	1.02**	0.24**	10.15**	0.70*	-0.16**	0.67**	0.43**
ICMB 08666 × ICMR 12555	-2.93**	-2.15**	0.66**	13.21**	5.08**	0.45**	2.34**	0.86**
ICMB 08666 × ICMR 100087	2.65**	2.25**	-0.01	10.18**	0.51	0.00	-0.78**	0.21**
ICMB 08666 × ICMR 1809	2.28**	0.97**	-0.18**	1.41	-0.55	0.10*	1.13**	0.26**

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Table 3. Cont...

Hybrid (s)	Days to maturity	Days to 50% flowering	Number of productive tillers plant^{-1}	Plant height (cm)	Panicle length (cm)	Panicle girth (cm)	1000 grain weight (g)	Grain yield (t ha^{-1})
ICMB 08666 × ICMR 100089	-2.16**	-1.50**	0.10*	4.81**	-0.82*	0.01	-1.91**	-0.28**
ICMB 08666 × ICMR 100549	1.08**	1.15**	-0.47**	-7.19**	-1.64**	-0.05	-1.27**	-0.69**
ICMB 08666 × ICMR 100556	-0.11	0.13	-0.05	-7.10**	-0.81*	-0.23**	-0.97**	-0.51**
ICMB 08666 × ICMR 100584	0.06	-0.96**	-0.23**	-2.02	-1.07**	-0.07	0.05	-0.19**
ICMB 08666 × ICMR 100587	0.51	-0.75*	-0.08	-15.35**	-0.82*	-0.13**	-0.27	0.29**
ICMB 04999 × ICMR 08444	0.86*	0.29	-0.29**	-3.90*	-0.75*	-0.13**	-1.53**	-0.52**
ICMB 04999 × ICMR 13999	-0.85*	-1.27**	0.11*	-9.75**	-2.24**	-0.36**	-1.28**	-0.24**
ICMB 04999 × ICMR 12555	3.84**	2.14**	-0.45**	-6.33**	-1.29**	-0.14**	-0.62**	0.16**
ICMB 04999 × ICMR 100087	1.40**	1.21**	0.10*	4.86**	-1.04**	-0.13**	-0.70**	-0.04
ICMB 04999 × ICMR 1809	0.24	1.09**	0.24**	3.28	0.66	0.01	0.60**	0.18**
ICMB 04999 × ICMR 100089	1.72**	0.21	-0.05	1.28	0.77*	0.28**	2.38**	0.37**
ICMB 04999 × ICMR 100549	-6.81**	-5.22**	0.67**	14.97**	4.02**	0.44**	1.75**	0.65**
ICMB 04999 × ICMR 100556	-0.95*	-0.49	0.06	-2.23	0.41	0.23**	0.80**	0.47**
ICMB 04999 × ICMR 100584	0.45	0.99**	-0.27**	-0.51	-0.09	0.07	-0.82**	-0.45**
ICMB 04999 × ICMR 100587	0.11	1.04**	-0.11*	-1.68	-0.46	-0.26**	-0.58**	-0.58**
ICMB 06111 × ICMR 08444	-2.87**	-1.21**	0.10*	-11.77**	0.70*	0.21**	0.49**	0.67**
ICMB 06111 × ICMR 13999	1.17**	1.23**	-0.25**	-6.61**	0.72*	0.05	1.19**	0.41**
ICMB 06111 × ICMR 12555	-0.22	-0.19	-0.14**	5.22**	1.01**	0.09*	0.95**	-0.00
ICMB 06111 × ICMR 100087	0.28	0.21	-0.02	-15.87**	-0.36	-0.09*	0.62**	-0.10
ICMB 06111 × ICMR 1809	0.96*	-0.24	0.49**	2.68	0.33	-0.18**	-0.95**	-0.38**
ICMB 06111 × ICMR 100089	0.48	-0.54	-0.39**	2.75	-0.36	-0.09*	-0.36*	0.08
ICMB 06111 × ICMR 100549	0.01	1.19**	-0.22**	0.75	-6.48**	-0.16**	-0.36*	-0.31**
ICMB 06111 × ICMR 100556	2.26**	1.93**	0.15**	16.89**	-0.04	-0.12**	-0.32	-0.33**
ICMB 06111 × ICMR 100584	0.91*	-0.92**	0.14**	-1.90	-0.00	0.14**	-0.88**	-0.04
ICMB 06111 × ICMR 100587	-2.98**	-1.46**	0.14**	7.84**	-0.34	0.15**	-0.37*	-0.08
S.E (S_{ij})	**0.32**	**0.40**	**0.04**	**1.67**	**0.34**	**0.04**	**0.18**	**0.05**
S.E (S_{ij}-S_{ik})	**0.45**	**0.57**	**0.06**	**2.36**	**0.48**	**0.06**	**0.26**	**0.08**
S.E (S_{ij}-S_{kl})	**0.35**	**0.43**	**0.05**	**1.83**	**0.38**	**0.04**	**0.20**	**0.06**

Cont...

Table 3. Cont...

Hybrid (s)	Green fodder yield (t ha^{-1})	Dry fodder yield (t ha^{-1})	SPAD chlorophyll meter readings (60 DAS)	Relative water content (%)	Harvest index (%)	Grain Fe content (ppm)	Grain Zn content (ppm)
ICMB 98222 × ICMR 08444	-3.36**	-1.85**	-2.70**	-0.56	8.99**	-2.24**	-2.59**
ICMB 98222 × ICMR 13999	3.82**	1.77**	-2.89**	3.04**	-5.93**	0.82*	2.57**
ICMB 98222 × ICMR 12555	-3.17**	-1.79**	-1.01*	-9.46**	6.47**	2.29**	-1.70**
ICMB 98222 × ICMR 100087	-0.93	-1.03**	-2.17**	4.43**	1.79*	5.10**	-5.38**
ICMB 98222 × ICMR 1809	1.98**	0.44*	2.17**	5.51**	-0.75	-2.59**	3.60**
ICMB 98222 × ICMR 100089	-1.93**	1.19**	1.01*	-16.10**	-7.06**	1.01*	-0.93**
ICMB 98222 × ICMR 100549	0.85	0.12	1.21*	5.40**	-3.59**	-4.98**	-0.58
ICMB 98222 × ICMR 100556	-3.08**	-0.88**	-0.30	5.58**	4.56**	-0.90*	-0.98**
ICMB 98222 × ICMR 100584	2.46**	1.15**	-0.82	6.48**	2.18*	-1.12**	2.17**
ICMB 98222 × ICMR 100587	3.34**	0.88**	5.42**	-4.31**	-6.67**	2.61**	3.83**
ICMB 99222 × ICMR 08444	0.60	-0.46*	3.54**	-4.21**	1.68	-3.02**	-8.24**
ICMB 99222 × ICMR 13999	2.07**	0.97**	-0.29	-6.43**	-9.42**	-0.15	3.66**
ICMB 99222 × ICMR 12555	-1.11*	-0.15	-3.79**	-8.69**	-6.73**	-4.48**	0.16
ICMB 99222 × ICMR 100087	-1.20*	-0.88**	3.66**	2.871**	5.17**	-3.84**	-2.29**
ICMB 99222× ICMR 1809	0.82	-0.13	-2.78**	8.71**	-2.68**	-2.23**	2.02**
ICMB 99222 × ICMR 100089	-1.57**	-0.55**	0.95	2.17*	3.05**	-1.12**	-2.09**
ICMB 99222 × ICMR 100549	1.27*	1.13**	-0.65	4.42**	1.01	6.29**	1.26**
ICMB 99222 × ICMR 100556	2.82**	1.956**	-0.40	-2.39**	-5.31**	6.21**	-0.88**
ICMB 99222 × ICMR 100584	-6.67**	-1.95**	-0.63	-7.66**	8.67**	5.30**	4.51**
ICMB 99222 × ICMR 100587	2.96**	0.05	0.39	11.21**	4.54**	-2.96**	1.87**
ICMB 08666 × ICMR 08444	0.38	1.48**	1.88**	-4.40**	-6.16**	-1.10**	8.89**
ICMB 08666 × ICMR 13999	-1.05*	-2.38**	-1.26*	1.12	12.12**	-5.93**	-4.17**
ICMB 08666 × ICMR 12555	0.29	-0.15	4.99**	0.95	5.44**	7.80**	2.60**
ICMB 08666 × ICMR 100087	-3.14**	0.09	0.84	-2.71**	1.76*	-1.83**	4.05**
ICMB 08666 × ICMR 1809	1.47**	-0.23	0.68	2.02*	2.54**	0.42	-1.13**

Cont...

Table 3. Cont...

Hybrid (s)	Green fodder yield (t ha^{-1})	Dry fodder yield (t ha^{-1})	SPAD chlorophyll meter readings (60 DAS)	Relative water content (%)	Harvest index (%)	Grain Fe content (ppm)	Grain Zn content (ppm)
ICMB 08666 × ICMR 100089	1.98**	-0.52**	-3.43**	5.51**	-0.66	0.32	-3.92**
ICMB 08666 × ICMR 100549	2.45**	-0.33	-3.76**	-9.35**	-5.94**	3.81**	1.68**
ICMB 08666 × ICMR 100556	-3.61**	-0.55**	-1.12*	-1.41	-2.09*	0.07	1.71**
ICMB 08666 × ICMR 100584	0.51	1.48**	0.45	0.84	-6.67**	-3.74**	-10.81**
ICMB 08666 × ICMR 100587	0.71	1.12**	0.73	7.43**	-0.34	0.16	1.09**
ICMB 04999 × ICMR 08444	-1.92**	-0.69**	-3.30**	3.60**	-4.11**	3.90**	-7.39**
ICMB 04999 × ICMR 13999	-5.54**	-0.27	4.83**	-0.90	-0.90	1.41**	1.02**
ICMB 04999 × ICMR 12555	0.72	0.97**	-0.15	13.70**	-1.95*	-7.04**	2.76**
ICMB 04999 × ICMR 100087	3.90**	0.65**	-0.79	-0.07	-2.69**	-1.19**	-1.68**
ICMB 04999 × ICMR 1809	-0.55	0.49*	1.83**	1.77	2.50**	3.52**	-2.95**
ICMB 04999 × ICMR 100089	1.89**	-0.01	0.64	3.82**	3.55**	-2.60**	5.52**
ICMB 04999 × ICMR 100549	-1.27*	0.94**	4.81**	-1.77	5.16**	-4.43**	2.61**
ICMB 04999 × ICMR 100556	2.44**	-0.43*	-3.68**	1.09	6.45**	0.49	2.22**
ICMB 04999 × ICMR 100584	4.92**	-0.14	-0.29	-0.68	-6.49**	1.93**	2.37**
ICMB 04999 × ICMR 100587	-4.60**	-1.51**	-3.91*	-20.56**	-1.51	3.11**	-4.47**
ICMB 06111 × ICMR 08444	4.29**	1.52**	0.57	5.57**	-0.40	2.46**	9.34**
ICMB 06111 × ICMR 13999	0.69	-0.10	-0.39	3.17**	4.14**	3.85**	-3.08**
ICMB 06111 × ICMR 12555	3.26**	1.12**	-0.04	3.50**	-3.23**	1.42**	-3.84**
ICMB 06111 × ICMR 100087	1.37**	1.17**	-1.54**	-4.52**	-6.03**	1.77**	5.30**
ICMB 06111 × ICMR 1809	-3.72**	-0.56**	-1.90**	-18.02**	-1.61	0.87*	-1.55**
ICMB 06111 × ICMR 100089	-0.37	-0.11	0.82	4.61**	1.11	2.38**	1.42**
ICMB 06111 × ICMR 100549	-3.32**	-1.86**	-1.68**	1.30	3.36**	-0.69	-4.98**
ICMB 06111 × ICMR 100556	1.43**	-0.09	5.51**	-2.87**	-3.62**	-5.87**	-2.07**
ICMB 06111 × ICMR 100584	-1.22*	-0.54**	1.28*	1.02	2.31**	-2.38**	1.77**
ICMB 06111 × ICMR 100587	-2.41**	-0.54**	-2.63**	6.23**	3.97**	-3.82**	-2.32**
S.E (S_{ij})	**0.52**	**0.19**	**0.50**	**0.91**	**0.88**	**0.41**	**0.33**
S.E (S_{ij}-S_{ik})	**0.73**	**0.27**	**0.70**	**1.29**	**1.25**	**0.59**	**0.46**
S.E (S_{ij}-S_{kl})	**0.57**	**0.21**	**0.55**	**1.00**	**0.97**	**0.45**	**0.36**

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