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Research Article

Combining ability analysis in Finger millet (*Eleusine coracana* (L.) Gaertn.) under salinity

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Abstract

Six lines and four testers differing in their response to salinity were hybridized in Line x Tester design and combing ability for ten quantitative traits and Na-K ratio was investigated. The study revealed total variance due to lines x testers was significant for all the characters under investigation. Variance due to *sca* was higher for all the characters indicating preponderance of non-additive gene action. On the basis of *per se* performances and *gca* effects GPU28, CO12 and Vl 149 were identified as best combiners for majority of the traits including grain yield per plant and Na^+: K^+ ratio. Based on *per se* performance, *sca* effects and standard heterosis, GPU28 x CO13 and CO12 x TRY1 were promising hybrids for grain yield . Based on significant *gca* effects of parents and non significant *sca* effects it is suggested for recombination breeding to develop tolerance under saline condition.

Key words: Finger millet, combining ability, salinity.

Introduction

Over 800 million hectares of land, six per cent of the total world's area, are salt affected either by salinity or sodicity (FAO, 2005). Irrigation with poor quality water and contamination of under ground water by salts has further enhanced the problem of soil salinity (Chinnusamy *et al*., 2005). Increasing the yield of crop plants in normal soils and in less productive lands, including salinized lands, is an absolute requirement for feeding the world (Yamaguchi and Blumwald, 2005). The use of some management options can ameliorate yield reduction under salinity stress. However, implementation of such practice is often limited because of high cost and availability of good quality water. Therefore, the need for genetic improvement of salt tolerance is great and is expected to increase dramatically in the future (Zeng *et al*., 2002).

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Finger millet which is a hardiest crop, known for its resilience and ability to provide assured harvest even under environmentally fragile habitats *viz.,* saline (Kaliappan *et al.,*1967) and alkaline (Rachie and Peters,1982) could be considered as a potential crop for problematic soils. In general, tolerance of a crop variety is found to be associated with its ability to restrict potentially toxic ion uptake like Na^+ and associated with preferential uptake of the balancing ion like K^+ (Hasegawa *et al*., 2000). Although the uptake of both Na and K is entirely independent, lower Na^+ and K^+ ratio is considered a desirable trait for salt tolerance (Singh and Mishra, 2005).

Among cereals barley is the most salt tolerant and rice is the least tolerant (Munns and Tester, 2008). Finger millet, though comparable to barley in terms of salt tolerance, is yet to be exploited as evident from very limited studies on combining ability for salt tolerance. Hence, the present study was undertaken with the objectives of (1) to estimate the *gca* of parents and *sca* of hybrids, (2) to understand the nature of gene action of various traits associated with salt stress and (3) to identify superior crosses for heterosis and recombination breeding.

Material and Methods

The experimental material consisted of ten finger millet genotypes *viz.,* CO 12, GPU 48, Indaf 5 and CO 13 (highly salt tolerant), TRY 1, VL 149, GPU 28 and PR 202 (moderately tolerant), CO 9 (moderate susceptible) and CO 11 (highly susceptible) as parents. Among the ten genotypes, four genotypes *viz.* VL 149, GPU 48, CO 13, and TRY 1 were used as testers because of the presence of purple pigmentation either at node or leaf margin or finger (so that true F_1 s could be fixed easily) and six genotypes *viz.,* CO 11, Indaf 5, PR 202, GPU 28, CO 12 and CO 9, irrespective of their salt tolerance were used as lines as they did not possess the purple pigmentation. Hand emasculation cum contact method of pollination as suggested by Ayyangar (1934) was adopted. Seeds of all the 24 hybrids and their respective parents were raised in randomized block design, replicated thrice with a spacing of 15 x 30 cm at Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal during June, 2005, under normal soil and subjected to salt stress with borewell water. The quality parameters of the irrigation water is given below:

Source	EC (dsm^{-1})	pH	SAR	RSC ($meql^{-1}$)
Soil	0.90	7.65	-	-
Irrigation water	2.44	8.40	22.40	18.60

The purpose of using irrigation water in the study was to impose salinity stress to growing plants and as per Gupta *et al*. (1994) classification the irrigation water used in the study is classified as saline sodic.

Plants were chosen at random and observations were made on days to 50 per cent flowering (days), plant height (cm), tillers per plant, productive tillers per plant, finger number per earhead, finger length (cm), grain number per earhead, 1000 grain weight (g), grain weight per earhead (g) and grain yield per plant (g) and Na^+: K^+ ratio**.** Na and K content in leaf samples at panicle initiation stage was estimated by adopting the method suggested by Stanford and English (1949) using flame photometer and a standard curve was fit and the values expressed in ppm. The contents of sodium and potassium in ppm were further converted in millimolar per gram dry weight (mmol g^{-1}dwt) as suggested by Munns (2005) which is described in two steps as below.

$$Na^+ \text{ or } K^+ \text{ content (mg / g)} = \frac{Na^+ \text{ or } K^+ \text{ (ppm)} \times 100}{\text{Weight of the sample} \times 2}$$

$$Na^+ \text{ or } K^+ \text{ content (mmol } g^{-1}\text{dwt)} = \frac{Na^+ \text{ or } K^+ \text{ (mg / g)}}{\text{Mol. Wt of } Na^+ \text{ or } K^+}$$

Further Na^+: K^+ ratio was calculated as ratio of content of Na to content of K. Lesser the Na^+: K^+ ratio better will be the salt tolerance.

The combining ability analysis was carried out as per the method suggested by Kempthorne (1957).

Results and Discussion

Significant differences were observed among the genotypes for all the 11 characters studied as revealed by analysis of varaiance. The Line x Tester interaction was significant for all the characters under investigation (Table 1).

The mean performance and *gca* effects of lines and testers are given in Table 2 and 3. Based on mean performance of different traits CO 12, GPU 28 and Indaf 5 among lines and TRY 1 and Co 13, among tester, were found to be better. The evaluation of the parents for their *gca* effects revealed that none of them proved best for all the characters studied. However, among the lines, CO 12 was the best combiner for ten out of 11 traits, followed by GPU 28 for nine traits and among testers VL 149 was superior for eight traits. All the three genotypes were both salt tolerant and high yielders. Evaluation of the parents based on mean performance and *gca* effects, revealed that among the lines, CO 12 was found to be superior followed by GPU 28, as it has shown high mean performance coupled with high *gca* effects for most of the traits. Even though CO 12 ranked better, the line GPU 28 was considered better for both grain yield and Na^+: K^+ ratio.

Similarly, among the testers TRY 1 and VL 149 were better performers. VL 149 was the best combiner for eight out 11 traits studies followed by TRY 1 for five traits. However, VL 149 was considered better as TRY 1 was a negative combiner for yield

Hence, these three genotypes *viz.,* GPU 28, CO 12 and VL 149 can be utilized in hybridization programme to get superior recombinants in the desirable direction.

The mean performance of hybrids, sca effects and standard heterosis of hybrids are presented in Tables 4, 5 and 6. The hybrid CO 12 x TRY 1 showed desirable *sca* effect for 10 out of eleven traits, followed by CO 12 x CO 13 and CO 9 x TRY 1 for eight traits and Indaf 5 x VL 149 for seven traits. These had favourable *sca* effect for grain yield per plant also. However, 11 of the 24 hybrids exhibited *sca* effect on desirable direction for both grain yield and salt tolerance (Na^+ : K^+ ratio). The desirable *sca* effects might have been due to low x low, high x high or high x low combiners. These crosses need to be evaluated further to confirm their superiority and could be used for generation advancement to select and derive elite genotypes.

Evaluation of hybrids based on the parameters viz., *per se* performance, *sca* effects and standard heterosis (TRY 1) is considered effective in selection of superior hybrids. CO 12 x TRY 1 followed by GPU 28 x CO 13 and CO 12 x CO 13 were superior for all the three parameters considered for most of the traits studied. However GPU 28 x CO 13 and CO 12 x TRY 1 could be utilized for heterosis breeding under salt stress condition, as they were superior for both Na^+ : K^+ ratio and grain yield per plant.

The proportional contribution of lines x testers to total variance (Table 7) revealed significant contribution of lines for most of the characters studied.

The magnitude of SCA variance was higher than GCA variance with GCA / SCA variance less than unity, indicating the pre dominance of non-additive gene action governing all the traits under salt stress condition. Similar results were also reported by Veena (1996), Mahadevaiah (2002) and Sumathi *et al.* (2005) in finger millet under non stress condition. Gregorio and Senadhira (1993) and Mishra (1995) reported on both additive and non additive gene action governing Na^+ : K^+ ratio in rice under saline condition. Hence postponing selection to later generations, is likely to culminate in isolation of superior genotypes as suggested by Panse (1942). Recurrent selection could also be adopted for the improvement of traits in self pollinated crops as reported by Compton (1968). Improvement of traits governed by non-additive genes (due to high SCA variance) would be achieved through hybridization among selected parents which may induce high *sca* effects in the crosses.

Conclusion

On the basis of *per se* performance and *gca* effects, the parents GPU 28, CO 12 and TRY 1 were identified as the best combiners for majority of the traits including grain yield per plant and Na^+: K^+ ratio. Hence these genotypes could be utilized in breeding programme for improvement of grain yield under salt stress.

Evaluation based on *per se* performance, *sca* effects and standard heterosis resulted in the identification of GPU 28 x CO 13 and CO 12 x TRY 1 as the best hybrids for heterosis breeding. Based on the significant *gca* effects of parents and non significant *sca* effects of hybrids, GPU 28 x GPU 48 was found to be superior for grain yield, and hence could be exploited through recombination breeding to get desirable segregants.

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Table 1. Analysis of variance for different characters

Source of variance	df	Mean square										
		DF	PH (cm)	TP	PT	FN	FL (cm)	GN	TGW (g)	GW (g)	$Na^+ : K^+$ ratio	GY (g)
Genotypes	33	94.49**	219.46**	2.64**	2.69**	0.78**	0.94**	152979.5**	0.43**	1.81**	0.105**	15.13**
Lines	5	186.08**	256.14	8.15**	7.14**	1.60**	0.69	142442.73*	0.98**	3.84**	0.15*	24.91**
Testers	3	54.20	332.19	0.80	0.33	0.28	0.23	20945.35	0.58	0.26	0.08	1.33
L x T	15	38.33**	155.01**	1.76**	1.86**	0.32**	0.64**	44414.81**	0.21**	0.99**	0.06**	3.77**
Error	66	0.50	0.74	0.13	0.07	0.05	0.01	2.63	0.02	0.01	0.0002	0.0004
GCA	-	0.86	1.14	0.03	0.02	0.01	-0.001	460.23	0.01	0.01	0.0005	0.11
SCA	-	27.92	78.55	1.04	0.94	0.21	0.17	21554.23	0.17	0.52	0.03	2.97
GCA/ SCA	-	0.03	0.02	0.03	0.02	0.05	-0.006	0.02	0.03	0.02	0.02	0.04

DF = Days to 50 % flowering PH = Plant height TP = Tillers per plant

PT = Productive tillers per plant FN = Finger number per earhead FL = Finger length

GN = Grain number per earhead TGW = 1000 grain weight GW = Grain weight per earhead

GY = Grain yield

Significance at 5% level ** Significance at 1% level

Table 2. Mean performance of parents for different characters

Parents	DF	PH (cm)	TP	PT	FN	FL (cm)	GN	TGW(g)	GW(g)	$Na^+ : K^+$ ratio	GY (g)
Lines											
CO 11	80.33	81.89	4.03	3.17	6.20	6.11	1602.42	2.17	3.85	0.83	13.87
GPU 28	74.33	80.57	6.12**	5.52**	8.13**	8.12**	2089.54	2.50	6.01**	0.30**	20.04**
Indaf 5	73.67	85.76	6.05**	5.50**	7.65	7.18	2072.49	2.23	6.15**	0.37	20.25**
PR 202	71.67	78.53	5.08	4.04	7.70	7.02	1823.13	2.77	5.23	0.68	17.40
CO 12	61.00**	85.40	5.25	5.10**	8.20**	7.63*	2246.34**	3.03**	6.10**	0.25**	19.02
CO 9	67.33	65.60**	4.52	3.53	6.93	5.55	1086.65	2.23	3.50	0.90	14.86
Testers											
VL 149	74.67	92.07	4.78	4.25	7.78	8.02**	2000.43	2.70	5.73	0.41	17.55
GPU48	74.33	79.07	4.28	4.23	7.72	7.43	2001.73	2.87**	5.62	0.33**	17.88
CO 13	73.33	89.04	5.16	4.77	8.50**	7.47	2301.72**	2.47	5.25	0.30**	19.95**
TRY 1	57.33**	61.95**	6.32**	5.60**	7.88	7.25	2013.60	3.30**	5.98**	0.28**	21.05**
Mean	70.80	79.99	5.16	4.57	7.67	7.18	1923.78	2.63	5.34	0.47	18.19
S.E.(M)	1.23	1.70	0.14	0.16	0.12	0.14	62.44	0.07	0.17	0.04	0.42
C.D.(5%)	3.48	4.81	0.40	0.45	0.34	0.40	176.58	0.19	0.48	0.11	1.19
C.D.(1%)	3.73	5.16	0.43	0.49	0.36	0.42	189.57	0.21	0.52	0.12	1.28

* Significance at 5% level ** Significance at 1% level

DF = Days to 50 % flowering PH = Plant height TP = Tillers per plant
PT = Productive tillers per plant FN = Finger number per earhead FL = Finger length
GN = Grain number per earhead TGW = 1000 grain weight GW = Grain weight per earhead
GY = Grain yield

Table 3. General combining ability effects of parents for different characters

Parents	DF	PH (cm)	TP	PT	FN	FL (cm)	GN	TGW (g)	GW(g)	Na^{+} : K^{+} ratio	GY (g)
Lines											
CO 11	4.431**	3.329**	-0.673**	-0.529**	-0.264**	-0.077**	-9.335**	-0.149**	-0.182**	0.045**	-1.685**
GPU 28	3.097**	5.788**	0.848**	1.036**	0.496**	0.308**	112.716**	0.493**	0.798**	-0.205**	2.005**
Indaf 5	1.764**	3.217**	-0.832**	-0.601**	0.180**	-0.300**	-113.513**	-0.307**	-0.658**	0.091**	-0.531**
PR 202	-1.569**	-3.800**	-0.739**	-0.818**	-0.549**	0.265**	-142.830**	0.043	-0.522**	0.042**	-1.386**
CO 12	-6.403**	-3.575**	0.618**	0.159*	0.138*	-0.156**	104.470**	0.110**	0.100**	-0.041**	0.659**
CO 9	-1.319**	-4.958**	0.778**	0.753**	-0.002	-0.039**	48.495**	-0.190**	0.464**	0.069**	0.940**
S.E.	0.204	0.249	0.104	0.074	0.063	0.025	0.469	0.040	0.034	0.004	0.006
Testers											
VL 149	-0.514**	5.062**	0.244**	0.196**	0.147**	0.045*	48.267**	0.063	-0.043	-0.096**	0.353**
GPU48	2.264**	-1.236**	-0.028	-0.057	-0.010	-0.031	-7.011**	-0.243**	0.077**	0.031**	0.054**
CO 13	0.153	1.320**	-0.265**	0.111	-0.159**	-0.139**	-31.936**	-0.004	-0.149**	0.053**	-0.281**
TRY 1	-1.903**	-5.145**	0.049	-0.028	0.022	0.123**	-9.319**	0.185**	0.115**	0.012**	-0.126**
S.E.	0.166	0.203	0.085	0.061	0.051	0.020	0.383	0.033	0.028	0.003	0.005

* Significance at 5% level ** Significance at 1% level `

Table 4 : Mean performance of hybrids for different characters

Hybrids	DF	PH (cm)	TP	PT	FN	FL (cm)	GN	TGW (g)	GW(g)	$Na^+ : K^+$ ratio	GY (g)
L1/T1	80.33	85.42	5.85**	5.67**	7.63	7.30	2100.01**	2.30	6.01**	0.30**	21.08
L1/T2	81.00	74.20**	4.67	4.67	7.43	7.01	2007.82	2.20	5.71	0.43	19.68
L1/T3	75.67	83.83	4.15	4.03	7.20	6.88	2000.88	2.30	4.94	0.58	18.61
L1/T4	74.33	79.17	4.00	3.60	7.05	7.52*	1952.31	2.63*	4.86	0.73	17.72
L2/T1	75.33	82.97	6.03**	5.75**	8.08**	7.43	2098.43**	3.03**	6.06**	0.22**	22.68**
L2/T2	74.33	83.00	6.53**	6.42**	8.15**	7.62*	2163.60**	2.57	6.72**	0.28**	23.09**
L2/T3	77.67	84.37	6.18**	6.18**	8.18**	7.89*	2213.60**	3.10**	6.65**	0.21**	23.85**
L2/T4	78.67	82.11	6.01**	5.88**	7.95**	7.32	2073.60*	3.20**	6.00**	0.32**	22.23**
L3/T1	74.67	79.00	5.62	5.62**	7.82**	7.21	1983.21	2.20	4.48	0.42	21.19
L3/T2	76.00	83.67	4.51	4.51	7.92**	6.76	1910.33	2.37	4.98	0.52	20.55
L3/T3	72.33	81.17	4.56	4.56	7.83**	6.82	1899.33	2.13	4.21	0.63	20.11
L3/T4	77.67	78.33	3.34	3.34	7.53	7.03	1851.44	2.00	5.94**	0.65	19.86
L4/T1	67.33**	81.77	3.89	3.89	7.43	7.33	1821.97	2.93**	4.87	0.46	19.13
L4/T2	75.67	75.50	4.50	4.50	7.27	8.12	1901.13	1.97	5.21	0.50	20.05
L4/T3	72.67	64.50**	4.43	4.43	6.32	7.41	1792.91	2.50	5.01	0.66	19.01
L4/T4	71.67*	71.50**	5.58	5.58**	7.17	7.21	2011.04	2.70**	5.05	0.41	20.09
L5/T1	64.00**	76.83	5.36	4.33	7.50	6.53	2021.13	2.77**	5.12	0.51	20.29
L5/T2	72.67	74.33**	5.50	4.45	7.42	6.83	2123.20**	2.57	5.10	0.63	21.07
L5/T3	70.67**	87.17	6.13**	5.86**	7.93**	7.36	2170.61*	2.27	6.31**	0.30**	22.50**
L5/T4	60.67**	56.67**	6.83**	6.08**	8.08**	7.67**	2201.30**	2.77**	6.11**	0.25**	22.61**
L6/T1	75.67	88.33	6.75**	6.10**	7.98**	8.01**	2412.40	2.13	6.56**	0.29**	23.49**
L6/T2	74.33	64.83**	6.17**	5.92**	7.31	7.00	1999.40	1.77	6.10**	0.62	21.63**
L6/T3	72.33	71.00**	4.99	4.99	7.15	6.33	1878.61	2.57	5.34	0.72	19.98**
L6/T4	66.00**	65.30**	6.57**	6.08**	7.92**	7.52**	2001.93	2.70**	6.10**	0.50	22.49
Grand mean	73.40	77.32	5.34	5.02	7.59	7.26	2024.59	2.48	5.56	0.46	20.96
S.E.	0.58	0.95	0.12	0.12	0.06	0.05	16.79	0.04	0.08	0.02	0.19
C.D. (5%)	1.64	2.69	0.34	0.34	0.17	0.14	47.48	0.11	0.23	0.06	0.54
C.D. (1%)	1.76	2.88	0.36	0.36	0.18	0.15	50.97	0.12	0.24	0.06	0.58

DF = Days to 50 % flowering; PH = Plant height; TP = Tillers per plant

PT = Productive tillers per plant; FN = Finger number per earhead; FL = Finger length

GN = Grain number per earhead; TGW = 1000 grain weight; GW = Grain weight per earhead

LI = CO 11; L2 = GPU 28; L3 = Indaf 5; L4 = PR 202; L5 = CO 12; L6 = CO 9

T1 = VL 149; T2 = GPU48; T3 = CO 13; T4 = TRY 1

Table 5. Specific combining ability effects of hybrids for different characters

Hybrids	DF	PH (cm)	TP	PT	FN	FL (cm)	GN	TGW (g)	GW(g)	$Na^+ : K^+$ ratio	GY (g)
L1/T1	3.014**	-0.295	0.935**	0.979**	0.156	0.075	36.488**	-0.196*	0.676**	-0.113**	1.455**
L1/T2	0.903*	-5.217**	0.028	0.232	0.113	-0.134**	-0.424	0.110	0.252**	-0.113**	0.350**
L1/T3	-2.319**	1.853**	-0.248	-0.347*	0.029	-0.163**	17.561**	-0.029	-0.292**	0.018*	-0.378**
L1/T4	-1.597**	3.658**	-0.715**	-0.864**	-0.299*	0.222**	-53.626**	0.115	-0.636**	0.209**	-1.427**
L2/T1	-0.653	-5.207**	-0.400	-0.503**	-0.156	-0.184**	-87.144**	-0.004	-0.258**	0.060**	-0.635**
L2/T2	-4.431**	1.123*	0.368	0.417**	0.071	0.084	33.304**	-0.165*	0.289**	-0.010	0.074**
L2/T3	1.014*	-0.058	0.261	0.238	0.250	0.466**	108.226**	0.129	0.224**	-0.098**	1.168**
L2/T4	4.069**	4.142**	-0.229	-0.152	-0.165	-0.366**	-54.388**	0.040	-0.476**	0.049**	-0.607**
L3/T1	0.014	-6.603**	0.865**	1.000**	-0.100	0.205**	2.865**	-0.038	-0.375**	-0.037**	0.411**
L3/T2	-1.431**	4.360**	0.027	-0.196	0.153	-0.164**	6.260**	0.435**	-0.002	-0.063**	0.070**
L3/T3	-2.986**	-0.694	0.321	0.255	0.216	0.004	20.188**	-0.038	-0.543**	0.018*	-0.036**
L3/T4	4.403**	2.937**	-0.213**	-1.059**	-0.269*	-0.045	-50.315**	-0.360**	0.920**	0.082**	-0.444**
L4/T1	-3.986**	3.179**	-0.950**	-0.566**	0.235	-0.234**	-108.058**	0.346**	-0.121	0.052**	-0.791**
L4/T2	1.569**	4.210**	-0.071	0.020	0.235	0.634**	26.377**	-0.315**	0.099	-0.041**	0.421**
L4/T3	0.681	-10.511**	0.091	-0.259	-0.569**	0.033	-56.918**	-0.021	0.124	0.101**	-0.278**
L4/T4	1.736	3.120**	0.930**	0.805**	0.100	-0.433**	138.598**	-0.010	-0.102	-0.112**	0.647**
L5/T1	-2.486**	-1.978**	-0.837**	-1.043**	-0.379**	-0.613**	-156.197**	0.113	-0.500**	0.186**	-1.679**
L5/T2	3.403**	1.819**	-0.428*	-0.676**	-0.305*	-0.235**	1.151	0.218**	-0.637**	0.172**	-0.597**
L5/T3	3.514**	12.097**	0.438*	0.788**	0.354**	0.403**	73.483**	-0.321**	0.802**	-0.173**	1.161**
L5/T4	-4.431**	-11.937**	0.827**	0.931**	0.330*	0.444**	81.562**	-0.010	0.335**	-0.185**	1.116**
L6/T1	4.097**	10.904**	0.388	0.134	0.245	0.751**	291.044**	-0.221**	0.579**	-0.148**	1.240**
L6/T2	-0.014	-6.297**	0.077	0.204	-0.268*	-0.185**	-66.671**	-0.282**	-0.001	0.056**	-0.318**
L6/T3	0.097	-2.686**	-0.865**	-0.675**	-0.279*	-0.743**	-162.542**	0.279**	-0.536**	0.134**	-1.637**
L6/T4	-4.181**	-1.921**	0.400	0.338*	0.303*	0.178**	-61.833**	0.224**	-0.042	-0.042**	0.715**

DF = Days to 50 % flowering; PH = Plant height; TP = Tillers per plant

PT = Productive tillers per plant; FN = Finger number per earhead; FL = Finger length

GN = Grain number per earhead; TGW = 1000 grain weight; GW = Grain weight per earhead

LI = CO11; L2 = GPU 28; L3 = Indaf 5; L4 = PR202; L5 = CO 12; L6 = CO 9

T1 = VL 149; T2 = GPU 48; T3 = CO 13; T4 = TRY 1

Table 6. Extent of standard heterosis (%) for different characters.

Hybrids	DF	PH	TP	PT	FN	FL	GN	TGW	GW	$Na^+ : K^+$ ratio	GY
L1/T1	40.12**	37.89**	-7.49*	1.19	-3.17	0.64	4.29**	33.33**	0.50	7.14*	0.14*
L1/T2	41.28**	19.78**	-26.16**	-16.67**	-5.71**	-3.31**	-0.29**	-33.33**	-4.57**	52.38**	-6.52**
L1/T3	31.98**	35.32**	-34.28**	-27.98**	-8.67**	-5.19**	-0.63**	-30.30**	-17.45**	107.14**	-11.58**
L1/T4	29.65**	27.80**	-36.71**	-35.71**	-10.53**	3.72**	-3.04**	-20.20**	-18.79**	160.71**	-15.82**
L2/T1	31.40**	33.93**	-4.59	2.68	2.50	2.39**	4.21**	-8.08**	1.28	-20.24**	7.74**
L2/T2	29.65**	33.99**	3.27	14.58**	3.38*	5.01**	7.45**	-22.22**	12.43**	0.00	9.69**
L2/T3	35.47**	36.20**	-2.16	10.42**	3.76*	8.78**	9.93**	-6.06*	11.26**	-23.81**	13.30**
L2/T4	37.21**	32.55**	-4.96	4.94	0.80	0.92	2.98**	-3.03	0.28	14.29**	5.61**
L3/T1	30.23**	27.53**	-11.13**	0.30	-0.80	-0.64	-1.50**	-33.33**	-25.03**	51.19**	0.67**
L3/T2	32.56**	35.06**	-28.69**	-25.60*	0.42	-6.80**	-5.13**	-28.28**	-16.78**	86.91**	-2.38**
L3/T3	26.16**	31.06**	-27.80**	-18.51**	-0.68	-5.97**	-5.68**	-35.35**	-29.60**	123.81**	-4.47**
L3/T4	35.47**	26.45**	-47.10**	-40.48**	-4.52**	-3.03**	-8.05**	-39.39**	-0.73	132.14**	-5.67**
L4/T1	17.44**	32.00	-38.40**	-31.55**	-5.79**	1.10	-9.52**	-11.11**	-18.51**	65.48**	-9.11**
L4/T2	31.98**	23.49**	-28.80**	-25.60**	-7.78**	11.99**	-5.59**	-40.40**	-12.82**	77.38**	-4.77**
L4/T3	26.74**	3.85**	29.96**	-31.55**	-19.87**	2.21**	-10.96**	-24.24**	-16.17**	135.71**	-9.68**
L4/T4	25.00**	15.42**	-11.71**	-11.07**	9.09**	-0.60	-0.13*	-18.18**	15.55**	45.24**	-4.55**
L5/T1	11.63**	24.03**	-15.14**	-22.62**	-4.86**	-9.93**	0.37**	16.16**	14.44**	83.33**	-3.61**
L5/T2	26.74**	20.00**	-12.98**	-20.60**	-5.92**	-5.79**	5.44**	-22.22**	14.72**	123.81**	0.11
L5/T3	23.25**	40.71**	-3.01	4.58	0.55	1.52*	7.80**	-31.31**	5.57**	8.33**	6.87**
L5/T4	5.81**	-8.52**	8.12*	8.63**	2.54	5.70**	9.32**	-16.16**	2.17	-10.71**	7.40**
L6/T1	31.98**	42.60**	6.80	8.99**	1.27	10.48**	19.81**	-35.35**	9.70**	3.57	11.59**
L6/T2	29.65**	4.66**	-2.43	5.71*	-7.23**	-3.49**	-0.71**	-46.47**	2.01	121.43**	2.77**
L6/T3	26.16**	14.62**	-12.10**	-10.95**	-9.26**	-12.68**	-6.70**	-22.22**	-10.70**	157.14**	-5.08**
L6/T4	15.12**	5.41**	3.90	8.63**	0.42	3.63**	-0.58**	-18.18**	1.95	76.76**	6.83**
S.E.	0.41	0.50	0.21	0.15	0.13	0.05	0.94	0.08	0.07	0.008	0.04

* Significance at 5% level ** Significance at 1% level

DF	=	Days to 50% flowering	PH	=	Plant height	TP	=	Tillers per plant
PT	=	Productive tillers per plant	FN	=	Finger number per earhead	FL	=	Finger length
GN	=	Grain number per earhead	TGW	=	1000 grain weight	GW	=	Grain weight per earhead

LI = CO 11 L2 = GPU 28 L3 = Indaf 5 L4 = PR 202 L5 = CO 12 L6 = CO9

TI = VL 149 T2 = GPU 48 T3 = CO 13 T4 = TRY 1

Table7. Proportional contribution of lines, tester and line x tester to total variance

Characters	Proportional contribution		
	Lines (per cent)	Testers (per cent)	Line x Tester (per cent)
Days to 50 per cent flowering	55.78	9.75	34.47
Plant height	27.83	21.65	50.52
Tillers per plant	58.58	3.45	37.97
Productive tillers per plant	55.24	1.53	43.23
Finger number per earhead	58.42	6.24	35.35
Finger length	25.21	4.96	69.83
Grain number per earhead	49.42	4.36	46.22
1000 grain weight	49.77	17.71	32.52
Grain weight per earhead	55.15	2.22	42.63
Na^+ : K^+ ratio	67.31	2.16	30.53
Grain yield per plant	39.23	12.63	48.14