Electronic Journal of Plant Breeding, 9 (1) : 116 - 123 (Mar 2018) DOI: 10.5958/0975-928X.2018.00014.5
ISSN 0975-928X

Research Article

Combining ability of rice genotypes under coastal saline conditions

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(Received: 14 Aug 2017; Revised: 18 Mar 2018; Accepted: 18 Mar 2018)

Abstract
Information on combining ability is derived from data on eleven yield and yield contributing characters in twelve male and four female parents utilised in line x tester fashion to estimate combining ability of rice genotypes under coastal saline condition. Dandi, Kalarata, NVSR 6108, Panvel 1 and NAUR 1 found the most promising parents on the basis of their combining bility and per se performance and hence they could be used extensively in breeding programme for improving grain yield in rice under coastal salt affected soil. Also, it could be concluded from this study that the parents differed in their combining ability effect for different traits and that no parent can be good combiner for all the traits under coastal saline condition.

Key words
Rice, L x T analysis, combining ability, gene action

Introduction
Rice is an important cereal crop in India. It is grown mainly in tropical and subtropical zones. The productivity of rice is being affected by biotic and abiotic factors. Among the various abiotic factors, coastal salinity is an important yield limiting factor. The salinity affects rice crop during different growth stages. The salinity at reproductive stage has adverse effect on spikelet fertility and thus limits grain yield (Matsushima *et al*., 1982). Hence, it is necessary to evolve high yielding salt tolerant rice varieties for coastal saline ecosystem. Line x tester analysis has been widely used by plant breeders to assess the combining ability of parents. This analysis provides valuable information on the nature of gene action, in addition to the combining ability of parents and hybrids. In the present study, an attempt was made to assess the combining ability of 16 rice genotypes and their 48 hybrids under coastal saline situation.

Materials and Methods
The experiment was conducted at Coastal Soil salinity Research Station, Danti, N.A.U., Navsari, Gujarat during *kharif* 2014. Three complete sets of 65 entries comprised of 48 F1’s, 4 females, 12 males were evaluated for their yield performance under saline soils. The experiment was laid out in a randomized block design replicated three times. The parents and F1’s were represented by a single row plot of 10 plants placed at 20 cm x 15 cm spacing. All the agronomical practices and plant protection measures were followed as and when required to raise a good crop of rice. Geographically, Danti is situated at 20°83’ N latitude and 72o 50’E longitude with an elevation of 2.5 meter above sea level on the western coastal belt of India. The soil of site was reserved as coastal saline type. The EC (1:2.5) (dS/m) of soil experimental plot was 5.25 (0-15 cm depth) and 3.89 (15-30cm depth), pH of the soil was 8.06(0- 15 cm depth) and 8-11 at 15-30 cm depth. During the investigation, various morphological traits *viz.*, Days to 50% flowering, Productive tillers hill^{-1}, Plant height (cm), Panicle length (cm), Number of grains panicle^{-1}, Spikelet fertility (%), Days to maturity, Grain yield plant^{-1} (g), Straw yield plant^{-1} (g), Harvest index (%), 1000-grain weight (gm), were studied. Analysis of Variance technique was followed to test the difference between the genotype of all characters and combining ability components in accordance with the procedure suggested by Kempthorne, 1957.

Results and Discussion
The nature and magnitude of genetic variance provide an idea about the relative role of fixable and non-fixable gene effects in the inheritance of character. This in turn helps in identifying suitable parents for hybridization as well as breeding method to be employed. The genetic variances were estimated from the analysis of variances for combining ability for eleven characters as suggested by Kempthorne, 1957. In any breeding programme, selection of parents primarily depends on their phenotypic divergence. In quantitatively inherited characters, prediction of ability of the parents to combine well, generate more variability and transmit desired gene combination to the progeny is rather

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difficult through parental phenotypes. Recent developments in biometrical genetics have made it possible to make such predictions with ease. Among various biometrical methods used to select the right parents, combining ability analysis (Sprague and Tatum, 1942) is widely used one. The nature of gene action has a bearing on development of efficient breeding programme. General combining ability effects and additive x additive gene action are theoretically fixable. On the other hand, specific combining ability attributed to non additive gene action and is not fixable. The results are presented in Table 1. The variation present in the hybrids was partitioned into portions attributable to females, males and female x male sources. Analysis of variance for combining ability revealed that mean squares due to females were significant for almost all the characters under study except productive tillers (11.71) and panicle length (18.71).

The estimation of general combining ability (gca) variances for females (σ^2 f) were significant for all the characters except productive tillers hill^{-1} and panicle length. General combining ability (gca) variances for males (σ^2 m) also recorded significant reaction for all the characters under study except productive tillers hill^{-1}, days to maturity and harvest index. On the other hand, specific combining ability (sca) variances for f x m interaction were highly significant for all the characters under study. The magnitude of gca variances was lower than sca variances for all the characters except number of grains panicle^{-1} and spikelet fertility (%). This exhibited the predominance of non-additive gene action over additive gene action. This was further supported by low magnitude of σ^2 gca / σ^2 sca ratios. Thirumeni *et al*. (2000) observed influence of additive gene action for grain number panicle'1 and panicle length based on GCA/SCA ratio, while the remaining characters including Na^+/K^+ ratio were under the influence of non-additive gene action. In general, the importance of both additive and non-additive gene actions for inheritance of component traits. Gregario and Senadhira (1993), Mishra *et al*. (1996), Mahmood *et al*. (2002), Mahmood *et al*. (2004), Singh *et al*. (2005), Geetha *et al*. (2006), Saha and Islam (2007), Singh *et al*. (2008), El-Mouhamady *et al*. (2010), Peyman *et al*. (2012), Singh *et al*. (2013) all these supported relevance of both additive and non additive type of gene action in inheritance of salt tolerance in rice. General combining ability effects of females (g_j) and of males (g_i) as well as specific combining ability effects of crosses (S_{ij}) for all the characters were also estimated. The concept of combining ability analysis has significant practical importance in plant breeding as it allows the prediction of the relative efficiency of parents based on early generation performance besides enabling to study the comparative performance of lines in hybrid combinations. Without genetic direction, plant breeders lack the rational basis to guide him in the choice of parents, in the manipulation of progenies and selection of superior parents.

The general combining ability effect enables the identification of desirable male and female parents presented in Table 2. Among male parents, Dandi was found to be good general combiner for grain yield per plant (2.31) followed by Kala rata (1.86) and NVSR 6108 (0.99). The parent NVSR 6108 hold promise in demonstrating good combining ability with seven yield and yield contributing characters. Among female parents, Panvel 1 (1.22) was found to be good general combiner for grain yield plant^{-1} followed by NAUR 1 (1.05). Further the parent Panvel 1 exhibited good combining ability with other five yield contributing characters *viz*; panicle length, spikelet fertility %, days to maturity, straw yield plant^{-1}, and 1000 grain weight and NAUR 1 had exhibited good combining ability with nine yield contributing characters *viz*; days to 50% flowering, productive tillers plant^{-1}, plant height, panicle length, no. of grains panicle^{-1}, spikelet fertility %, days to maturity, harvest index and 1000 grain weight. Such a differential response of parents to combining ability was also reported by Karthikeyan *et al*.(2009), Kumar *et al*. (2010), Shanthi *et al*. (2011), Peyman *et al*. (2012), Sharifi (2012), El-Mouhamady *et al*. (2013), Gopikannan and Ganesh (2013a), Singh *et al*. (2013) and Moumeni and Vahed (2013).

The estimates of sca effects revealed that none of the cross was superior for all the characters. Estimation of specific combining ability was presented in Table 3. However, best three hybrids on the basis of significant positive sca effects for grains yield per plant were NAUR 1 x CSR 27 (3.57), GNR 3 x IR 71895-3R-9-3-1 (2.20) and GNR *3* x GR 11 (2.12). These crosses also registered high and positive sca effects for some of its yield attributes. The highest significant sca effects in desired direction for various characters were exhibited by different hybrids *viz.*, GAR 13 x IR 76346-B-B-10-1-1-1 (-6.77) for days to fifty percent flowering, NAUR 1 x NVSR 6108 for Productive tillers hill^{-1} (2.11) and Straw yield plant^{-1}. (4.20) The hybrid NAUR 1 x CSR 23 for plant height (11.15) and harvest index (%) (4.13). NAUR 1 x Dandi for Number of grains panicle^{-1} (16.13), NAUR 1 X IR 71895-3R-2-1-2 for Spikelet fertility (%) (5.25), Panvel 1 X NVSR 6108 for panicle length (3.35) and GAR 13 X NVSR 6100 for no. of days to maturity (9.56). Further it can be revealed that with high sca effects at least one good general combiner was necessary for the hybrids. In view of the *per se* performance of parents and their gca effect for grain yield per plant, its components and salt tolerance studied, Dandi, Kalarata, NVSR 6108, Panvel 1 and NAUR 1 found the most promising parents and hence they could be used extensively in breeding programme for improving grain yield in rice under coastal salt affected soil. Combining ability analysis reflects usefulness of individuals as parents in the hybridization programme as well as simultaneously to screen the hybrids for coastal saline areas. Edwin and Subbaraman (1997) reported that breeder can exploit non-additive variance through heterosis breeding or other breeding methodologies like biparental mating, recurrent selection and diallel selective mating.

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Electronic Journal of Plant Breeding, 9 (1) : 116 - 123 (Mar 2018) DOI: 10.5958/0975-928X.2018.00014.5
ISSN 0975-928X

Table 1. Analysis of Variance (mean squares) and variance estimates for different characters in rice

Source		Days to 50% flowering	Productive tillers hill^{-1}	Plant height (cm)	Panicle length (cm)	Number of grains panicle^{-1}	Spikelet fertility (%)	Days to maturity	Grain yield plant^{-1} (g)	Straw yield plant^{-1} (g)	Harvest index (%)	1000-grain weight (gm)
Replications/Environments	2	3.36	0.99	26.08	0.16	47.92	7.43	7.63	7.78	4.83	19.15 *	2.89
Females (F)	3	501.47 **	11.71	471.87 **	18.71	4092.95 **	264.21 **	560.06 **	86.96 **	52.89 *	95.36 **	123.68 **
Males (M)	11	77.81	7.30	528.10 **	32.87 **	3789.41 **	768.78 **	82.16	20.98 *	49.93 **	21.99	48.17 **
Females x Males (F x M)	33	56.81 **	5.74 **	126.21 **	10.23 **	403.35 **	36.41 **	75.17 **	9.42 **	14.36 **	16.29 **	15.37 **
Error	94	4.16	0.80	17.75	0.96	53.04	16.09	3.72	2.58	4.22	5.62	3.11
σ2 Females		2.34 **	0.30	12.69 *	0.49	111.98 **	6.92 **	15.45 **	12.69 *	1.36 *	2.50 **	3.35 **
σ2 Males		1.52 *	0.55	42.77 **	2.66 **	310.64 **	62.79 **	6.53	42.77 **	3.84 **	1.37	3.77 **
σ2 gca		2.14 **	0.37 **	20.21 **	1.03 **	161.64 **	20.88 **	13.22 **	20.21 **	1.98 **	2.22 **	3.46 **
σ2 sca		2.24 **	1.66 **	37.11 **	3.08 **	113.90 **	7.05 **	23.78 **	37.11 **	3.48 **	3.60 **	4.16 **
σ2 gca/σ2sca		0.96	0.22	0.54	0.34	1.42	2.96	0.56	0.54	0.57	0.62	0.83

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Table 2. Estimation of general combining ability effects of parents for different characters in rice

	Days to 50% flowering	Productive tillers hill^{-1}	Plant Height (cm)	Panicle length (cm)	Number of grains panicle^{-1}	Spikelet fertility (%)	Days to Maturity	Grain yield plant^{-1} (g)	Straw yield plant^{-1} (g)	Harvest index (%)	1000 grain weight (g)
GNR 3	-3.84 **	0.66 **	-5.28 **	-1.01 **	-6.18 **	-1.25	-5.81 **	-2.15 **	-0.41	-1.92 **	0.07
NAUR 1	-1.81 **	0.28 *	2.47 **	0.47 **	14.03 **	1.82 **	1.69 **	1.05 **	-1.01 **	2.03 **	1.77 **
GAR 13	0.85 *	-0.42 **	2.22 **	-0.03	-10.05 **	-3.20 **	1.19 **	-0.12	-0.34	0.23	-2.57 **
Panvel 1	4.80 **	-0.53 **	0.59	0.56 **	2.20	2.63 **	2.94 **	**1.22 ****	1.76 **	-0.33	0.73 *
S.E.(gi)	0.33	0.14	0.64	0.17	1.31	0.65	0.33	0.27	0.33	0.39	0.28
IR 71907-3R-2-1-2	-0.09	-0.11	3.35 **	0.65 *	-2.80	-6.28 **	4.25 **	1.12 *	1.17 *	0.08	1.81 **
IR 71895-3R-9-3-1	-0.09	-0.13	-4.59 **	-1.57 **	-12.06 **	-0.54	1.58 **	-0.92	-1.31 *	0.37	2.41 **
NVSR 6108	2.41 **	0.82 **	-0.24	2.63 **	5.87 *	11.19 **	4.49 **	0.99 *	1.81 **	-0.61	-1.59 **
NVSR 6100	-2.84 **	-0.21	-5.01 **	-0.43	-11.38 **	-6.36 **	-1.26 *	0.09	-1.35 *	1.35 *	-0.28
CSR 23	-0.08	-1.13 **	3.69 **	0.02	-8.05 **	-6.31 **	-2.01 **	-1.69 **	-0.98	-0.87	1.46 **
CSR 27	1.49 *	1.36 **	2.33 *	1.65 **	35.95 **	12.14 **	0.58	0.01	3.98 **	-3.40 **	-1.15 *
Pokkali	5.91 **	0.92 **	-4.41 **	-0.28	5.04 *	0.24	-2.01 **	-0.99 *	0.13	-1.13	2.04 **
Dandi	-2.59 **	0.32	-0.49	1.06 **	32.04 **	12.16 **	-0.76	**2.31 ****	1.78 **	0.59	-2.84 **
GNR 2	-2.34 **	-0.79 **	-2.73 *	-1.84 **	-17.13 **	-1.98	0.66	-1.45 **	-2.26 **	0.50	0.57
GR 11	0.66	-0.94 **	-7.40 **	-3.12 **	-16.63 **	-11.43 **	-3.34 **	-1.20 *	-2.92 **	1.51 *	-3.91 **
Kala Rata	0.24	0.34	17.89 **	1.70 **	2.29	2.15	1.16 *	1.86 **	1.39 *	0.65	0.75
IR 76346-B-B-10-1-1-1	-2.76 **	-0.46	-2.38 *	-0.46	-13.13 **	-4.99 **	-3.34 **	-0.13	-1.42 *	0.97	0.74
S.E.(gj)	0.58	0.25	1.11	0.29	2.27	1.13	0.56	0.48	0.57	0.68	0.49

* and ** = Significant at 5% and 1% levels of probability, respectively

Table 3. Estimation of SCA effects for various characters in rice under coastal saline soil.

		Days to 50% flowering	Productive tillers hill-1	Plant Height (cm)	Panicle length (cm)	Number of grains panicle -1	Spikelet fertility (%)	Days to Maturity	Grain yield plant-1 (g)	Straw yield plant-1 (g)	Harvest index (%)	1000-grain weight (g)
1	GNR 3 x IR 71907-3R-2-1-2	3.92 **	0.07	0.68	-0.89	-1.48	2.48	8.06 **	-0.01	1.52	-1.20	2.58 **
2	GNR 3 x IR 71895-3R-9-3-1	4.59 **	0.49	-1.90	0.22	13.43 **	-4.14	7.39 **	2.20 *	2.92 *	-0.41	1.40
3	GNR 3 x NVSR 6108	2.09	-2.06 **	1.13	-2.54 **	9.18 *	-0.15	-5.19 **	0.76	-1.26	1.96	3.49 **
4	GNR 3 x NVSR 6100	1.01	0.97	-0.63	-1.88 **	-10.89 *	-0.46	-1.44	-0.46	-1.73	1.18	0.88
5	GNR 3 x CSR 23	-1.87	-0.13	-0.49	0.53	12.77 **	1.73	-4.02 **	-2.36 *	-0.17	-3.00 *	-0.01
6	GNR 3 x CSR 27	1.01	-1.13 *	0.46	1.73 **	-3.23	-0.33	-1.60	1.17	0.57	0.92	-0.12
7	GNR 3 x Pokkali	-2.08	-1.95 **	-0.10	2.57 **	-2.31	-2.19	2.65 *	0.74	2.22	-1.15	0.20
8	GNR 3 x Dandi	1.76	0.84	0.68	1.09	-11.98 **	2.56	-2.60 *	-1.26	0.22	-1.22	1.01
9	GNR 3 x GNR 2	-2.49 *	-0.31	5.18 *	1.22 *	-5.81	1.75	-4.69 **	-1.61	-3.22 **	1.25	-4.23 **
10	GNR 3 x GR 11	-6.16 **	1.37 **	2.39	-0.59	-4.31	-1.31	-4.36 **	2.12 *	-1.36	3.59 **	-5.74 **
11	GNR 3 x Kala Rata	-4.74 **	0.62	-0.77	0.22	-5.23	0.18	-0.19	2.03 *	0.16	1.94	0.36
12	GNR 3 x IR 76346-B-B-10-1-1-1	2.92 *	1.22 *	-5.76 *	-1.68 **	9.85 *	-0.13	5.98 **	-3.32 **	0.15	-3.86 **	0.19
13	NAUR 1 x IR 71907-3R-2-1-2	2.56 *	0.45	-5.92 **	1.10	5.63	-3.09	4.56 **	-0.30	3.18 **	-3.07 *	-2.04 *
14	NAUR 1 x IR 71895-3R-9-3-1	3.90 **	0.06	-5.40 *	0.75	-11.78 *	5.25 *	2.56 *	-0.89	-3.17 **	2.24	-2.80 **
15	NAUR 1 x NVSR 6108	3.06 **	2.11 **	-4.07	-0.99	3.30	1.51	0.31	0.02	4.20 **	-3.55 *	1.34
16	NAUR 1 x NVSR 6100	-6.35 **	-1.12 *	6.34 **	0.54	1.88	1.38	-6.27 **	1.42	1.18	0.21	2.16 *
17	NAUR 1 x CSR 23	-1.19	-0.73	11.15 **	-1.01	-11.45 *	1.96	-0.19	0.07	-3.94 **	4.13 **	-1.57
18	NAUR 1 x CSR 27	-1.35	-0.16	5.75 *	-1.38 *	15.88 **	-1.91	-0.44	3.57 **	0.27	2.92 *	-0.05
19	NAUR 1 x Pokkali	0.90	1.12 *	0.84	2.45 **	-7.20	-2.10	3.15 **	-2.83 **	-2.44 *	-0.73	0.86
20	NAUR 1 x Dandi	-1.94	-0.79	5.46 *	-2.39 **	16.13 **	1.49	-3.44 **	1.21	0.41	0.57	0.54
21	NAUR 1 x GNR 2	-0.52	-0.21	-7.11 **	-0.02	-13.03 **	-0.59	-2.19	-1.88	0.10	-2.02	0.05
22	NAUR 1 x GR 11	-4.19 **	-0.32	-4.39	-0.77	7.80	-5.17 *	-2.85 *	-0.22	2.33 *	-2.51	2.32 *
23	NAUR 1 x Kala Rata	-0.10	2.06 **	-8.39 **	0.15	8.55	3.58	2.65 *	-0.98	-2.48 *	1.14	-1.25
24	NAUR 1 x IR 76346-B-B-10-1-1-1	5.23 **	-2.47 **	5.73 *	1.57 **	-15.70 **	-2.30	2.15	0.81	0.35	0.67	0.42
25	GAR 13 x IR 71907-3R-2-1-2	-3.10 **	0.62	-0.59	0.20	-14.95 **	3.75	-8.93 **	-0.70	-1.24	0.38	0.24
26	GAR 13 x IR 71895-3R-9-3-1	-2.10	1.50 **	7.51 **	-1.45 **	-6.04	3.14	-5.27 **	0.44	0.05	0.21	1.41
27	GAR 13 x NVSR 6108	-4.27 **	0.42	-5.63 *	0.18	-10.28 *	-1.48	1.81	-1.07	-1.52	0.07	-4.64 **
28	GAR 13 x NVSR 6100	4.98 **	-0.35	-0.71	0.84	8.63	3.08	9.56 **	-0.51	-0.90	0.36	-1.89
29	GAR 13 x CSR 23	3.81 **	1.04 *	-14.68 **	0.56	11.97 **	-0.59	-0.02	0.68	2.38 *	-1.34	1.81
30	GAR 13 x CSR 27	0.65	0.64	5.32 *	1.39 *	-9.04 *	0.43	0.73	-2.09 *	-0.47	-1.80	-0.18
31	GAR 13 x Pokkali	-2.44 *	0.79	-1.70	-4.21 **	13.55 **	2.36	-6.68 **	1.94 *	-0.13	1.97	0.45
32	GAR 13 x Dandi	5.40 **	-1.48 **	-4.82 *	-0.62	-4.79	-5.30 *	6.72 **	0.18	-0.16	0.30	0.69
33	GAR 13 x GNR 2	2.15	-0.43	4.75 *	2.31 **	13.05 **	-3.68	2.64 *	1.57	0.88	0.81	1.75

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34	GAR 13 x GR 11	0.15	0.25	6.82 **	-0.34	-1.79	3.71	4.31 **	-0.84	-2.08	1.13	1.70
35	GAR 13 x Kala Rata	1.56	-2.96 **	0.86	0.65	-15.37 **	-7.85 **	0.15	-0.57	3.11 **	-3.17 *	-1.73
36	GAR 13 x IR 76346-B-B-10-1-1-1	-6.77 **	-0.03	2.86	0.51	15.05 **	2.42	-5.02 **	0.98	0.07	1.10	0.38
37	Panvel 1 x IR 71907-3R-2-1-2	-3.38 **	-1.14 *	5.83 *	-0.40	10.80 *	-3.14	-3.68 **	1.00	-3.46 **	3.89 **	-0.79
38	Panvel 1 x IR 71895-3R-9-3-1	-6.38 **	-2.05 **	-0.23	0.48	4.38	-4.24	-4.68 **	-1.74	0.20	-2.05	-0.01
39	Panvel 1 x NVSR 6108	-0.88	-0.47	8.56 **	3.35 **	-2.20	0.12	3.06 **	0.29	-1.43	1.52	-0.20
40	Panvel 1 x NVSR 6100	0.37	0.50	-5.01 *	0.51	0.38	-4.01	-1.85	-0.45	1.45	-1.74	-1.15
41	Panvel 1 x CSR 23	-0.80	-0.18	4.03	-0.08	-13.28 **	-3.09	4.23 **	1.60	1.73	0.21	-0.23
42	Panvel 1 x CSR 27	-0.30	0.66	-11.55 **	-1.74 **	-3.62	1.81	1.31	-2.64 **	-0.37	-2.04	0.34
43	Panvel 1 x Pokkali	3.62 **	0.04	1.86	-0.81	-4.04	1.93	0.90	0.16	0.35	-0.09	-1.51
44	Panvel 1 x Dandi	-5.21 **	1.43 **	-1.32	1.91 **	0.63	1.25	-0.69	-0.13	-0.47	0.34	-2.23 *
45	Panvel 1 x GNR 2	0.87	0.95	-2.82	-3.52 **	5.80	2.52	4.23 **	1.92 *	2.24	-0.03	2.43 *
46	Panvel 1 x GR 11	10.20 **	-1.30 *	-4.81 *	1.70 **	-1.70	2.77	2.89 *	-1.06	1.11	-2.21	1.72
47	Panvel 1 x Kala Rata	3.29 **	0.28	8.29 **	-1.02	12.05 **	4.08	-2.60 *	-0.48	-0.78	0.10	2.61 **
48	Panvel 1 x IR 76346-B-B-10-1-1-1	-1.38	1.28 *	-2.84	-0.39	-9.20 *	0.00	-3.10 **	1.54	-0.57	2.09	-0.99
	S.E. (Sij)	**1.15**	**0.50**	**2.22**	**0.57**	**4.56**	**2.26**	**1.13**	**0.95**	**1.14**	**1.35**	**0.98**
	Minimum	-6.77	-2.96	-14.68	-4.21	-15.70	-7.85	-8.93	-3.32	-3.94	-3.86	-5.74
	Maximum	10.20	2.11	11.15	3.35	16.13	5.25	9.56	3.57	4.20	4.13	3.49
	Positive	13.00	9.00	13.00	10	12	1	16	6	6	4	6
	Negative	12.00	10.00	11.00	9	12	3	15	5	6	5	6