Combining Ability Analysis for Yield and Yield Components in Some Important Upland Rice Germplasms of Nagaland

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ABSTRACT

Combining ability analysis for yield and yield components in some important upland rice germplasms of Nagaland was carried out in rice through line x tester analysis of 45 intervarietal crosses developed by crossing 3 testers with 15 lines along with parents and checks. The 45 crosses along with 18 parents and three standard checks were grown in a randomized block design with three replications and were evaluated for early flowering and maturity along with grain yield per plant and other yield components. The experiments were conducted at the Main Scheme Farm, ICAR Research Complex for NEH Region, Nagaland Centre, Jharnapani, Medziphema, Nagaland in *kharif* 2009 and 2010. Analysis of variance for line x tester revealed highly significant differences between the lines x tester for the characters studied except for effective tillers per hill, filled grains per panicle and unfilled grains per panicle with sca variance (ó^{2}s) and non- additive (ó^{2}D) variance components higher than genetic variance (ó^{2}g) and additive (ó^{2}A) variance for almost all the characters under study. The estimates of gca effects indicated that, Koyapvu Tsok, Manchio Tsük among lines and RCM-5 and Teke among testers are good general combiners for grain yield per plant. Out of the 45 crosses, 21 crosses exhibited positive sca effects for grain yield per plant. The best sca effects were observed in the cross, Leikhumo (T) x Teke for plant height, which also showed best sca effects for filled grains per panicle.

Keywords: Additive, Crosses, General combining ability, Germplasm, Non-additive, Specific combining ability, Variance,

INTRODUCTION

Success of any plant breeding programme depends on the choice of appropriate genotypes as parents in the hybridization programme. The combining ability studies of the parents provide information, which helps in the selection of better parents for effective breeding. Combining ability analysis also provides information on additive and dominance variance. Its role is important to decide parents, crosses and appropriate breeding procedure to be followed to select desirable segregants. Accordingly, the present investigation was undertaken to get an idea of the combining ability for yield and other related traits with a view to identify good combiners, which may be used to create a population with favourable genes in some of the upland rice varieties in Nagaland.

MATERIALS AND METHODS

The experimental material comprised of three testers - RCM-5, Bhalum-1 and Teke, selected on the basis of their morphological differences. Crosses were made in line x tester fashion along with 15 lines *viz*. Epyo Tsok, Koyapvu Tsok, Thumpak tsok, Meiduina (SARS-62), Thakie (SARS-14), Manchio Tsük, Yepro Tsük, Khumkia Emumo, Laza Tssok, Tekonglu, Rukhatung,

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Tangmo tsuk (SARS-4), Leikhumo (T) SARS-51, Leikhumo (D) and Shomboro Epyu.

The resulting 45 crosses along with 18 parents and three standard checks RCM-5, Teke and Bhalum-1were grown in randomized block design in three replications at the Main Scheme Farm, ICAR Research Complex for NEH Region, Nagaland Centre, Jharnapani, Medziphema, Nagaland in *kharif* 2009 and 2010. Each entry was planted in a 3 meter long row with inter and intra row spacing of 20 x 15 cm. Two lines of each entry were planted in each replication. All the recommended agronomic and plant protection practices were uniformly applied throughout the crop growth period. Flowering and maturity were recorded on a plot basis, and ten plants were selected randomly to record the observations on grain yield and yield components viz., days to first flowering, days to 50% flowering, days to 100% flowering, days to 80% maturity, plant height at maturity, panicle length, filled grains per panicle, unfilled grains per panicle, grain yield per plant and 1000 grain weight respectively, and their mean values were subjected to statistical analysis.

RESULTS AND DISCUSSION

Analysis of variance (Table 1) revealed highly significant difference among line x tester for almost all the characters studied, indicating that the materials chosen were desirable. The lines showed significant differences for almost all the traits except for panicle length. The above findings suggested that there was diversity among the lines. Koyapvu Tsok, Manchio Tsük among lines and RCM-5 and Teke among testers were proved to be good general combiners for grain yield per plant.

Components of genetic variance viz. general combining ability (*gca*) and specific combining ability (*sca*) variances, the ratio of *gca* and *sca* variances, additive and non- additive components

Table 1: Analysis of variance and variance estimates for combining ability in upland rice

		Mean sum of squares										
		Days to first flowering	Days to 50% flowering	Days to 100% flowering	Days to 80% maturity	Effective tillers/ hill	Plant height	Panicle length	Filled grains per panicle	Unfilled grains per panicle	Grain yield per plant	1000 grain weight
Source	d.f.	1	2	3	4	5	6	7	8	9	10	11
Replication	2	**	**	**	NS	NS	NS	NS	*	NS	NS	NS
		11.75	15.48	6.54	3.12	0.58	2.04	1.14	730.34	831.78	14.77	0.16
Treatment	62	**	**	**	**	**	**	**	**	NS	**	**
		60.49	82.90	89.91	70.95	2.94	415.85	5.04	425.24	843.40	16.83	22.14
Parents	17	**	**	**	**	**	**	**	*	**	**	**
		64.60	94.27	121.44	29.63	3.69	456.42	4.89	337.16	2836.34	13.72	13.90
Parents Vs	1	**	**	NS	**	NS	**	NS	**	NS	NS	**
Crosses		32.28	10.08	0.06	218.08	2.12	298.99	4.29	2046.47	1170.49	11.08	24.32
Crosses	44	**	**	**	**	**	**	**	**	NS	**	**
		59.54	80.16	79.77	83.57	2.66	402.83	5.11	422.42	65.97	18.16	25.27
Lines	14	**	**	**	**	**	**	NS	**	NS	**	**
		136.96	191.87	198.66	175.06	5.98	685.89	5.72	950.90	51.99	30.06	52.92
Testers	2	NS	NS	NS	**	NS	NS	**	NS	NS	NS	NS
		36.23	50.29	62.81	165.81	1.17	41.96	13.95	4.98	57.09	19.29	7.91
Line x	28	**	**	**	**	NS	**	**	NS	NS	**	**
Testers		22.49	26.44	21.54	31.96	1.12	287.07	4.17	188.01	73.59	12.13	12.69
Error	124	1.46	1.19	1.14	3.13	0.79	47.68	1.96	168.12	766.62	5.82	1.53
ó^{2}g		0.47	0.68	0.74	0.66	0.02	1.47	0.01	2.98	-0.10	0.08	0.16
ó^{2}s		7.01	8.41	6.80	9.61	0.11	79.80	0.74	6.63	-231.01	2.10	6.86
ó^{2}g/ ó^{2}s		0.07	0.08	0.11	0.07	0.18	0.02	0.02	0.45	0.00	0.04	0.02
ó^{2}A		0.94	1.37	1.48	1.31	0.04	2.95	0.02	5.97	-0.19	0.15	0.32
ó^{2}D		7.01	8.41	6.80	9.61	0.11	79.80	0.74	6.63	-231.01	2.10	6.86

*, ** Significant at 5% and 1% levels of probability, respectively; NS = Not Significant

of gene action were presented in Table 1. Out of the 11 characters studied, *sca* variance (ó^{2}s) and non –additive (ó^{2}D) variance components were higher than genetic variance (ó^{2}g) and additive (ó^{2}A) variance for almost all the characters studied except for unfilled grains per panicle whereas *gca* variance (ó^{2}g) and additive component of gene action (ó^{2}A) were higher than *sca* variance (ó^{2}s) and non additive variance (ó^{2}D).

Both additive and non- additive gene action appeared to play a significant role in controlling the expression of the traits in the present studies. The major role of non –additive component was evident for days to first flowering, days to 50% flowering, days to 100% flowering, days to 80% maturity, effective tillers per hill, plant height, panicle length, filled grains per panicle, grain yield per plant and 1000 grain weight except for unfilled grains per panicle. For the characters namely unfilled grains per panicle, additive component of variance was important. For effective tillers per hill and panicle length equal importance of both additive and non- additive components were observed suggesting these materials could be exploited beneficially in future upland rice breeding programme by adopting appropriate breeding strategy in order to evolve high-yielding upland rice varieties.

The parents Koyapvu Tsok, Manchio Tsük among lines and RCM-5 and Teke among testers were proved to be good combiners for grain yield per plant (Table 2). Koyapvu Tsok proved to be the best combiner for days to first flowering, days to 50% flowering, days to 100% flowering and for days to 80% maturity (second) for earliness. The second best combiner, Manchio Tsük for panicle length (second), filled grains per panicle, grain yield per plant proved to be good combiner for higher yield.

Table 2: Estimates of general combining ability (*gca*) effects in upland rice

Sl. No	Crosses	Days to first flowering	Days to 50% flowering	Days to 100% flowering	Days to 80% maturity	Effective tillers/ hill	Plant height	Panicle length	Filled grains per panicle	Unfilled grains per panicle	Grain yield per plant	1000 grain weight
Testers												
1	RCM-5	0.61**	1.09**	1.27**	2.01**	0.18	-0.28	0.01	0.31	-1.20	0.72*	0.01
2	Teke	0.41*	-0.07	-0.21	-1.81	-0.11	1.07	0.55**	-0.35	0.17	-0.17	-0.42
3	Bhalum-1	-1.03	-1.02	-1.06	-0.21	-0.07	-0.80	-0.56	0.03	1.03	-0.55	0.42
	S. Ed.	0.18	0.16	0.16	0.26	0.13	1.03	0.21	1.93	4.13	0.36	0.18
Lines												
1	Epyo Tsok	5.75**	4.84**	4.39**	2.64**	-1.16	12.66**	-0.80	7.06	1.08	1.42	3.15**
2	Koyapvu Tsok	7.86**	7.51**	6.61**	5.30**	0.15	-5.42	-0.72	-7.61	-1.32	-1.49	-1.41
3	Tangmo Tsuk	1.64**	0.29	-0.73	-9.14	0.09	-2.97	0.68	2.79	1.28	0.72	-1.65
4	Leikhumo (T)	4.30**	4.62**	4.27**	-1.03	-0.53	-2.34	0.07	-1.65	3.82	-1.45	0.86
5	Shomboro Epyu	-0.59	4.73**	5.72**	-0.36	-0.03	-11.95	-0.97	-5.27	5.11	-0.79	0.51
6	Leikhumo (D)	0.86*	3.62**	3.39**	3.30**	1.14**	-15.30	0.43	-2.05	-4.43	-0.37	-1.51
7	Thakie	-3.14	-4.16	-2.95	2.97**	-1.59	5.29*	0.34	18.28**	-2.35	2.71**	0.26
8	Manchio Tsük	-3.36	-5.38	-5.06	-2.14	-0.35	5.01*	0.92	24.26**	-1.00	2.94**	0.09
9	Meiduina	-4.70	-5.93	-7.06	-2.03	-0.43	12.55**	0.66	-3.19	-0.04	-0.78	3.53**
10	Tekonglu	-2.59	-2.04	-1.28	4.97**	0.51	4.43	-1.27	-9.53	-0.43	-1.41	0.33
11	Rukhatung	3.75**	4.29**	4.94**	5.53**	0.07	0.29	0.32	-9.40	0.29	-1.92	4.67**
12	Yepro Tsük	-1.14	-0.38	0.83*	1.53*	-0.34	-8.12	-0.99	-12.10	0.07	-2.67	-3.74
13	Laza Tssok	-1.59	-2.16	-1.95	-6.14	1.57**	-5.40	-0.09	-4.17	-2.95	2.43**	-3.15
14	Khumkia Emumo	-4.81	-6.38	-7.39	-0.03	0.08	12.62**	1.27**	6.29	0.21	-1.00	0.45
15	Thumpak Tsok	-2.25	-3.49	-3.73	-5.36	0.82**	-1.35	0.32	-3.71	0.65	1.68*	-2.39
	S. Ed.	0.40	0.36	0.36	0.59	0.30	2.30	0.47	4.32	9.23	0.80	0.41

Note: *, ** Significant at 5% and 1% level, respectively

The best combiner among testers, i.e. RCM-5 for days to first flowering, days to 50% flowering, days to 100% flowering, days to 80% maturity, filled grains per panicle, grain yield per plant and ranked second for plant height, panicle length and 1000 grain weight. Second best combiner Teke for plant height, panicle length and ranked second for days to first flowering, days to 50% flowering, days to 100% flowering, unfilled grains per panicle and grain yield per plant.

The present result indicated that the genotypes with high *per se* performance for a character are, in general, the good general combiner of the particular character. The present findings are in general agreement with that of Kumar et al. (2007) and Tyagi et al. (2008). High specific combining ability (*sca*) results mostly from dominance and interaction effects existed between the hybridizing parents. Out of the 45 crosses, 21 crosses exhibited positive *sca* effects for grain yield per plant (Table 3 and 4). In the present study, the cross Leikhumo

Table 3: Specific combining ability (*sca*) effects for early flowering and maturity in upland rice

Sl. No.	Crosses	Days to first flowering	Days to 50% flowering	Days to 100% flowering	Days to 80% maturity
1	Epyo Tsok x RCM-5	-0.50	-1.31	-2.27	-1.68
2	Koyapvu Tsok x RCM-5	-0.28	-0.64	-1.16	-1.35
3	Tangmo Tsuk x RCM-5	-1.06	-0.42	-0.83	-3.24
4	Leikhumo (T)x RCM-5	2.94**	1.24	0.50	2.65*
5	Shomboro Epyu x RCM-5	-4.84	-4.53	-1.27	4.32**
6	Leikhumo (D)x RCM-5	-1.28	-1.76	-1.94	-3.35
7	Thakie x RCM-5	-1.28	-1.31	-2.61	-2.01
8	Manchio Tsük x RCM-5	0.94	1.24	2.50**	0.10
9	Meiduina x RCM-5	0.27	-0.20	-0.50	3.99**
10	Tekonglu x RCM-5	1.50*	4.24**	4.73**	-1.01
11	Rukhatung x RCM-5	3.83**	3.58**	2.17**	-0.24
12	Yepro Tsük xRCM-5	4.39**	4.91**	3.95**	-1.57
13	Laza Tssok x RCM-5	-3.50	-2.64	-1.27	-1.90
14	Khumkia Emumo x RCM-5	-0.28	-0.42	-0.50	2.99**
15	Thumpak Tsok x RCM-5	-0.84	-1.98	-1.50	2.32*
16	Epyo Tsok x Teke	1.70*	2.51**	2.55**	2.14*
17	Koyapvu Tsok x Teke	-0.08	-0.49	0.33	3.47**
18	Tangmo Tsuk x Teke	0.47	0.40	0.33	3.59**
19	Leikhumo (T) x Teke	-2.86	-2.60	-1.67	-4.86
20	Shomboro Epyu x Teke	2.03**	3.29**	0.21	-5.86
21	Leikhumo (D)x Teke	-1.08	-0.60	-0.45	0.47
22	Thakie X Teke	0.92	0.18	0.88	1.81
23	Manchio Tsük xTeke	-0.86	-1.60	-2.34	-4.08
24	Meiduina x Teke	-1.19	-0.71	-0.34	-0.19
25	Tekonglu x Teke	0.03	-1.27	0.21	-0.19
26	Rukhatung x Teke	3.03**	3.73**	3.99**	2.59*
27	Yepro Tsük x Teke	-2.41	-2.60	-1.90	1.25
28	Laza Tssok x Teke	2.36**	1.51*	0.21	-1.08
29	Khumkia Emumo x Teke	-0.08	-0.27	-0.67	-0.19
30	Thumpak Tsok x Teke	-1.97	-1.49	-1.34	1.14
31	Epyo Tsok x Bhalum-1	-1.19	-1.20	-0.27	-0.46
32	Koyapvu Tsok x Bhalum-1	0.36	1.13	0.84	-2.13
33	Tangmo Tsuk x Bhalum-1	0.59	0.02	0.50	-0.35
34	Leikhumo (T) x Bhalum-1	-0.08	1.36*	1.17	2.21*
35	Shomboro Epyu x Bhalum-1	2.81**	1.24	1.06	1.54
36	Leikhumo (D) x Bhalum-1	2.36**	2.36**	2.39**	2.87**
37	Thakie x Bhalum-1	0.36	1.13	1.73**	0.21
38	Manchio Tsük x Bhalum-1	-0.08	0.36	-0.16	3.99**
39	Meiduina x Bhalum-1	0.92	0.91	0.84	-3.79
40	Tekonglu x Bhalum-1	-1.53	-2.98	-4.94	1.21
41	Rukhatung x Bhalum-1	-6.86	-7.31	-6.16	-2.35
42	Yepro Tsük x Bhalum-1	-1.97	-2.31	-2.05	0.32

43	Laza Tssok x Bhalum-1	1.14	1.13	1.06	2.99**
44	Khumkia Emumo x Bhalum-1	0.36	0.69	1.17	-2.79
45	Thumpak Tsok x Bhalum-1	2.81**	3.47**	2.84**	-3.46
	S. Ed.	0.70	0.63	0.62	1.02

Note: *, ** Significant at 5% and 1% level, respectively

Table 4: Specific combining ability (*sca*) effects for yield attributing traits in upland rice

Sl. No.	Crosses	Effective tillers/ hill	Plant height	Panicle length	Filled grains per panicle	Unfilled grains per panicle	Grain yield per plant	1000 grain weight
1	Epyo Tsok x RCM-5	0.25	1.30	-0.99	9.19	-1.12	1.72	-1.79
2	Koyapvu Tsok x RCM-5	0.10	4.02	0.29	4.39	-0.96	0.09	-1.08
3	Tangmo Tsuk x RCM-5	-0.11	-7.89	-1.01	-4.62	1.03	-3.20	-2.30
4	Leikhumo (T)x RCM-5	-0.76	-11.78	-0.88	-7.15	3.25	-2.61	-1.95
5	Shomboro Epyu x RCM-5	-0.25	-14.26	0.50	0.66	-4.07	1.55	0.82
6	Leikhumo (D)x RCM-5	0.003	1.26	0.26	1.21	1.31	1.54	-0.67
7	Thakie x RCM-5	0.35	6.00	-0.94	-9.43	-6.69	2.03	1.20
8	Manchio Tsük x RCM-5	1.24*	3.13	1.06	8.92	-4.97	2.85*	-1.03
9	Meiduina x RCM-5	-0.08	0.76	0.26	-8.36	-0.96	0.98	0.34
10	Tekonglu x RCM-5	0.05	-8.43	-1.32	-0.92	1.51	-0.37	1.43
11	Rukhatung x RCM-5	0.43	-3.61	-0.42	2.22	4.16	-0.77	1.76
12	Yepro Tsük xRCM-5	-0.24	0.50	-0.10	0.91	2.60	-0.67	-0.23
13	Laza Tssok x RCM-5	-1.08	9.99*	0.05	1.40	2.15	-2.66	0.74
14	Khumkia Emumo x RCM-5	0.02	11.35**	2.60**	4.22	6.22	0.10	0.15
15	Thumpak Tsok x RCM-5	0.07	7.65	0.64	-2.64	-3.48	-0.59	1.25
16	Epyo Tsok x Teke	-0.19	-8.02	1.34	-5.00	3.84	-0.63	-0.66
17	Koyapvu Tsok x Teke	-0.23	0.31	-0.66	-6.08	3.42	0.05	4.71**
18	Tangmo Tsuk x Teke	-0.37	8.14*	-0.08	-4.31	-0.004	-1.27	2.73**
19	Leikhumo (T) x Teke	0.69	22.82**	1.93*	18.20*	0.37	2.83*	0.23
20	Shomboro Epyu x Teke	0.21	12.38**	0.22	-3.32	-3.74	0.27	-0.65
21	Leikhumo (D)x Teke	0.07	-2.79	-1.02	1.71	-1.88	-1.11	-1.03
22	Thakie X Teke	-0.22	-3.00	0.67	6.60	2.46	0.72	0.58
23	Manchio Tsük xTeke	-0.06	1.36	0.40	8.65	10.45	0.12	-1.17
24	Meiduina x Teke	0.26	-2.07	-0.72	-1.21	-3.71	-0.91	-1.24
25	Tekonglu x Teke	-0.29	-1.79	0.38	-2.12	-5.62	0.47	-0.98
26	Rukhatung x Teke	-0.60	-11.74	-0.95	-6.31	-0.06	-0.98	-1.06
27	Yepro Tsük x Teke	0.75	-1.11	-0.46	-1.09	-3.36	0.76	0.29
28	Laza Tssok x Teke	-0.37	-11.82	-0.08	-1.02	3.57	0.40	-2.99
29	Khumkia Emumo x Teke	0.46	-4.58	-0.26	-2.26	-6.23	0.08	-0.36
30	Thumpak Tsok x Teke	-0.12	1.91	-0.71	-2.42	0.51	-0.80	1.62
31	Epyo Tsok x Bhalum-1	-0.06	6.72	-0.36	-4.18	-2.73	-1.09	2.45*
32	Koyapvu Tsok x Bhalum-1	0.13	-4.33	0.37	1.69	-2.46	-0.14	-3.63
33	Tangmo Tsuk x Bhalum-1	0.47	-0.25	1.09	8.93	-1.03	4.47**	-0.43
34	Leikhumo (T) x Bhalum-1	0.07	-11.04	-1.05	-11.05	-3.62	-0.23	1.72
35	Shomboro Epyu x Bhalum-1	0.05	1.88	-0.73	2.66	7.81	-1.82	-0.17
36	Leikhumo (D) x Bhalum-1	-0.07	1.53	0.76	-2.92	0.58	-0.43	0.36
37	Thakie x Bhalum-1	-0.13	-3.00	0.27	2.83	4.23	-2.76	-1.78
38	Manchio Tsük x Bhalum-1	-1.18	-4.50	-1.46	-17.58	-5.48	-2.97	2.20*
39	Meiduina x Bhalum-1	-0.18	1.31	0.46	9.57	4.67	-0.07	0.90
40	Tekonglu x Bhalum-1	0.24	10.22**	0.94	3.04	4.11	-0.11	-0.45
41	Rukhatung x Bhalum-1	0.17	15.35**	1.37	4.09	-5.00	1.75	-0.70
42	Yepro Tsük x Bhalum-1	-0.51	0.61	0.56	0.18	0.76	-0.08	0.06
43	Laza Tssok x Bhalum-1	1.44**	1.83	0.03	-0.37	-5.72	2.26	2.25*
44	Khumkia Emumo x Bhalum1	-0.48	-6.76	-2.34	-1.96	0.01	-0.17	0.20
45	Thumpak Tsok x Bhalum-1	0.05	-9.56	0.07	5.06	2.97	1.39	-2.87
	S. Ed.	0.51	3.99	0.81	7.49	15.99	1.39	1.39

Note: *, ** Significant at 5% and 1% level, respectively

(T) x Teke exhibited the highest *sca* effects for plant height, filled grains per panicle and second highest for panicle length. Similarly, Manchio Tsuük x RCM-5 exhibited second highest *sca* effects for effective tillers per plant and grain yield per plant also exhibited highest value of relative heterosis, heterobeltiosis, standard heterosis for panicle length and second highest for relative and standard heterosis in the character plant height. Similarly, many of the characters also showed the same result in relation to *sca* effect and heterotic effects.

While confirming the general agreement that "the larger the *sca* effect, the greater is the heterotic effect in the cross," independent of heterotic effect from the *sca* effect could not be ruled out for the specific character of specific cross combinations according to the number of genes governing the traits, their linkage relationship, the gene frequency in the parental lines, unpredictability of environment conditions etc. The result is in agreement with the work of Ghara et al. (2012) and Patil et al. (2012).

Future implications

i) Population-1 with the tester RCM-5 can be utilized most effectively in the segregating generations of upland rice as it was found to be the most desirable population followed almost equally by population-III in deriving superior lines as well as maintaining variability in the populations.

ii) The superior yielding lines in the present study deserve further evaluation to screen the best lines, which after multilocational testing at different agro-climatic zones may be proposed for zone specific recommendations.

iii) The early genotypes can be further evaluated for yield and other characters to observe their performance in actual farm situations under the local environment of mid to low altitude foot hills of the district.

iv) Although upland rice can be grown as *pre-kharif* crop in the mid to low altitude foot hills of the state, it can also be tried at lowland rice areas where lowland rice cultivation is not possible due to scarcity of water and moisture stress conditions emerging out of the climate change and erratic rainfall patterns as these genotypes have by default moisture stress tolerant or resistance genes in them.

REFERENCES

Ghara AG. Nematzadeh G, Bagheri N, Ebrahimi A, Oladi M (2012). Evaluation of general and specific combining ability in parental lines of hybrid rice. International J Agri 2(4): 455-460

Kumar S, Singh HB, Sharma JK (2007). Combining ability analysis for grain yield and other associated traits in rice. Oryza 44 (2): 108-114

Patil VA, Vashi RD, Patil PP, Shinde DA (2012). Line x tester analysis in rice (*Oryza sativa* L.) Plant Archives 12(1): 463-469

Tyagi JP, Singh T, Singh VP (2008). Combining ability analysis in rice. Oryza 45(3): 235-238