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COMBINING ABILITY ANALYSIS FOR YIELD AND YIELD COMPONENTS IN RICE VARIETIES OF DIVERSE ORIGIN

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Abstract: Twenty-eight hybrids, produced from diallel crossing excluding reciprocals among eight parents, were studied along with the parents for combining ability for yield and 17 yield components. The study revealed importance of both additive and non-additive gene effects in governing yield and most of the yield components with preponderance of non-additive gene action for most of the yield components. Additive gene action was found important for 1000-grain weight, second uppermost internodal length and height of plant at harvest. The parent Vyttila 3 was found to be a good general combiner. The hybrids PK3355-5-1-4 x Hraswa, Vyttila 3 x IR60133-184-3-2-2, Vyttila 3 x IR36, Vyttila 3 x Mattatriveni and IR36 x Mattatriveni have shown significant favourable *sca* effect for yield and different yield components.

Key words: Diallel analysis, combining ability, additive and non-additive gene effects, *gca* effect, *sca* effect

INTRODUCTION

In order to formulate efficient breeding programmes, for improvement of yield, it is essential to characterize the nature and mode of gene action that determines the yield and its components. A sound breeding methodology rests on a correct understanding of the gene effects involved. The results of general (*gca*) and specific (*sca*) combining abilities of eight promising lines and their all possible combinations excluding reciprocals are discussed.

MATERIALS AND METHODS

The materials comprised of eight high yielding, photo-insensitive, eco-geographically different varieties namely, Mattatriveni, Hraswa, Mahsuri, Vyttila 3, Kachsiung Sen Yu 338, IR36, IR60133-184-3-2-2, and PK3355-5-1-4. The 36 entries (28 crosses and eight parents) were grown in a randomized block design with two replications at the Agricultural Research Station, Mannuthy, Trichur. A single seedling per hill was transplanted at a spacing of 20 cm x 15 cm in lines. Each genotype was grown in a single row of 10 plants. Data were collected from all plants, leaving one border plant on each side of each genotype (Dhaliwal and Sharma, 1990). Observations were recorded on 18 characters namely, second uppermost internodal length (cm), number of days of 50% flowering, leaf area plant^{-1} at maximum tillering stage, number of days to harvest, height of plant at harvest (cm), ratio of vegetative phase to reproductive phase, number of panicles m^{-2}, number of spikelets panicle^{-1}, number of tertiary branches panicle^{-1}, length of panicle (cm), number of grains panicle^{-1}, spikelet sterility percentage, 1000-grain weight (g), L/B ratio of grain, grain yield plant^{-1} (g), harvest index, amylose content (%) and alkali spreading value. The combining ability analysis was carried out as per Griffing (1956), Method-2.

RESULTS AND DISCUSSION

Analysis of variance for combining ability (Table 1) showed that mean square due to general combining ability (*gca*) was significant for all the characters except for ratio of vegetative phase to reproductive phase. Mean squares due to specific combining ability (*sca*) were significant for all the characters. This suggests the importance of both additive and non-additive gene effects in the material under study. Hence any approach that facilitates simultaneous exploitation of additive and non-additive gene effects would be the most desirable for the improvement of these traits.

The estimates of components due to *gca* and *sca* effects and their ratio (Table 2) showed that non-additive gene effect was higher than additive gene effect for all the characters except for 1000-grain weight, second uppermost internodal length and height of plant at harvest. This shows that although the mean square for *gca* (additive genetic variance) was significant, the dominant component may be predominant for all the characters except the above three traits, for which additive component may be predominant. Occurrence of both additive and non-additive gene effects with preponderance of non-additive gene action for yield and important yield components in rice were reported by several scientists like Peng and Virmani (1990), Manuel and Prasad (1992), Sharma *et al.* (1996) and Ganesan *et al.* (1997).

Table 1. Analysis of variance for combining ability in 8 x 8 half diallel analysis using Griffing's Method-2

Source	Mean sum of squares								
	Degrees of freedom	No. of days to 50% flowering	No. of days to harvest	Ratio of veg. phase to reprod. phase	No. of panicles m^{-2}	No. of spikelets $panicle^{-1}$	No. of tertiary branches $panicle^{-1}$	No. of grains $panicle^{-1}$	Spikelet sterility %
Gca	7	284.84**	109.54	0.03	73181**	9547**	3126**	11916**	397.93**
Sca	28	191.33**	243.17**	0.06**	350610**	1939**	76.44	2274**	483.69**
Error	35	22.11	12.88	0.01	287.27	199.93	8.03	174.59	10.71
Gca/Sca		1.49	0.45	0.50	2.09	4.92	4.09	5.24	0.82

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

Table 1. Continued

Source	Mean sum of squares									
	Harvest index	1000-grain weight	2nd uppermost internodal length	Height of plant at harvest	Leaf area $plant^{-1}$ at maxi. tillering stage	Length of panicle	L/B ratio of grain	Amylose content	lkali preading alue	Yield $plant^{-1}$
Gca	0.030**	54.12**	133.29**	2440**	190106**	21.37**	0.610**	56.84**	1.00**	30.68**
Sca	0.020**	5.84**	13.140**	231.76**	141498**	6.48**	0.100**	15.28**	0.64**	34.50**
Error	0.001	1.28	0.353	24.21	1312	0.89	0.005	0.40	0.20	2.23
Gca/Sca	1.500	9.27	10.14	9.57	1.34	3.30	6.100	3.72	1.56	0.89

Table 2. Estimates of components of genetic variance from 8 x 8 half diallel analysis using Griffing's Method-2

Components	Mean sum of squares							
	No. of days to 50% flowering	No. days to harvest	Ratio of veg. phase to reprod. phase	No. of panicles m^{-2}	No. of spikelets $panicle^{-1}$	No. of tertiary branches $panicle^{-1}$	No. of grains $panicle^{-1}$	Spikelet sterility %
Variance due to additive genetic effect	26.20	9.67	0.002	7289	934.79	30.46	1174	38.72
Variance due to non-additive genetic effect	169.22	230.29	0.050	34772	1739	68.41	2100	472.98
Variance due to error	22.11	12.88	0.010	287.27	199.93	8.01	174.59	10.71
Ratio of additive to non-additive genetic effect	0.15	0.04	0.040	0.21	0.54	0.45	0.56	0.08

Table 2. Continued

Components	Mean sum of squares									
	Harvest index	1000-grain weight	nd uppermost nternodal ength	Height of plant at harvest	eaf area lant^{-1} at max. illering stage	Length of panicle	L/B ratio of grain	Amylose content	lkali preading alue	Yield plant^{-1}
Variance due to additive genetic effect	0.003	5.28	13.29	241.63	18879	2.05	0.060	5.64	0.08	2.85
Variance due to non-additive genetic effect	0.020	4.56	12.79	207.55	140186	5.59	0.095	14.9	0.44	32.27
Variance due to error	0.001	1.28	0.35	24.21	1312	0.89	0.005	0.40	0.20	2.23
Ratio of additive genetic effect to non-additive genetic effect	0.150	1.16	1.04	1.16	0.13	0.37	0.630	0.38	0.18	0.09

Table 3. General combining ability effects and mean performance (in next row) of 8 parents from 8 x 8 half diallel analysis using Griffing's Method-2

Parents	No. of days to 50% flowering	No. of days to harvest	No. of panicles m^{-2}	No. of spikelets panicle^{-1}	No. of tertiary branches panicle^{-1}	No. of grains panicle^{-1}	Spikelet sterility %	Harvest index
Mahsuri	10.32**	4.11**	-85.36**	71.97**	12.26**	81.99**	-11.53**	-0.11**
	104.50	132.00	82.50	248.50	33.00	233.50	5.70	0.06
PK3355-5-1-4	0.22	1.11	-1.61	-0.02	-1.20	-2.29	1.20	-0.01
	83.50	121.00	95.50	115.70	17.70	111.55	3.60	0.51
Vyttila 3	-8.02**	-3.49**	193.84**	-0.99	0.41	-18.30**	11.36**	0.03*
	83.50	110.50	43.00	112.25	20.50	103.95	7.40	0.72
IR60133-184-3-2-2	2.78	4.96**	-23.11**	-17.12**	-2.66**	-17.84**	2.34*	-0.04**
	84.00	114.00	66.00	101.70	16.90	97.50	4.15	0.42
Kachsuing Sen Yu 338	0.93	0.11	-48.71**	1.70	2.57**	5.72	-2.45*	-0.01
	83.50	121.00	86.00	156.00	25.00	142.00	9.05	0.46
IR36	-0.68	-0.29	23.19**	-20.54**	-4.55**	-22.16**	-0.84	0.01
	83.50	114.00	66.00	100.50	16.10	95.20	5.25	0.56
Hraswa	-1.38	-2.84*	-4.36	-26.78**	-5.57**	-19.48**	-1.23	0.06**
	69.50	106.00	71.00	117.30	16.80	108.95	7.35	0.92
Mattatriveni	-4.18**	-3.69**	-53.86**	-8.22	-1.26	-7.64	1.14	0.06**
	79.9	110.0	46.50	102.60	16.10	77.50	24.50	0.69
SE (gi)	1.39	1.06	5.01	4.18	0.84	3.91	0.97	0.01
CD (0.05)	2.82	2.16	10.18	8.49	1.71	7.94	1.97	0.02
CD (0.01)	3.79	2.90	13.68	11.41	2.29	10.67	2.65	0.03
SE (gi-gj)	2.10	1.61	7.58	6.32	1.27	5.91	1.46	0.01
CD (0.05)	4.27	3.26	15.39	12.84	2.58	12.00	2.97	0.02
CD (0.01)	5.73	4.38	20.69	17.25	3.47	16.13	3.99	0.03

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

Table 3. Continued

Parents	1000-grain weight (g)	2nd uppermost internodal length (cm)	Height of plant at harvest (cm)	Leaf area plant^{-1} at max. tillering stage (cm^2)	Length of panicle (cm)	L/B ratio of grain	Amylose content (%)	Alkali spreading value	Yield plant^{-1} (g)
Mahsuri	-4.20**	4.78**	20.76**	-42.85**	0.55	0.02	2.94**	-0.50**	-0.69
	21.60	24.85	125.70	308.15	27.50	3.16	24.30	1.00	12.44
PK3355-5-1-4	-0.07	0.57**	-3.94*	33.99**	-0.32	0.08**	0.99**	0.60**	-0.49
	24.65	16.60	81.10	167.50	23.15	3.64	24.45	3.00	7.65
Vyttila 3	3.97**	6.09**	28.18**	315.11**	2.94**	-0.31**	2.03**	0.15	4.29**
	35.70	24.75	115.00	136.15	26.45	2.66	23.17	2.50	3.61
IR60133-184-3-2-2	-0.55	-2.72**	-6.12**	-55.04**	-0.02	0.40**	-1.42**	-0.15	-1.11*
	26.65	12.50	78.90	212.55	24.45	3.80	20.89	3.00	5.20
Kachsiung Sen Yu 338	1.31**	-2.10**	-4.83**	-124.42**	0.78**	-0.29**	-4.21**	-0.10	-0.62
	30.05	17.00	77.00	77.65	25.75	2.63	12.35	2.00	11.36
IR36	-1.02**	-2.20**	-12.79**	-0.19	-1.17**	0.25**	-0.06	0.15	-0.37
	24.30	13.25	65.70	83.40	20.65	3.63	23.29	2.00	5.68
Hraswa	1.07**	-4.03**	-13.58**	-109.46**	-1.56**	-0.09**	-1.91**	-0.05	-0.74
	30.55	15.35	72.80	234.55	21.85	2.79	20.66	2.50	14.39
Mattatriveni	0.50	-0.40*	-7.68**	-17.14	-1.23**	-0.06**	1.63**	-0.10	-0.26
	25.60	16.15	77.10	160.85	22.65	2.64	25.85	2.50	8.27
SE (gi)	0.33	0.17	1.46	10.72	0.28	0.02	0.18	0.13	0.44
CD (0.05)	0.68	0.48	2.96	21.75	0.57	0.04	0.37	0.27	0.90
CD (0.01)	0.90	0.35	3.99	29.27	0.76	0.05	0.49	0.35	1.20
SE (gi-gj)	0.51	0.27	2.20	16.20	0.18	0.03	0.28	0.20	0.67
CD (0.05)	1.03	0.55	4.47	32.89	0.37	0.06	0.57	0.41	1.36
CD (0.01)	1.39	0.74	6.00	44.23	0.49	0.08	0.76	0.55	1.83

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

General combining ability effects

The genotype Vyttila 3 was found to be a good general combiner for grain yield and important yield components like number of days to 50 per cent flowering (earliness), number of days to harvest (short duration), number of panicles m^{-2}, harvest index, 1000-grain weight, length of panicle, leaf area plant^{-1} at maximum tillering stage and amylose content (Table 3). Apart from Vyttila 3, good general combiners for different characters are Mattatriveni for early flowering, Hraswa and Mattatriveni for short duration, IR36 for number of panicles m^{-2}, Mahsuri for number of spikelets panicle^{-1}, number of grains panicle^{-1}, number of tertiary branches panicle^{-1} and less spikelet sterility percentage; Hraswa and Mattatriveni for harvest index; Kachsiung Sen Yu 338 and Hraswa for 1000-grain weight; IR60133-184-3-2-2, Kachsiung Sen Yu 338, IR36, Hraswa and Mattatriveni for short height and reduced second uppermost internodal length; Kachsiung Sen Yu 338 for long panicle; IR36, IR60133-184-3-2-2 and PK3355-5-1-4 for long grains and Mahsuri, PK3355-5-1-4 and Mattatriveni for amylose content.

Specific combining ability effects

Five hybrids namely PK3355-5-1-4 x Hraswa, Vyttila 3 x IR60133-184-3-2-2, Vyttila 3 x IR36, Vyttila 3 x Mattatriveni and IR36 x Mattatriveni

Table 4. Specific combining ability effects and mean performance of hybrids from 8x8 half diallel analysis using Griffing's Method-2

Cross combinations	No. of days to 50% flowering	No. of days to harvest	Ratio of veg. phase to repro. phase	No. of panicles m^{-2}	No. of spikelets $panicle^{-1}$	No. of tertiary branches $panicle^{-1}$	No. of grains $panicle^{-1}$	Spikelet sterility %
Mahsuri x PK3355-5-1-4	-3.02	-12.88**	0.41**	21.79	-47.30**	-6.35*	-37.57**	-4.82
	105.00	125.00	1.66	99.00	164.00	27.50	158.00	3.40
Mahsuri x Vyttila 3	0.23	-2.28	0.10	-206.66**	27.42*	11.79**	33.68**	-8.28*
	100.00	131.00	1.26	66.00	237.75	47.25	213.25	10.10
Mahsuri x IR60133-184-3-2-2	8.93*	5.77	0.12	2.29	10.55	4.61	17.73	-5.91
	119.50	147.50	1.29	58.00	204.75	37.00	197.75	3.45
Mahsuri x Kachsiung Sen Yu 338	14.28**	13.12**	0.06	35.89*	71.48**	14.38**	66.42**	0.58
	123.00	150.00	1.31	66.00	284.50	52.00	270.00	5.15
Mahsuri x IR36	-10.62*	-2.48	-0.12	-36.01*	-18.78	-5.25*	-7.20	-4.12
	96.50	134.00	1.08	66.00	172.00	25.25	168.50	2.05
Mahsuri x Hraswa	4.08	-0.43	0.17	-11.96	-59.04**	-9.48**	-68.64**	6.86*
	110.50	133.50	1.40	62.50	125.50	20.00	109.75	12.65
Mahsuri x Mattatriveni	13.38**	16.92**	-0.14	16.54	85.25**	18.91**	88.28**	-4.76
	117.00	150.00	1.11	41.50	288.35	52.70	278.50	3.40
PK3355-5-1-4 x Vyttila 3	-1.17	4.72	0.00	254.09**	5.16	2.25	-39.03**	29.69**
	88.50	135.00	1.10	610.50	143.50	24.25	56.25	60.80
PK3355-5-1-4 x IR60133-184-3-2-2	-6.47	-3.73	-0.07	25.54	-1.20	-0.98	-12.24	8.91**
	94.00	135.00	1.02	165.00	121.00	17.95	83.50	31.00
PK3355-5-1-4 x Kachsi-ung Sen Yu 338	-13.12**	-5.86	-0.06	-14.86*	22.48	6.84*	28.20*	-7.50*
	85.50	128.00	1.12	99.00	163.50	31.00	147.50	9.80
PK3355-5-1-4 x IR36	12.48**	11.52**	-0.20	-119.76**	-18.29	-3.29	3.08	-12.96**
	109.50	145.00	0.93	66.00	100.50	13.75	94.50	5.95
PK3355-5-1-4 x Hraswa	37.18**	14.07**	0.56**	-59.21**	105.45**	17.98**	113.40**	-13.12**
	133.50	145.00	1.71	99.00	218.00	34.00	207.50	5.40
PK3355-5-1-4 x Matta-triveni	2.98	19.92**	-0.32**	23.29	-19.10	-11.08**	-56.34**	34.51**
	96.50	150.00	0.87	132.00	112.00	9.25	49.60	55.40
Vyttila 3 x IR60133-184-3-2-2	-5.22	-0.13	-0.12	130.59**	19.76	0.95	38.02**	-15.75**
	87.00	134.00	0.89	465.60	141.00	21.50	117.75	16.50

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

Table 4. Continued

Cross combinations	Harvest index	1000 grain weight (g)	2nd uppermost internodal length (cm)	Height of plant at harvest (cm)	Leaf area plant^{-1} at max.. tillering stage (cm2)	Length of panicle (cm)	L/B ratio of grain	Amylose content (%)	Alkali spreading value	Yield plant^{-1} (g)
Mahsuri x PK3355-5-1-4	0.07*	0.85	1.00	-4.43	108.95**	-2.38**	-0.27**	-1.57**	-0.66	1.39
	0.40	21.00	25.10	102.50	539.45	22.00	2.82	21.41	2.00	7.70
Mahsuri x Vyttila 3	009**	-1.84	-2.63**	-8.35	-102.22**	-0.93	0.18**	-3.96**	0.29	-3.32*
	0.47	22.35	27.00	130.70	609.40	26.70	2.88	20.06	2.50	7.78
Mahsuri x IR60133-3-2-2	0.12**	-2.07	2.18**	8.50	297.39**	-2.28*	-0.21**	0.60	0.09*	-0.96
	0.43	17.60	23.00	113.25	638.85	22.40	3.20	21.17	2.00	4.73
Mahsuri x Kachsiung Sen Yu 338	0.07*	-2.78*	0.37	3.46	10.42	0.22	0.19**	5.92**	1.04*	-1.79
	0.42	18.75	21.80	109.50	282.50	25.70	2.90	23.70	3.00	4.40
Mahsuri x IR36	0.10**	-1.45	3.57**	-6.19	-137.07**	0.62	-0.42**	-3.11**	-0.21	-2.28
	0.47	17.75	24.90	91.90	261.25	24.15	2.84	18.82	2.00	4.16
Mahsuri x Hraswa	-0.08**	-1.24	1.59**	-3.79	-99.24**	-1.68	0.13	0.53	-0.01	-3.78**
	0.33	20.05	21.10	93.50	187.60	21.45	3.05	20.61	2.00	2.29
Mahsuri x Matta-triveni	0.00	-2.62*	0.86	22.66**	10.78	1.93*	0.16*	2.86**	0.54	-1.94
	0.41	17.10	24.00	125.85	390.15	25.40	3.11	26.48	2.50	4.60
PK3355-5-1-4 x Vyt-tila 3	-0.26**	-0.62	6.63**	31.75**	473.54**	1.59	0.04	1.38*	1.69**	-1.29
	0.22	27.70	32.05	146.10	1262.00	28.35	2.80	23.44	5.00	10.01
PK3355-5-1-4 x IR60133-184-3-2-2	0.07*	-1.14	-2.41**	-9.15	284.74**	-1.21	-0.47**	-1.01	-0.51	0.23
	0.48	22.65	14.20	70.90	703.05	22.60	3.00	17.60	2.50	6.12
PK3355-5-1-4 x Kachsiung Sen Yu 338	0.04	-2.26*	1.88**	2.56	166.77*	-0.36	-0.48**	4.43**	-0.56	2.27
	0.49	23.40	19.10	83.90	515.70	24.25	2.30	20.17	2.50	8.65
PK3355-5-1-4 x IR36	0.03	1.18	-4.37**	-7.39	-152.76**	0.04	0.24**	-0.63	2.69**	-3.88**
	0.49	24.50	12.75	66.00	320.40	22.70	3.57	19.34	6.00	2.75
PK3355-5-1-4 x Hraswa	-0.01	0.83	1.95**	19.91**	117.66**	6.54**	-0.08	-5.27**	-0.61	4.55**
	0.49	26.25	17.25	92.50	481.55	28.80	2.91	12.86	2.50	10.82
PK3355-5-1-4 x Mattatriveni	-0.08*	0.41	1.92**	-30.99**	-319.21**	-3.50**	0.03	-4.09**	-0.56	-5.54**
	0.43	24.25	20.85	47.60	137.00	19.10	3.04	17.58	2.50	1.20
Vyttila 3x IR60133-184-3-2-2	0.15**	-1.54	2.02**	7.88	211.97**	2.44**	-0.33**	-0.57	-0.06	12.75**
	0.61	26.30	24.15	120.05	911.40	29.50	2.76	19.08	2.50	23.43

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

Table 4. Continued

Cross combinations	No. of days to 50% flowering	No. of days to harvest	Ratio of veg. phase to repro. phase	No. of panicles m^{-2}	No. of spikelets $panicle^{-1}$	No. of tertiary branches $panicle^{-1}$	No.of grains $panicle^{-1}$	Spikelet sterility %
Vyttila x Kachsiung Sen Yu 338	-5.87	-13.28**	0.08	-12.31	-35.56**	-7.02*	-11.55	-15.26**
	84.50	116.00	1.17	297.00	104.50	18.75	91.75	12.20
Vyttila x IR 36	-2.27	5.12	-0.12	575.79**	65.68**	5.60	-31.92*	47.23**
	86.50	134.00	0.93	957.00	183.50	24.25	43.50	76.30
Vyttila x Hraswa	3.93	27.67**	-0.30*	398.84**	-27.58*	-4.89	-60.60**	50.47**
	92.00	154.00	0.77	752.50	84.00	12.75	17.60	79.15
Vyttila x Mattatriveni	6.23	8.52*	-0.13	-122.66**	-4.64	-2.45	22.06	-20.35**
	91.50	134.00	0.96	181.50	125.50	19.50	112.00	10.70
IR60133-184-3-2-2 x Kachsiung Sen Yu 338	17.83**	25.27**	-0.09	39.64*	-19.42	-2.70	-73.25**	51.06**
	119.00	163.00	0.99	132.00	104.50	20.00	30.50	69.50
IR60133-184-3-2-2 x IR36	13.43**	25.67**	-0.19	-43.76**	45.06**	8.12**	39.48**	1.40
	113.00	163.00	0.85	120.50	146.75	23.70	115.35	21.45
IR60133-184-3-2-2 x Hraswa	-1.37	-6.78*	0.16	-37.71*	-54.45**	-9.47**	-43.45**	-5.31
	97.50	128.00	1.23	99.00	41.00	5.10	35.10	14.35
IR60133-184-3-2-2 x Mattatriveni	10.93*	11.07**	-0.18	-12.71	6.50	0.62	-0.89	3.77
	107.00	145.00	0.91	74.50	120.50	19.50	89.50	25.80
Kachsiung Sen Yu 338 x IR 36	13.78**	5.52	0.02	-72.66**	-63.51**	-10.86**	-48.64**	-4.41
	111.50	138.00	1.14	66.00	57.00	9.95	50.80	10.85
Kachsiung Sen Yu 338 x Hraswa	9.48	9.07**	-0.18	-45.11**	21.23	3.81	26.98*	-10.17**
	106.50	139.00	0.98	66.00	135.50	23.60	129.10	4.70
Kachsiung Sen Yu 338 x Mattatriveni	-4.72	-10.08**	0.36**	30.89	-23.22	1.40	-17.56	-5.09
	89.50	119.00	1.53	92.50	109.50	25.50	96.40	12.15
IR36 x Hraswa	2.58	2.47	0.06	-87.51**	-29.53**	-4.17	-22.24	0.12
	98.00	132.00	1.17	95.50	62.50	8.50	52.00	16.60
IR36 x Mattatriveni	-4.12	-11.68**	0.38**	72.99**	14.91	5.02	20.17	-4.05
	88.50	117.00	1.51	206.50	125.50	22.00	106.25	14.80
Hraswa x Mattatriveni	-5.42	-4.13	0.12	11.54	-19.10	-4.07	-9.51	-11.26**
	86.50	122.00	1.28	117.50	85.25	11.90	79.25	7.10
SE (Sij)	4.26	3.25	0.11	15.37	12.82	2.57	11.98	2.97
CD (0.05)	8.66	6.61	0.22	31.20	26.03	5.22	24.32	6.03
CD (0.01)	11.63	8.87	0.30	41.96	35.00	7.02	32.71	8.11
SE S(iJ)-S(jk)	6.30	4.81	0.16	22.74	18.97	3.80	17.73	4.39
CD (0.05)	12.81	9.77	0.32	46.16	38.51	7.72	35.99	8.91
CD (0.01)	17.20	13.13	0.44	62.08	51.79	10.37	48.40	11.98
SE S(iJ)-S(jk)	5.95	4.54	0.15	21.44	17.89	3.58	16.71	4.14
CD (5%)	12.07	9.21	0.31	43.52	36.31	7.27	33.93	8.40
CD (1%)	16.24	12.39	0.41	58.53	48.84	9.77	45.62	11.30

Table 4. Continued

Cross combinations	Harvest index	1000-grain weight (g)	2nd uppermost internodal length (cm)	Height of plant at harvest (cm)	Leaf area plant^{-1} at max.. tillering stage (cm^2)	Length of panicle (cm)	L/B ratio of grain	Amylose content (%)	Alkali spreading value	Yield plant^{-1} (g)
Vyttila x IR60133-184-3-2-2	0.07*	0.50	-4.65**	9.44*	-15.40	-1.76*	0.00	5.37**	-0.11	1.08
	0.56	30.20	18.10	122.90	614.65	26.10	2.39	22.24	2.50	12.24
Vyttila x Kachsiung Sen Yu 338	-0.13**	-2.67**	5.10**	16.44**	1166.72**	3.49**	-0.19**	1.98**	-0.85*	14.48**
	0.38	24.70	27.75	121.95	1921.00	29.40	2.75	22.89	2.00	25.90
Vyttila x IR36	-0.36**	-1.21	0.13	-4.61	-15.36	-0.07	-0.18**	-2.86**	-0.16	-4.54**
	0.19	28.25	20.95	100.10	629.65	25.45	2.42	16.31	2.50	6.51
Vyttila x Hraswa	0.06	0.71	5.80**	10.39*	147.62**	2.40**	-0.09	-1.49*	-0.11	5.74**
	0.61	28.60	30.25	121.00	884.95	28.25	2.53	21.22	2.50	17.26
Vyttila x Mattatriveni	-0.16**	0.88	1.56**	-4.66	121.31**	0.24	0.30**	-1.30*	0.19	-3.19*
	0.26	24.30	15.50	74.50	381.20	25.15	3.40	12.11	2.50	2.57
IR60133-184-3-2-2 x Kachsiung Sen Yu 338	-0.04	2.96**	3.46**	16.59**	-319.78**	3.14**	-0.11	-3.38**	-0.56	-1.26
	0.40	25.80	17.30	87.80	64.35	26.10	3.54	14.18	2.00	4.76
IR60133-184-3-2-2 x IR36	-0.10**	-2.64*	-3.76**	-24.16**	-238.65**	-4.11**	0.33**	-2.26**	-0.36	-4.45
	0.38	22.30	8.25	46.25	36.20	18.45	3.64	13.46	2.00	1.20
IR60133-184-3-2-2 x Hraswa	-0.11**	-1.36	-1.39*	2.94	-123.53**	1.10	0.48**	-1.45*	-0.31	-2.96*
	0.37	22.00	14.25	79.25	243.65	24.00	3.82	17.81	2.00	3.16
IR60133-184-3-2-2 x Mattatriveni	-0.05	0.39	0.70	-12.40**	-228.40**	-1.06	-0.45**	-7.72**	-0.11	-4.79**
	0.42	25.10	15.15	60.10	86.35	22.70	2.50	7.06	2.50	1.73
Kachsiung Sen Yu 338 x IR36	0.02	-1.10	-5.33**	14.35**	202.28**	3.19**	0.04	-3.20**	0.09	-1.83
	0.54	25.70	7.30	86.05	407.75	26.55	2.65	9.73	2.50	4.31
Kachsiung Sen Yu 338 x Hraswa	-0.01	0.12	0.59	-5.85	-31.25	-0.55	0.03	-6.86**	0.14	-1.95
	0.51	25.35	16.85	71.75	266.5	23.15	2.61	9.61	2.50	4.67
Kachsiung Sen Yu 338 x Mattatriveni	-0.08*	-2.62*	-2.98**	-13.49**	-209.26**	-3.06**	0.29**	1.18*	0.84*	-5.43**
	0.46	21.85	9.55	50.25	120.45	18.35	3.45	18.26	3.50	0.96
IR36 x Hraswa	0.02	-1.64	-3.26**	4.10	589.72**	-0.85	0.39**	2.93**	-0.11	5.31**
	0.56	21.25	12.90	73.75	1011.75	20.90	3.58	23.55	2.50	12.18
IR36 x Mattatriveni	-0.06	0.01	-0.88	-7.95	214.34**	-2.45**	-0.46**	1.02	0.09	-1.26
	0.52	25.00	13.45	60.90	527.10	18.90	2.39	19.80	2.50	5.23
SE (Sij)	0.03	1.03	0.54	4.46	32.85	0.85	0.06	0.57	0.40	1.35
CD (0.05)	0.06	2.09	1.09	9.06	66.68	1.73	0.13	1.16	0.82	2.75
CD (0.01)	0.08	2.81	1.47	12.18	89.68	2.32	0.16	1.56	1.09	3.69
SE S(iJ)-S(jk)	0.04	1.52	0.80	6.60	48.60	1.26	0.09	0.84	0.60	2.00
CD (0.05)	0.09	3.09	1.62	13.40	98.66	2.57	0.19	1.71	1.22	4.07
CD (0.01)	0.11	4.15	2.18	18.02	132.68	3.44	0.25	2.29	1.64	5.46
SE S(iJ)-S(jk)	0.04	1.43	0.75	6.22	45.82	1.19	0.09	0.80	0.57	1.89
CD (0.05)	0.08	2.91	1.53	12.63	93.02	2.42	0.18	1.62	1.15	3.84
CD (0.01)	0.11	3.90	2.05	16.98	125.09	3.25	0.25	2.18	1.56	5.16

exhibited significant *sca* effects for grain yield per plant (Table 4). Among these hybrids, three hybrids have at least one parent (Vyttila 3) with positive *gca* effect. The hybrid PK3355-5-1-4 x Hraswa showed significant favourable *sca* effects for seven yield components (Table 4). The hybrids Vyttila 3 x IR60133-184-3-2-2 for six yield components, Vyttila 3 x IR36 for four yield components, Vyttila 3 x Mattatriveni for three yield components and IR36 x Mattatriveni for seven yield components. In these hybrids all kinds of parental combinations like high x high, high x low, medium x medium and medium x low were found. This suggests that either additive x additive and/or additive x dominance genetic interactions were predominant. The superiority of these crosses may be due to complementary and duplicate type gene interactions. Similar results were earlier reported by Dhaliwal and Sharma (1990), Katre and Jambhale (1996) and Ramalingam *et al.* (1997). Therefore, these crosses are expected to produce desirable segregants and could be exploited successfully in varietal improvement programme.

The present study reveals importance of both additive and non-additive gene effects in governing yield and most of the yield attributes with predominance of non-additive gene action for most of the yield attributes. In this situation, where both non-additive and additive components were important for the expression of characters, especially when the former component is predominant, simple pedigree method of selection would be ineffective for its improvement. At the same time population improvement programme like reciprocal recurrent selection which may allow to accumulate the fixable gene effects as well as to maintain considerable variability and heterozygosity for exploiting non-fixable gene effects will prove to be the most effective method (Joshi, 1979). However, rice being a highly self-pollinated crop, forming single seed per pollination, this selection procedure is not practicable. So a possible choice is the use of biparental mating among selected crosses or use of selection procedure such as diallel selective mating (Jensen, 1970) to exploit both the additive and non-additive genetic components. The parent Vyttila 3 could be utilized in hybridization programme because of its general combining ability for yield and a number of yield components. Hybrids namely PK3355-5-1-4 x Hraswa, Vyttila 3 x IR60133-184-3-2-2, Vyttila x IR36, Vyttila 3 x Mattatriveni and IR36 x Mattatriveni could be utilized for hybrid rice programme or for selecting out favourable segregants from segregating generations.

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