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Full Length Research Paper

Studies of genetics of yield and yield component characters in F_2 and F_3 generations of rice (*Oryza sativa* L.)

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Three parents with three different durations were crossed in full diallel fashion. The resultant six hybrids were selfed along with their three parents to get six F_2's. The F_2's were selfed to obtain six F_3's. The aforementioned five generations of the six crosses were studied for days to flowering, number of productive tillers per plant, number of filled grains per panicle, 100 seed weight, grain L/B ratio, grain yield per plant and harvest index. The distribution pattern of the segregating generations revealed that, the F_3's of the cross ADT 38 x ADT 37 for hundred seed weight and the F_3's the cross ADT 38 x ADT 44 for grain yield per plant showed normal symmetrical distribution. The kurtosis value was almost negligible indicating mesocurtic nature of the distribution. The F_3's of ADT 38 x ADT 44 recorded high mean coupled with higher coefficient of variation, indicating the presence of additive genetic control. The higher mean performance in F_3 may be due to accumulation of favourable genes. All the other crosses and generations showed asymmetric distribution in positive as well as negative direction, for almost all the characters of interest. The mean was comparatively higher but the coefficients of variation were comparatively lower, indicating the preponderance of non-additive genetic control in the expression of the traits of interest. It is better to resort to intermating of segregants followed by recurrent selection for further improvement. The F_3's unique cross ADT 38 x ADT 44 had taken less number of days to first flowering, higher grain L/B ratio coupled with higher grain yield. A simple selection among the F_3 progenies of the cross ADT 38 x ADT 44 may yield some useful segregants with earliness, desirable grain quality and higher grain yield.

Key words: Rice, segregating generations, F_2, F_3.

INTRODUCTION

The population of India is 1030 million. It is increasing by 17 million yearly (Singh, 2002). To meet the food demand of growing population, five million tones of additional food grain is required, out of which, two million share is of rice. Hence, rice demand of 143 million tones by 2030 has to be met by increased rice productivity per unit time and area. To meet the increasing demand, rice production must be increased in spite of less land, less water and less pesticides in a sustainable way (Anandan et al., 2009a). Among the various options for increasing rice production, earliness breeding has to be proved to be one of the best strategies and it has tremendous scope in Indian agriculture.

Grain quality has become an important issue affecting domestic consumption and possibly international trade of rice (Anandan et al., 2009b). Varietal improvement is the surest and most economical means of improving grain quality without any added cost or adverse effect on grain yield (Ludh, 2002). Market quality firstly depends on the physical appearance of the grain like grain length, grain length/breadth ratio, etc. (Kaosa-ard and Juliano, 1991). Development of early maturing genotypes with higher grain yield coupled with acceptable quality needs inten-

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sive research in genetic and plant breeding. The present investigation was designed (1) to study the segregating populations (F_2's and F_3's) of six crosses, for seven earliness, quality and grain yield characters and (2) to identify useful segregates with high yield coupled with earliness.

MATERIALS AND METHODS

The present investigation was carried out during 2007 to 2009 using the experimental material consisting of five generations including, P_1, P_2, F_1, F_2 and F_3 of three direct and three reciprocal crosses involving three varieties of rice such as, ADT 37 (P_1 - short durations); ADT 38 (P_2 - medium duration) and ADT 44 (P_3 - long duration). The experiment was conducted in a randomized block design with three replications at the experimental farm of Plant Breeding, Annamalai University (11°24' N latitude, 79°43' E longitude, 6 ft altitude), Tamil Nadu, India. The crosses were randomized within each replication followed by randomization of each generation within each replication. One row was allotted to each of P_1, P_2 and F_1 generations, whereas, each F_2 generations were grown in 10 rows. Each row was three meters long, with a plant to plant distance of 15 cm and row to row distance of 20 cm. Data were recorded 10 plants for replication in parents and F_1's and 200 plants per replication in F_2's and F_3's for days to first flowering, number of productive tillers per plant, number of filled grains per panicle, 100 seed weight (g), grain length/breadth ratio (grain L/B ratio), grain yield per plant (g) and harvest index. The segregating populations were described with the standard statistical parameters derived with the use of the software INDOSTAT.

RESULTS AND DISCUSSION

Variability is a pre-requisite for successful selection of superior progenies from segregating generations. Variability can be created by hybridization and/or mutation. F_2 is an ideal generation in which segregation and recombination are maximum for imposing selection. F_3 generation is equally important in the process of selection. The magnitude of recombination potential depends on the genetic diversity of the parents. A populations is said to be superior when it shows high mean coupled with high variability. The present investigation aims to determine the magnitude and extent of variability and pattern of segregation in F_2 and F_3 generations of six crosses of rice. Six crosses were studied for seven earliness, quality and grain yield characters in five generations. The salient results are given in Tables (1 to 7).

The mean number of days to first flowering was lesser in the F_1's of P_1 x P_2 than its parents and reciprocal cross F_1's (Table 1). The F_2 and F_3 progenies of P_2 x P_1 came to first flowering earlier than its homozygous and heterozygous parents as well as its direct cross. In general, the mean of F_1's was lesser than F_2's and F_3's. On the contrary, the mean of F_3's was higher than the mean of F_1's and F_2's, indicating the occurrence of transgressive segregation in the negative direction in almost all the cross combinations. Transgressive segregation may arise due to the dominance and dominance interaction in addition to additive x additive interactions which is fixable. It may also arise due to recombination of genes. The coefficient of variation was higher in F_2's than in F_3's. It may be due to setting down of the homozygosity. The mean, median and mode were dissimilar in almost all the generations and all the crosses. It is indicated that, the distributions was asymmetrical. The mean and median were lesser than mode in the F_2's and F_3's of P_1 x P_2, indicating the distribution was negatively skewed, whereas the reverse was true in the F_2's and F_3's of its reciprocal cross, indicating the distribution was positively skewed. Hence, selection for earliness can be practiced well in the F_2's and F_3's of P_1 x P_2 than in its reciprocal F_2 and F_3 populations. The mean was higher than median and mode in the F_2's of P_1 x P_3, indicating that the distribution was positively skewed. On the contrary the reverse was true in the F_2's and F_3's of P_3 x P_1, as well as in F_3's of P_1 x P_3 as well as F_3's of P_1 x P_3, where the distribution was negatively skewed and hence, selection may be practiced for earliness. A similar trend was almost observed in the F_2 and F_3 populations of the cross P_2 x P_3. The kurtosis value was less than three in F_2's and F_3's of all the six crosses indicating that, the curve was platykurtic. It indicated that the progenies are not more closely bunched around the mode. The influence of maternal cytoplasm in the distribution pattern was quite conceivable. The F_3's of the reciprocal cross P_2 x P_1 came to early flowering. These progenies are worthy of exploitation for obtaining early maturing lines in future generations.

The mean number of productive tillers per plant was high with the F_1 hybrids of P_2 x P_3 than their parents and its direct cross F_1's (Table 2). The F_2 progenies recorded higher mean than their homozygous grand parents (P_2 and P_3) but lesser than their heterozygous immediate parents (F_1's of P_2 x P_3). However, the F_3 progenies of P_2 x P_3 registered lower mean than their F_2's, F_1's. It indicated the presence of high inbreeding depression. The coefficient of variation was higher with the F_2 and F_3 progenies of the cross P_3 x P_2. The mean, median and mode were dissimilar in all the crosses and in all the generations. It indicated the presence of asymmetrical distribution for this character. The mean was lesser than median and mode in the F_2's of P_1 x P_2, P_1 x P_3 and P_2 x P_3. It indicated that the distribution was negatively skewed. Such a trend was also observed in F_3's of P_1 x P_3 and P_3 x P_1. On the other hand, the F_2's P_2 x P_1, P_3 x P_1 and P_2 x P_3 recorded higher mean than median and mode, indicating that the distribution was positively skewed. Such a trend was also witnessed for the F_3's of P_1 x P_2, P_2 x P_1, P_1 x P_3 and P_3 x P_1. Hence, selection for higher number of productive tillers may be practiced among these progenies. The kurtosis value was less than three in almost all the crosses except the F_2's of P_2 x P_1 and F_3's of P_3 x P_1. It indicated that the distribution was

Table 1. First, second, third and fourth degree statistics-days to first flowering.

Parameter			F1		F2		F3	
Cross 1	**P1**	**P2**	**P1 x P2 (Direct)**	**P2 x P1 (reciprocal)**	**Direct**	**Reciprocal**	**Direct**	**Reciprocal**
Minimum					52.00	53.00	58.00	63.00
Maximum					98.00	100.00	108.00	103.00
Range					46.00	47.00	50.00	40.00
Mean	79.00	99.47	73.27	78.13	78.08	75.08	84.93	75.43
Median					79.50	74.00	86.00	74.00
Mode					83.00	73.00	89.00	74.00
Skewness					-0.35	0.33	-0.39	2.08
Kurtosis					-0.46	-0.21	0.41	9.84
Coefficient of variation	2.00	2.00	2.00	2.00	0.11	0.14	0.09	0.06
Cross 2	**P1**	**P3**	**P1 x P3**	**P3 x P1**				
Minimum					52.00	56.00	67.00	64.00
Maximum					104.00	103.00	104.00	104.00
Range					52.00	47.00	37.00	40.00
Mean	79.00	114.87	83.47	95.20	75.27	82.37	81.08	86.93
Median					73.00	82.00	83.00	88.00
Mode					73.00	95.00	85.00	88.00
Skewness					0.46	-0.18	-0.04	-0.22
Kurtosis					0.54	-1.05	1.00	-0.41
Coefficient of variation	2.00	1.00	3.00	1.00	0.11	0.15	0.07	0.09
Cross 3	**P2**	**P3**	**P2 x P3**	**P3 x P2**				
Minimum					53.00	66.00	63.00	66.00
Maximum					102.00	100.00	96.00	100.00
Range					49.00	34.00	33.00	34.00
Mean	99.47	114.87	84.00	82.67	74.31	78.23	77.88	78.23
Median					73.00	78.00	79.00	78.00
Mode					73.00	79.00	79.00	83.00
Skewness					0.43	0.61	-0.12	0.61
Kurtosis					0.60	-0.32	-0.04	-0.32
Coefficient of variation	2.00	1.00	3.00	2.00	0.11	0.11	0.07	0.11

platykurtic, in the progenies except F_2's of P_2 x P_1 and F_3's of P3 x P_1. It indicated that, the progenies were not bunched around the mode in all the generations and crosses except F_2's P_2 x P_1 and F_3's of P_3 x P_1. The distribution was leptokurtic in these generations. In general, the distribution pattern was influenced by the maternal cytoplasm.

The F_3 progenies of the cross P_2 x P_1 recorded higher number of filled grains per panicle. The F_1's and F_2's of this cross registered lesser number of filled grains per panicle than its F_3's (Table 3). The F_1's demonstrated higher number of filled grains per panicle than their parents. The F_2's evinced higher number of filled grains per panicle than F_1's. Thus, the occurrence of transgressive segregation was well evidenced. Hence, selection could well be practiced in F_3's of P_2 x P_1 for number of filled grains per panicle. The coefficient of variation was higher in all the segregating generations. The higher mean coupled with higher coefficient of variations in F_3's of P_2 x P_1 may indicate that, the released variability is it additive in nature. Hence, simple selection would yield some useful segregants. The mean, median and mode were dissimilar in all the generations of all the cross combinations. It indicated that the distribution was asymmetrical. The mean was higher than median and mode in F_2's and F_3's of P_1 x P_3 and P_3 x P_1

Table 2. First, second, third and fourth degree statistics – number of productive tillers per plant.

Parameter			F1		F2		F3	
Cross 1	**P1**	**P2**	**P1 x P2**	**P2 x P1**	**Direct**	**Reciprocal**	**Direct**	**Reciprocal**
Minimum					5.00	7.00	6.00	8.00
Maximum					25.00	30.00	23.00	24.00
Range					20.00	23.00	17.00	16.00
Mean	9.40	13.53	14.67	16.00	12.90	15.27	15.13	13.56
Median					13.00	15.00	15.00	13.00
Mode					13.00	15.00	15.00	13.00
Skewness					0.11	0.98	-0.17	0.68
Kurtosis					0.25	3.50	-0.10	0.43
Coefficient of variation	8.00	10.00	9.00	11.00	0.28	0.23	0.21	0.23
Cross 2	**P1**	**P3**	**P1 x P3**	**P3 x P1**				
Minimum					8.00	8.00	6.00	9.00
Maximum					26.00	25.00	21.00	33.00
Range					18.00	17.00	15.00	24.00
Mean	9.40	18.53	18.93	17.27	16.16	13.55	10.65	14.46
Median					16.00	13.00	10.00	14.00
Mode					17.00	13.00	10.00	14.00
Skewness					0.03	0.68	0.64	2.18
Kurtosis					-0.44	0.74	1.07	11.90
Coefficient of variation	8.00	5.00	9.00	9.00	0.25	0.24	0.22	0.17
Cross 3	**P2**	**P3**	**P2 x P3**	**P3 x P2**				
Minimum					7.00	5.00	8.00	5.00
Maximum					25.00	25.00	27.00	25.00
Range					18.00	20.00	19.00	20.00
Mean	13.53	18.53	22.27	17.00	15.46	11.44	14.39	11.44
Median					15.00	11.00	15.00	11.00
Mode					16.00	8.00	15.00	16.00
Skewness					0.41	1.16	0.67	1.16
Kurtosis					-0.59	1.49	1.49	1.49
Coefficient of variation	10.00	5.00	6.00	13.00	0.23	0.34	0.20	0.34

as well as in F_2's of P_3 x P_2. It indicated that the distribution was positively skewed in these generations, whereas in other generations of other crosses, it was negatively skewed. The kurtosis value in all the crosses and generations were less than three, indicating that the progenies were not bunched around the mode.

Hundred grain weight was higher in the F_3's of P_2 x P_3 and P_1 x P_2 (Table 4). There was a gradual increase in hundred grain weight in F_1's, F_2's and F_3's of these cross combinations, illustrating the occurrence of transgressive segregation for this trait. The coefficient of variation was higher for this trait in all the segregating generations. However, there was a slight decrease in the percentage of variation in F_3's than in F_2's, indicating the setting down of homozygosity. Interestingly, the mean, median and mode were similar in F_3's of P_2 x $P_{1,}$ indicating that the distribution was symmetrical (Figure 1a). The kurtosis value was least in the F_3 generation indicating the meso-curtic nature of the distribution. The mean and coefficient of variation was considerably high in P_2 x P_1. This trend together with symmetrical distribution amply indicated the additive genetic control of this trait. Hence, there exists chance for improvement by simple selection. On the contrary, the mean, median and mode were asymmetrical in all the generations of the remaining five cross combinations as well as in the F_2's of P_2 x P_1 (Figure 1b).

Table 3. First, second, third and fourth degree statistics – number of filled grains per panicle.

Parameter			F1		F2		F3	
Cross 1	**P1**	**P2**	**P1 x P2**	**P2 x P1**	**Direct**	**Reciprocal**	**Direct**	**Reciprocal**
Minimum					120.00	105.00	104.00	140.00
Maximum					293.00	286.00	286.00	274.00
Range					173.00	181.00	182.00	134.00
Mean	110.2	122.13	198.53	171.20	191.40	184.31	195.33	204.08
Median					189.00	184.00	193.00	206.00
Mode					229.00	194.00	230.00	234.00
Skewness					0.20	0.13	0.06	-0.13
Kurtosis					-0.54	-0.57	-0.57	-1.04
Coefficient of variation	2.00	3.00	2.00	1.00	0.19	0.21	0.17	0.16
Cross 2	**P1**	**P3**	**P1 x P3**	**P3 x P1**				
Minimum					82.00	120.00	105.00	98.00
Maximum					293.00	255.00	252.00	254.00
Range					211.00	135.00	147.00	156.00
Mean	110.2	162.27	172.40	167.60	184.98	188.52	171.62	165.09
Median					186.00	189.00	170.00	162.50
Mode					168.00	178.00	147.00	174.00
Skewness					-0.11	-0.10	0.13	0.28
Kurtosis					-0.50	-0.22	-0.79	-0.35
Coefficient of variation	2.00	2.00	2.00	1.00	0.23	0.16	0.19	0.19
Cross 3	**P2**	**P3**	**P2 x P3**	**P3 x P2**				
Minimum					108.00	115.00	95.00	115.00
Maximum					274.00	277.00	278.00	277.00
Range					166.00	162.00	183.00	162.00
Mean	122.13	162.27	204.73	206.13	196.63	197.57	179.97	197.57
Median					198.00	196.00	179.00	196.00
Mode					234.00	194.00	198.00	243.00
Skewness					-0.23	-0.11	0.12	-0.11
Kurtosis					-0.53	0.31	0.11	0.31
Coefficient of variation	3.00	2.00	1.00	1.00	0.16	0.14	0.17	0.14

It indicated that the distribution was asymmetrical. The mean was higher than median and mode in F_2's of P_1 x P_2, P_3 x P_2 and F_3's of P_2 x P_3 and P_3 x P_2. It indicated that the distribution was positively skewed in these generations. The kurtosis value was less than three in almost all the cross combinations indicating that the distribution was platykurtic.

The mean L/B ratio of grain was higher in the F_3's of P_2 x P_3 (Table 5). The grain L/B ratio in F_3's of P_2 x P_3 was higher than their F_2's but lesser than their F_1's. The F_1's of the cross P_2 x P_3 registered the maximum L/B ratio of grain. The presence of inbreeding depression was quite obvious. The coefficient of variation was higher in all the segregating generations of all the crosses. The mean, median and mode were dissimilar in all the crosses and in all the generations. It indicated that the distribution was asymmetrical. The mean was higher than median and mode in F_2's of P_1 x P_2, P_3 x P_1 and P_2 x P_3. Similarly, the mean was higher than median and mode in F_3's of P_1 x P_2 and P_1 x P_3. It indicated that the distribution was

Table 4. First, second, third and fourth degree statistics – hundred grain weight.

Parameter			F1		F2		F3	
Cross 1	**P1**	**P2**	**P1 x P2**	**P2 x P1**	**Direct**	**Reciprocal**	**Direct**	**Reciprocal**
Minimum					1.63	1.72	2.01	1.82
Maximum					2.86	2.84	2.86	2.56
Range					1.23	1.12	0.85	0.74
Mean	2.34	2.24	2.12	2.18	2.14	2.23	2.43	2.13
Median					2.12	2.24	2.43	2.13
Mode					2.04	2.34	2.54	2.13
Skewness					0.65	0.02	0.09	0.22
Kurtosis					1.21	0.31	-0.83	-0.59
Coefficient of variation	2.00	1.00	1.00	1.00	0.09	0.09	0.08	0.07
Cross 2	**P1**	**P3**	**P1 x P3**	**P3 x P1**				
Minimum					1.57	1.80	1.93	1.90
Maximum					3.05	2.84	2.51	2.90
Range					1.48	1.04	0.58	1.00
Mean	2.34	2.22	2.32	2.30	2.10	2.28	2.26	2.32
Median					2.09	2.28	2.27	2.33
Mode					2.14	2.34	2.36	2.44
Skewness					0.64	0.10	-0.20	0.15
Kurtosis					0.76	-0.49	-0.78	-0.01
Coefficient of variation	2.00	0.00	1.00	1.00	0.13	0.09	0.06	0.07
Cross 3	**P2**	**P3**	**P2 x P3**	**P3 x P2**				
Minimum					1.55	1.55	2.06	1.55
Maximum					2.89	2.75	2.86	2.75
Range					1.34	1.20	0.80	1.20
Mean	2.24	2.22	2.11	2.06	2.21	2.25	2.50	2.25
Median					2.23	2.24	2.49	2.24
Mode					2.27	2.17	2.34	2.22
Skewness					-0.10	-0.19	-0.07	-0.19
Kurtosis					-0.25	0.60	-0.52	0.60
Coefficient of variation	1.00	0.00	1.00	1.00	0.11	0.09	0.07	0.09

positively skewed. Hence, selection for higher L/B ratio of grain may be practiced among these progenies. On the other hand, in the remaining crosses and generations the distribution was negatively skewed. The kurtosis value was less than three in almost all the generations of the entire cross combinations except the F_2's and F_3's of P_3 x P_2. It indicated that the progenies were not bunched around the mode in all the generations and crosses except the F_2's and F_3's of P_3 x P_2. In these generations, the distributions were leptokurtic. There were spectacular maternal cytoplasmic influences in the expression of this trait.

The F_1's of P_3 x P_1 recorded higher grain yield per plant than its parents (Table 6). In general, all the segregating progenies registered lesser grain yield per plant than their F_1's indicating the occurrence of higher inbreeding depression and trangressive segregation in the negative direction. However, there was a slight spurt in mean grain yield in F_3's than F_2's. The coefficient of variation was higher in all the segregating generations. The mean,

Table 5. First, second, third and fourth degree statistics-grain length/breath ratio.

Parameter			F1		F2		F3	
Cross 1	**P1**	**P2**	**P1 x P2**	**P2 x P1**	**Direct**	**Reciprocal**	**Direct**	**Reciprocal**
Minimum					1.80	1.83	1.87	2.09
Maximum					3.74	3.67	3.42	3.22
Range					1.94	1.84	1.55	1.13
Mean	1.87	2.77	2.44	2.37	2.40	2.49	2.64	2.51
Median					2.38	2.47	2.69	2.49
Mode					2.31	2.58	2.71	2.44
Skewness					0.80	0.59	0.05	0.61
Kurtosis					2.19	1.33	-0.25	0.56
Coefficient of variation	2.00	2.00	1.00	1.00	0.12	0.12	0.12	0.08
Cross 2	**P1**	**P3**	**P1 x P3**	**P3 x P1**				
Minimum					1.63	1.56	2.00	1.92
Maximum					3.43	3.68	3.29	3.39
Range					1.80	2.12	1.29	1.47
Mean	1.87	2.81	2.60	2.60	2.26	2.49	2.64	2.79
Median					2.28	2.50	2.64	2.83
Mode					2.43	2.44	2.44	3.06
Skewness					0.35	0.18	-0.15	-0.41
Kurtosis					1.11	0.20	-0.46	-0.54
Coefficient of variation	2.00	3.00	1.00	1.00	0.13	0.16	0.11	0.11
Cross 3	**P2**	**P3**	**P2 x P3**	**P3 x P2**				
Minimum					1.73	1.56	2.30	1.56
Maximum					3.71	5.45	3.59	5.45
Range					1.98	3.89	1.29	3.89
Mean	2.77	2.81	3.01	2.58	2.73	2.70	2.96	2.70
Median					2.83	2.73	2.94	2.73
Mode					2.53	2.96	3.34	3.18
Skewness					-0.34	0.81	0.01	0.81
Kurtosis					-0.79	3.85	-1.27	3.85
Coefficient of variation	2.00	3.00	1.00	1.00	0.15	0.17	0.11	0.17

median and mode were almost similar in the F_3's of P_2 x P_3, indicating the symmetrical distribution (Figure 1c). The kurtosis value was also negligible, indicating the mesocurtic nature of the distribution. It may indicate the influence of additive gene action in the inheritance of grain yield per plant in this cross. The mean, median and mode were dissimilar in all the other generations of all the other cross combinations indicating the asymmetrical distribution. The mean was higher than the median and mode in F_2's of P_2 x P_1 and F_3's of P_1 x P_2, indicating the positive skewed nature of the distribution. In all the other generations and crosses the distribution was negatively skewed.

Harvest index was higher in the F_1's than their parents (Table 7). But, F_2's and F_3's recorded lesser harvest index than the F_1's. However, there was a slight increase in harvest index in F_3's than the F_2's. Occurrence of transgressive segregation in the negative direction was quite obvious. The coefficient of variation was higher in the segregating generations. But the mean was lesser. It

Table 6. First, second, third and fourth degree statistics – grain yield per plant.

Parameter			F1		F2		F3	
Cross 1	**P1**	**P2**	**P1 x P2**	**P2 x P1**	**Direct**	**Reciprocal**	**Direct**	**Reciprocal**
Minimum					8.89	9.22	10.09	12.02
Maximum					45.72	36.32	32.19	39.90
Range					36.83	27.10	22.10	27.88
Mean	28.74	34.87	32.70	34.76	17.44	17.61	16.17	19.26
Median					16.36	16.04	15.86	18.57
Mode					17.50	15.80	13.28	22.23
Skewness					1.09	1.04	1.15	0.98
Kurtosis					2.16	1.25	1.11	1.08
Coefficient of variation	6.00	5.00	8.00	11.00	0.33	0.30	0.28	0.29
Cross 2	**P1**	**P3**	**P1 x P3**	**P3 x P1**				
Minimum					8.68	10.61	11.89	12.24
Maximum					47.60	42.70	35.80	48.71
Range					38.92	32.09	23.91	36.47
Mean	28.74	38.46	38.50	40.08	19.05	21.35	20.83	24.66
Median					18.81	20.94	20.68	24.06
Mode					20.50	25.84	23.04	25.50
Skewness					0.75	0.31	0.40	0.58
Kurtosis					0.81	0.05	-0.07	0.48
Coefficient of variation	6.00	3.00	9.00	9.00	0.36	0.28	0.19	0.28
Cross 3	**P2**	**P3**	**P2 x P3**	**P3 x P2**				
Minimum					10.06	5.88	13.30	5.88
Maximum					41.48	37.62	42.97	37.62
Range					31.42	31.74	29.67	31.74
Mean	34.87	38.46	39.56	37.55	20.56	16.22	22.14	16.22
Median					20.98	15.25	22.21	15.25
Mode					22.43	15.00	22.34	23.13
Skewness					0.54	0.68	0.69	0.68
Kurtosis					1.00	1.05	0.95	1.05
Coefficient of variation	5.00	3.00	7.00	12.00	0.25	0.34	0.24	0.34

may indicate that harvest index may be controlled by non-additive genes. The mean, median and mode were almost similar in the F_3's of P_3 x P_1, indicating that the distribution was symmetric (Figure 1d). The kurtosis value less, indicating the mesocurtic nature of the distribution. The mean, median and mode were dissimilar in all the remaining cross combinations. It indicated that the distribution was asymmetric. The mean was higher than mode in F_2's of P_1 x P_2 and F_3's of P_1 x P_3. It indicated the distribution was positively skewed for trait in these generations of these cross combinations. In the remaining cross combinations it was negatively skewed. The kurtosis value was less than three in the all generations of the entire cross combinations, indicating that the progenies were not bunched around the mode.

The present study indicated that, almost all the characters were predominantly controlled by non-additive genes in the presence of little influence of additive genes.

Table 7. First, second, third and fourth degree statistics – harvest index.

Parameter					F1		F2		F3
Cross 1	**P1**	**P2**	**P1 x P2**	**P2 x P1**	**Direct**	**Reciprocal**	**Direct**	**Reciprocal**
Minimum					12.89	14.66	13.78	24.46
Maximum					76.12	74.08	61.68	58.76
Range					63.23	59.42	47.90	34.30
Mean	48.86	49.18	58.68	54.88	44.72	39.84	44.61	41.61
Median					46.13	39.88	46.87	42.58
Mode					43.48	44.34	47.30	44.26
Skewness					-0.12	-0.18	-0.89	-0.09
Kurtosis					0.66	0.68	0.40	-1.04
Coefficient of variation	4.00	3.00	6.00	6.00	0.23	0.25	0.21	0.20
Cross 2	**P1**	**P3**	**P1 x P3**	**P3 x P1**				
Minimum					11.74	12.48	23.64	17.55
Maximum					67.32	62.97	66.08	71.48
Range					55.58	50.49	42.44	53.93
Mean	48.86	49.72	56.80	55.42	42.98	33.80	49.82	48.96
Median					44.33	34.21	51.13	48.96
Mode					55.00	39.33	41.02	48.92
Skewness					-0.57	0.14	-0.50	-0.69
Kurtosis					-0.03	-0.49	-0.35	1.50
Coefficient of variation	4.00	3.00	6.00	4.00	0.26	0.30	0.18	0.17
Cross 3	**P2**	**P3**	**P2 x P3**	**P3 x P2**				
Minimum					17.30	13.41	24.60	13.41
Maximum					71.86	67.24	63.40	67.24
Range					54.56	53.83	38.80	53.83
Mean	49.18	49.72	58.43	56.05	39.22	44.90	46.27	44.90
Median					37.77	47.27	46.55	47.27
Mode					43.72	54.38	52.42	51.78
Skewness					0.55	-0.69	-0.31	-0.69
Kurtosis					-0.24	0.18	-0.69	0.18
Coefficient of variation	3.00	3.00	3.00	3.00	0.31	0.24	0.19	0.24

Hence, improvement in any of the characters could well be achieved by resorting to population improvement programmes. Anderson (1939), Al-Jibouri et al. (1958), Jensen (1970), Hallauer (1981), Ramage (1981), Frey (1984), Delogu et al. (1988) and Rajeswari et al. (2009) have suggested recurrent selection as a basic breeding approach in autogamous crops. Diallel selective mating design suggested by Jenson (1970) can also be adopted, which will promote more recombination. On the other hand, certain unique crosses which showed normal symmetrical distribution with high mean and high coefficient of variation like the F_3's of P_2 x P_3, for grain yield per plant, could be improved by resorting to simple pure line selection. These progenies had also taken less number of days to first flowering with higher L/B ratio of grain.

Hence, there is a possibility for the simultaneous im-

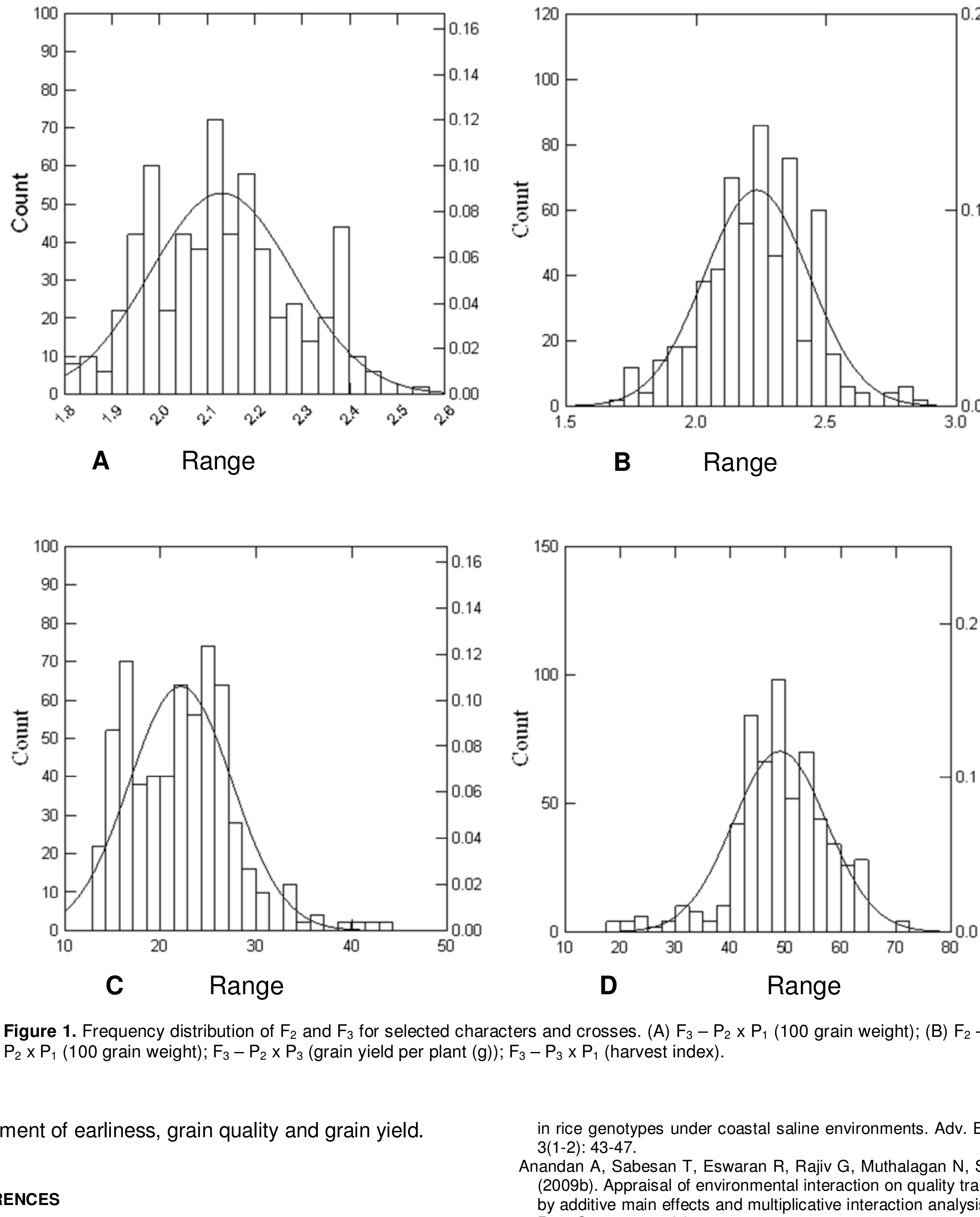

Figure 1. Frequency distribution of F_2 and F_3 for selected characters and crosses. (A) $F_3 - P_2 \times P_1$ (100 grain weight); (B) $F_2 - P_2 \times P_1$ (100 grain weight); $F_3 - P_2 \times P_3$ (grain yield per plant (g)); $F_3 - P_3 \times P_1$ (harvest index).

provement of earliness, grain quality and grain yield.

REFERENCES

Al-Jibouri HA, Miller PA, Robinson HF (1958). Genotypic and environmental variances and co-variance in upland cotton cross of interspecific origin. J. Agron. 50: 633-636.

Anandan A, Sabesan T, Eswaran R, Prakash M (2009a). Additive main effects and multiplicative interactions analysis of yield performances in rice genotypes under coastal saline environments. Adv. Biol. Res. 3(1-2): 43-47.

Anandan A, Sabesan T, Eswaran R, Rajiv G, Muthalagan N, Suresh R (2009b). Appraisal of environmental interaction on quality traits of rice by additive main effects and multiplicative interaction analysis. Cereal Res. Commun. 37(1): 139-148.

Anderson E (1939). Recombination in species crosses. Genetics, 14: 668-698.

Delogu G, Corenzoni C, Marocco A, Martiniello P, Oduardi M, Stanca AM (1988). A recurrent selection programme for grain yield in winter barley. Euphytica, 37: 105-110.

Frey KJ (1984). Breeding approaches for increasing cereal crop yields. In: Cereal production, Butter worths, London, pp. 47-69.
Hallauer AR (1981). Selection and breeding methods. In: Plant breeding II, IOWA state univ. Press., America, pp. 3-55.
Jensen NE (1970). A diallel selective mating system for cereal breeding Crop Sci. 10: 629-635.
Kaosa-ard M, Juliano BO (1991). Assessing rice quality characters and prices in selected international markets. In: Rice grain marketing and quality issues, IRRI, Philippines. pp. 25-35.
Ludh SB (2002). Quality evaluation for domestic and international consumers. In: Genetic evaluation and utilization (GEU) in rice improvement held between 6th may to 4th June, Central Rice Res. Institute, Cuttack. pp. 135-140.
Rajeswari S, Thirugnanakumar S, Anandan A, Krishnamurthi M (2009). Somaclonal Variation in Sugarcane through tissue culture and evaluation for quantitative and quality traits. Euphytica, 168(1): 71-80.
Ramage RT (1981). Comments about the use of male sterile facilitated recurrent selection. Barley Newslett. 24: 52-53.
Singh BN (2002). Rice in India: a Global Scenario. In: Training manual of summer school on genetic evaluation and utilization (GEU) in rice improvement held between 6^{th} May to 4^{th} June, 2002, Central Rice Research Institute, Cuttack, pp. 1-12.