

*Full Length Research Paper*

# Studies of genetics of yield and yield component characters in F<sub>2</sub> and F<sub>3</sub> 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<sub>2</sub>'s. The F<sub>2</sub>'s were selfed to obtain six F<sub>3</sub>'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<sub>3</sub>'s of the cross ADT 38 x ADT 37 for hundred seed weight and the F<sub>3</sub>'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<sub>3</sub>'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<sub>3</sub> 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<sub>3</sub>'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<sub>3</sub> 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<sub>2</sub>, F<sub>3</sub>.

## 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  $P_1 \times P_2$  than its parents and reciprocal cross  $F_1$ 's (Table 1). The  $F_2$  and  $F_3$  progenies of  $P_2 \times P_1$  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  $\times$  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  $P_1 \times P_2$ , 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  $P_1 \times P_2$  than in its reciprocal  $F_2$  and  $F_3$  populations. The mean was higher than median and mode in the  $F_2$ 's of  $P_1 \times P_3$ , indicating that the distribution was positively skewed. On the contrary the reverse was true in the  $F_2$ 's and  $F_3$ 's of  $P_3 \times P_1$ , as well as in  $F_3$ 's of  $P_1 \times P_3$  as well as  $F_3$ 's of  $P_1 \times P_3$ , 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  $P_2 \times P_3$ . 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  $P_2 \times P_1$  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  $P_2 \times P_3$  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  $P_2 \times P_3$ ). However, the  $F_3$  progenies of  $P_2 \times P_3$  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  $P_3 \times P_2$ . 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  $P_1 \times P_2$ ,  $P_1 \times P_3$  and  $P_2 \times P_3$ . It indicated that the distribution was negatively skewed. Such a trend was also observed in  $F_3$ 's of  $P_1 \times P_3$  and  $P_3 \times P_1$ . On the other hand, the  $F_2$ 's  $P_2 \times P_1$ ,  $P_3 \times P_1$  and  $P_2 \times P_3$  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  $P_1 \times P_2$ ,  $P_2 \times P_1$ ,  $P_1 \times P_3$  and  $P_3 \times P_1$ . 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  $P_2 \times P_1$  and  $F_3$ 's of  $P_3 \times P_1$ . 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	
<b>Cross 2</b>	<b>P1</b>	<b>P3</b>	<b>P1 x P3</b>	<b>P3 x P1</b>					
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	
<b>Cross 3</b>	<b>P2</b>	<b>P3</b>	<b>P2 x P3</b>	<b>P3 x P2</b>					
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<sub>2</sub>'s of P<sub>2</sub> x P<sub>1</sub> and F<sub>3</sub>'s of P<sub>3</sub> x P<sub>1</sub>. It indicated that, the progenies were not bunched around the mode in all the generations and crosses except F<sub>2</sub>'s P<sub>2</sub> x P<sub>1</sub> and F<sub>3</sub>'s of P<sub>3</sub> x P<sub>1</sub>. The distribution was leptokurtic in these generations. In general, the distribution pattern was influenced by the maternal cytoplasm.

The F<sub>3</sub> progenies of the cross P<sub>2</sub> x P<sub>1</sub> recorded higher number of filled grains per panicle. The F<sub>1</sub>'s and F<sub>2</sub>'s of this cross registered lesser number of filled grains per panicle than its F<sub>3</sub>'s (Table 3). The F<sub>1</sub>'s demonstrated higher number of filled grains per panicle than their parents. The F<sub>2</sub>'s evinced higher number of filled grains

per panicle than F<sub>1</sub>'s. Thus, the occurrence of transgressive segregation was well evidenced. Hence, selection could well be practiced in F<sub>3</sub>'s of P<sub>2</sub> x P<sub>1</sub> 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<sub>3</sub>'s of P<sub>2</sub> x P<sub>1</sub> 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<sub>2</sub>'s and F<sub>3</sub>'s of P<sub>1</sub> x P<sub>3</sub> and P<sub>3</sub> x P<sub>1</sub>

**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
<b>Cross 2</b>	<b>P1</b>	<b>P3</b>	<b>P1 x P3</b>	<b>P3 x P1</b>					
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
<b>Cross 3</b>	<b>P2</b>	<b>P3</b>	<b>P2 x P3</b>	<b>P3 x P2</b>					
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  $P_3 \times P_2$ . 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  $P_2 \times P_3$  and  $P_1 \times P_2$  (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  $P_2 \times P_1$ , 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  $P_2 \times P_1$ . 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  $P_2 \times P_1$  (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
<b>Cross 2</b>	<b>P1</b>	<b>P3</b>	<b>P1 x P3</b>	<b>P3 x P1</b>					
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
<b>Cross 3</b>	<b>P2</b>	<b>P3</b>	<b>P2 x P3</b>	<b>P3 x P2</b>					
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<sub>2</sub>'s of P<sub>1</sub> x P<sub>2</sub>, P<sub>3</sub> x P<sub>2</sub> and F<sub>3</sub>'s of P<sub>2</sub> x P<sub>3</sub> and P<sub>3</sub> x P<sub>2</sub>. 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<sub>3</sub>'s of P<sub>2</sub> x P<sub>3</sub> (Table 5). The grain L/B ratio in F<sub>3</sub>'s of P<sub>2</sub> x P<sub>3</sub> was higher than their F<sub>2</sub>'s but lesser than their F<sub>1</sub>'s. The F<sub>1</sub>'s

of the cross P<sub>2</sub> x P<sub>3</sub> 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<sub>2</sub>'s of P<sub>1</sub> x P<sub>2</sub>, P<sub>3</sub> x P<sub>1</sub> and P<sub>2</sub> x P<sub>3</sub>. Similarly, the mean was higher than median and mode in F<sub>3</sub>'s of P<sub>1</sub> x P<sub>2</sub> and P<sub>1</sub> x P<sub>3</sub>. 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
<b>Cross 2</b>	<b>P1</b>	<b>P3</b>	<b>P1 x P3</b>	<b>P3 x P1</b>					
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
<b>Cross 3</b>	<b>P2</b>	<b>P3</b>	<b>P2 x P3</b>	<b>P3 x P2</b>					
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<sub>2</sub>'s and F<sub>3</sub>'s of P<sub>3</sub> x P<sub>2</sub>. It indicated that the progenies were not bunched around the mode in all the generations and crosses except the F<sub>2</sub>'s and F<sub>3</sub>'s of P<sub>3</sub> x P<sub>2</sub>. In these generations, the distributions were leptokurtic. There were spectacular

maternal cytoplasmic influences in the expression of this trait.

The F<sub>1</sub>'s of P<sub>3</sub> x P<sub>1</sub> 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<sub>1</sub>'s indicating the occurrence of higher inbreeding depression and transgressive segregation in the negative direction. However, there was a slight spurt in mean grain yield in F<sub>3</sub>'s than F<sub>2</sub>'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
<b>Cross 2</b>	<b>P1</b>	<b>P3</b>	<b>P1 x P3</b>	<b>P3 x P1</b>					
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
<b>Cross 3</b>	<b>P2</b>	<b>P3</b>	<b>P2 x P3</b>	<b>P3 x P2</b>					
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  $P_2 \times P_3$ , 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  $P_2 \times P_1$  and  $F_3$ 's of  $P_1 \times P_2$ , 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
<b>Cross 2</b>	<b>P1</b>	<b>P3</b>	<b>P1 x P3</b>	<b>P3 x P1</b>					
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
<b>Cross 3</b>	<b>P2</b>	<b>P3</b>	<b>P2 x P3</b>	<b>P3 x P2</b>					
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<sub>3</sub>'s of P<sub>3</sub> x P<sub>1</sub>, indicating that the distribution was symmetric (Figure 1d). The kurtosis value less, indicating the mesokurtic 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<sub>2</sub>'s of P<sub>1</sub> x P<sub>2</sub> and F<sub>3</sub>'s of P<sub>1</sub> x P<sub>3</sub>. 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.



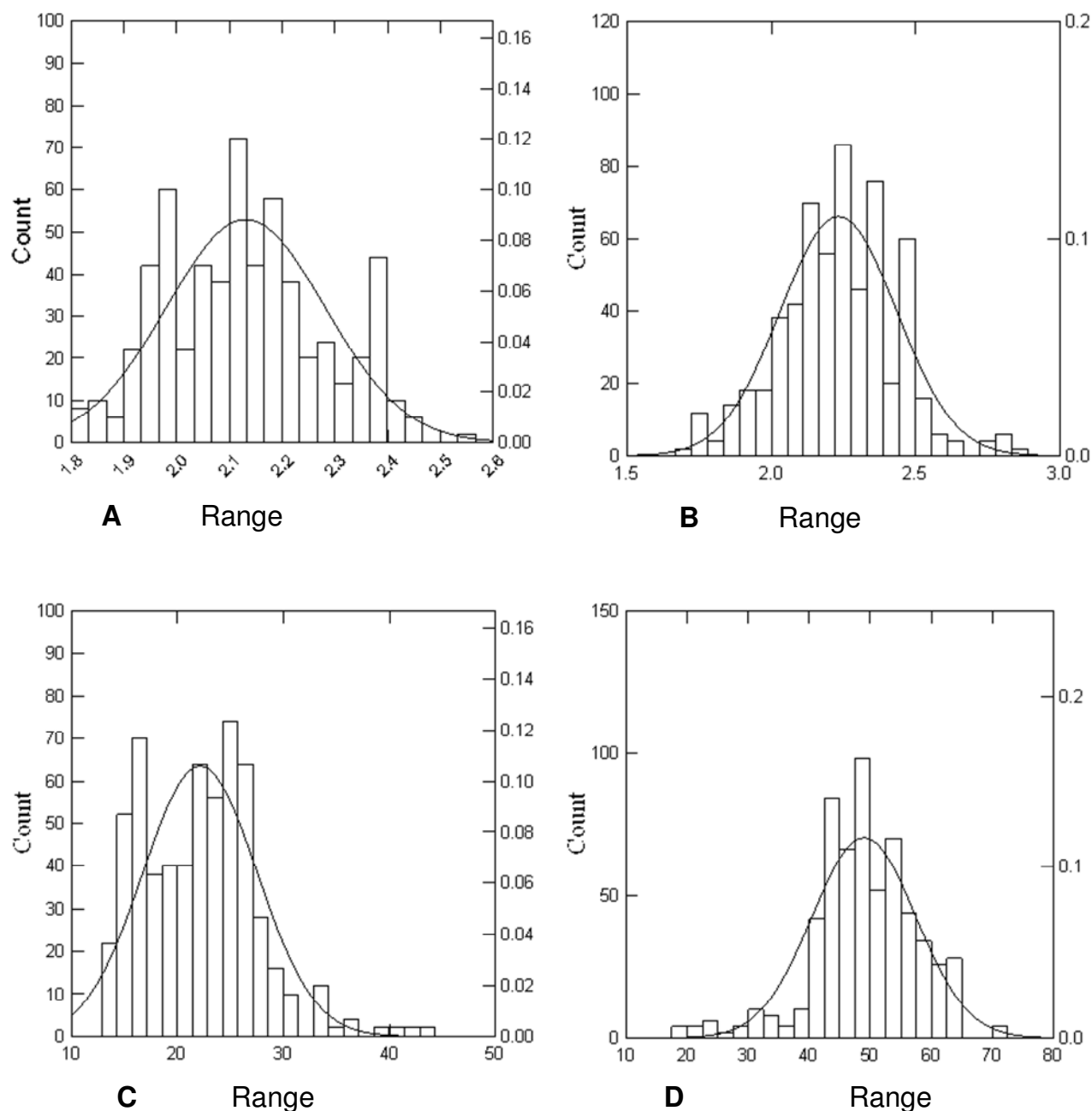
**Table 7.** First, second, third and fourth degree statistics – harvest index.

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
<b>Cross 2</b>	<b>P1</b>	<b>P3</b>	<b>P1 x P3</b>	<b>P3 x P1</b>					
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
<b>Cross 3</b>	<b>P2</b>	<b>P3</b>	<b>P2 x P3</b>	<b>P3 x P2</b>					
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 Jensen (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  $P_2 \times P_3$ , 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.

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