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Genetic Variability Studies on Different Genetic Populations of Rice under Drought Condition

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Abstract: Drought is a major natural disaster that has been striking one or other regions of the world with a canny regularity. To develop high yielding genotypes coupled with drought tolerance, populations with high variability serves always as prime source for effective selection. Present variability studies of different breeding populations showed high phenotypic and high and moderate genotypic coefficients of variation for most of the traits studied. The traits viz., days to 70% RWC, leaf rolling, leaf drying, harvest index, biomass yield and grain yield expressed high or moderate heritability along with high genetic advance. Hence, these characters offer much scope for improvement by way of simple selection techniques. The three traits, days to flowering, panicle length and plant height showed low heritability with low genetic advance offers little scope for improvement by way of selection. Biparental mating and F_3 showed the similar trend of variability, heritability and genetic advance implied that single cycle of intermating of segregants in F_2 is not sufficient to release variability. Hence more cycles of intermating of selected segregants is suggested.

Key words: *Biparental progenies*, coefficient of variation, drought, genetic advance, heritability, rice

Introduction

Drought is a major natural hazard that has been historically associated with food shortages of varying intensities including those that have resulted in major famines. Rice is the most important cereal in Asia, in view of its recognition as an important crop requiring constant and continued research efforts to stabilize production. It is cultivated in a wide range of ecosystems under varying temperature and water regimes. Varietal improvement still remains the major strategy for increasing production and productivity under rainfed lowland condition. Success in any breeding programme is dependent on the knowledge and understanding of the inheritance of the characters of interest. But the main drawback in breeding for drought tolerance is that it is a very complex character and as such is not a simple character governed by one or two genes but explained to be controlled by a number of physio-morphological characters being independently controlled by many genes (Fukai and Cooper, 1995).

To develop high yielding genotypes coupled with drought tolerance, population with high variability serves always as prime source for effective selection, particularly the role by F_2 segregants in throwing much variability is highly recognized. The F_2 are the critical generation in rice breeding and they determine the eventual success or failure of the hybridization programme (Jennings *et al*., 1979). Also many mating designs were proposed by many authors to know the genetics of quantitative characters. Biparental mating (BIP) is one of the simplest random mating designs available to effect

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forced recombination and breaking down undesirable linkages as pointed out by Comstock and Robinson (1952). The inter-crossing in the F_2 segregants or BIPs provides chances of finding superior recombinants in F_3 or later generations and a great amount of concealed genetic variations particularly of the additive type would be released thereby improving response to selection (Moll and Robinson, 1967). Many reports previously pointed out the importance of variability for drought tolerance and yield traits separately in rice. In brief, Selvarani and Rangasamy (1997) reported that Phenotypic Coefficient of Variation (PCV) was higher than Genotypic Coefficient of Variation (GCV) for days to flowering in F_2 generation of six intervarietal crosses and also high heritability with low genetic advance. In productive tillers per plant, Kumar and Ramesh (1998) recorded high heritability with high genetic advance but contrarily Venkataramana and Hittalmani (1999) obtained low to moderate heritability and genetic advance for this trait. Moderate to high coefficient of variability was observed by Unnikrishnan (1982), Ganesan (1987), Marimuthu *et al*. (1990) and Thakur *et al*. (1998) in F_2 generation for grain yield. Ample genetic variability for root morphological traits and other components (primary traits) of drought resistance has been documented over the past few decades. These studies have been conducted on specific primary trait(s) of interest and its (their) contribution to drought resistance (Ludlow and Muchow, 1990; Acevedo and Fereres, 1993; Sadiq *et al*., 1994; Hemamalini *et al*., 2000). But limited studies were carried out combining both drought tolerant and yield traits in rice.

Clear understanding of the variability parameters such as PCV, GCV, heritability (h^2) and Genetic Advance (GA) of the breeding material related to drought tolerance and grain yield is much essential to know their inherent potential and based on the capacity, the breeders should propose the suitable breeding methodology. Hence the present research was combinedly carried out to know the variability present among the drought tolerant and yield and its component traits in various genetic populations under drought condition.

Materials and Methods

The present study consisted of three genetic populations, Biparental Progenies (BIPs) from Norungan/ASD 18, F_3s from Norungan/ASD 18 and Nootripathu/PMK 2 and Recombinant Inbred Lines (RILs) from IR 58821/IR 52561. The experiments were conducted at the research farm premises of Agricultural College and Research Institute, Madurai from 2003 to 2004 (latitude: 9°54`E; longitude: 78°.8`N; altitude: 147 m MSL).

BIPs

The F_1 harvested seeds of Norungan/ASD 16 was used for production of BIPs. Two sets of four males and five females were randomly selected in F_2 and mated in North Carolina Design II (NCD II) (Comstock and Robinson, 1948). Forty BIPs were raised in randomized block design with two replications adopting a spacing of 20 cm between rows and 10 cm between plants. IR 50, the most susceptible variety for drought was raised in between the sets and along the borders as an indicator for moisture stress.

F_3

Two F_1 harvested seeds of Norungan/ASD 16 and Nootripathu/PMK 2 were raised. In each cross, 60 plants were selected at random, harvested separately and used for F_3 evaluation. For F_3 evaluation, in each cross, 60 F_3 families were raised along with the parents. In each family and parent 40 plants were raised in non-replicated rows adopting a spacing 20×10 cm. Single seedling per hill was planted.

RILs

The 148 RILs derived from a cross between two advanced breeding lines viz., IR 58821-23-B-1-2-1 (abbreviated as IR 58821) and IR 52561-UBN-1-1-2 (abbreviated as IR 52561). The RILs were developed from the F_2 generation by single seed decent to F_7 generation at International Rice Research Institute (IRRI), Philippines. Both parental lines are of *indica* types and suited to rainfed lowland condition. IR 58821 possesses thicker roots with high root penetration ability than IR 52561. The RILs along with three checks were raised in two seasons [summer (May-July) and fall (Sep-Dec), 2003] in an augmented design under both drought and full water regime conditions.

All the three breeding materials were raised under transplanted condition in a clay loam soil type (Madhukur series). At peak tillering stage, the irrigation was withheld to impose drought. IR 50, the stress indicator started to show stress symptoms within 2-3 days. RWC 70% was the best indicator for studying the drought stress (Chandrababu *et al*., 1999) and also it shows the real physiological stress of the plant irrespective of soil or other environmental conditions. Hence due weight age has been given to this trait and RWC was taken in all populations at regular intervals. When most of the populations attain 70% RWC, the drought tolerant parameters viz., leaf rolling and leaf drying were scored and the field was re-irrigated. After one week, the drought recovery rate was recorded. At physiological maturity, four drought tolerant traits viz., spikelet fertility, root length, root dry weight and root/shoot ratio and yield and its component traits including days to flowering, plant height, number of productive tillers per plant, panicle length, grains per panicle, hundred grain weight, biomass yield, grain yield per plant and harvest index were recorded on ten plants at random in all populations. In addition to that, in RILs the same set was raised under fully irrigated condition as control and only nine yield and it component traits were recorded.

Statistical Analyses

The mean data collected from 40 BIPs, 60 F_3 families in each of two crosses along with parents and 148 RILs were subjected for statistical analysis.

BIPs

The mean data of 40 BIPs for all characters were subjected to analysis of variance of randomized block design. After ascertaining the significant difference among the BIPs, the data were subjected to analysis of variance appropriate to North Carolina Design II (NCD II) (Comstock and Robinson, 1948, 1952). The heritability estimates (h^2) on real sense were calculated using the formula given by Hallauer and Miranda (1981). Expected gains from full sib family selection were calculated by means of the procedure outlined by Robinson *et al*. (1949).

F_3

The data from 60 F_3 families of two F_2 crosses along with parents were used for variability studies. According to Goulden (1952), the variances were worked out. PCV and GCV were calculated using the methods suggested by Burton (1952). Heritability (h^2) in the broad sense was calculated according to the formula suggested by Lush (1940) and expressed in percentage. Genetic advance was estimated by the method formulated by Johnson *et al*. (1955).

RIL

The mean data of 148 RILs for all character both under drought and fully irrigated condition were subjected to analysis of variance appropriate for augmented design. The PC, GC, PCV, GCV, h^2 and GA were worked out as per standard statistical method for homozygous population.

Results and Discussion

Creation and utilization of genetic variability are the important factors for crop improvement. The potentiality of a breeding method is judged on the extent of variability generated in different quantitative traits (Allard, 1960), as it indicates the extent of recombination for effective selection. Crop improvement programmes in majority of the self pollinated crops depend mainly on hybridization followed by selection in segregating generations. Hence, in the present study F_3 generation of two crosses viz., Norungan/ASD 16 and Nootripathu/PMK 2 were studied for variability. However, the linkage of genes for desirable and undesirable traits is the limiting factor to proceed with selection of superior recombinants in the segregating progenies obtained through hybridization. Moreover, the probability that any one F_2 individual in a cross would carry all or most of the potentially adaptive genes is very remote. And it is true that, strict inbreeding or pedigree selection from early segregating generations will not produce the best balanced genotype. These limitations could be overcome by intermating the related F_2 individuals in pairs (Balyan and Verma, 1985). Biparental mating, a systematic random mating process plays a significant role in improvement of autogamous species by breaking the unfavourable linkages, thereby increasing the probabilities of obtaining rare recombinants and releasing concealed genetic variation, particularly of additive nature. The use of biparental mating in an early segregating generation like F_2 of an appropriate cross could be of much use in widening variability and consequently in making considerable gains (Kampli *et al*., 2002). Keeping this in view, the BIPs were produced from the F_2 generation of Norungan/ASD 16 and evaluated. Variability studies in homozygous population gives a clear picture about the variation present among a collection of genotypes, which will be useful to proceed further with the different breeding programmes. So, variability studies were taken up in 148 RILs of a cross IR 58821/IR 52561, which were in F_7 generation.

Variability in a population is measured by the estimates like phenotypic and genotypic variance and phenotypic and genotypic coefficients of variation. In the present study, high phenotypic and high and moderate genotypic coefficients of variation were observed for most of the traits in all breeding materials taken. In BIPs (Table 1), the traits viz., days to flowering, plant height, productive tillers per plant, harvest index, grain yield, days to 70% RWC, leaf drying, root length, dry root weight, hundred grain weight and biomass yield showed high variability. Moderate phenotypic and genotypic coefficients of variation were noticed in drought recovery rate, root/shoot ratio, panicle length, grains per panicle and spikelet fertility. Leaf rolling expressed moderate phenotypic coefficient of variation and low genotypic coefficient of variation. In F_3, the traits viz., days to 70% RWC, leaf rolling, leaf drying, drought recovery rate, productive tillers per plant, grains per panicle, spikelet fertility, biomass yield, dry root weight, root/shoot ratio, harvest index, grain yield and hundred grain weight showed high variability in both the crosses. Moderate coefficient of variation was observed for panicle length and plant height, whereas low phenotypic and genotypic coefficient of variation was noticed for days to flowering in both the crosses (Table 2 and 3). In RILs (Table 4), under stress condition, the traits viz., leaf drying, drought recovery rate, productive tillers per plant, hundred grain weight, dry root weight, root/shoot ratio, leaf rolling, grains per panicle, root length, biomass yield, harvest index and grain yield and in controlled condition, the traits viz., harvest index, grain yield, productive tillers per plant, plant height, grains per panicle, panicle length and biomass yield exhibited high variability. In stress condition, moderate phenotypic and low genotypic coefficient of variation was exhibited by the following traits viz., days to 70% RWC, plant height and panicle length. Two traits viz., days to flowering and canopy temperature recorded low phenotypic and genotypic coefficients of variation. In controlled condition, hundred grain weight and days to flowering expressed moderate or low phenotypic and genotypic coefficients of variation. This showed the existence of considerable amount of variability for most of the traits (except days to flowering, panicle length and plant height), which could enable selection of high yielding genotypes coupled with drought tolerance.

Table 1: Genetic variability parameters in BIPs

	Mean	Range	PCV (%)	GCV (%)	h^2 (%)	GA (%)
RWC	8.19	6.00-11.15	20.58	17.01	68.43	45.49
LR	5.80	3.10-7.80	10.34	7.71	46.77	33.19
LD	3.96	2.10-5.90	22.89	18.69	65.98	26.26
DRR	5.26	2.50-7.20	18.53	10.59	27.83	8.93
DF	77.21	73.00-80.50	29.37	21.22	43.15	3.98
PH	96.32	84.60-103.10	31.34	22.39	50.12	8.53
PT	10.43	6.00-14.50	28.27	20.22	27.12	18.91
PL	25.11	22.20-29.50	12.22	10.51	42.05	9.32
GP	104.35	60.30-153.85	18.3	11.15	12.65	14.18
SF	69.66	41.21-89.40	17.15	10.13	28.26	33.87
HGW	1.82	1.30-2.28	23.57	12.24	39.26	11.48
BMY	68.16	24.21-147.81	20.32	16.75	23.61	25.55
RL	12.98	8.15-22.85	32.37	17.62	21.30	17.64
DRW	13.61	6.71-32.03	50.74	18.37	8.99	12.86
RS	0.38	0.17-1.01	16.73	12.29	7.42	54.36
HI	0.26	0.10-0.64	31.28	27.23	6.64	69.66
GY	17.72	6.30-38.43	35.23	22.19	16.32	28.11

Table 2: Genetic variability parameters in F_3 - Norungan/ASD 16

	Mean	Range	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA (%)
RWC	7.36	4-10	2.84	2.34	22.90	20.78	82.39	38.86
LR	2.46	1-9	0.39	0.33	25.39	23.35	84.62	44.25
LD	2.14	1-9	0.24	0.19	22.89	20.37	79.17	37.33
DRR	2.18	1-9	0.71	0.53	38.65	33.39	74.65	59.44
DF	80.90	75-84	4.49	3.79	2.62	2.41	84.41	4.55
PH	78.25	48.5-98.5	87.17	76.25	11.93	11.16	87.47	21.50
PT	8.93	4-16	6.27	4.12	28.04	22.73	65.71	37.96
PL	21.89	14.5-32.4	11.42	8.45	15.43	13.27	73.99	23.53
GP	106.18	10-218	1735.36	1324.00	39.23	34.27	76.30	61.66
SF	62.96	49-93.18	337.87	303.35	29.20	27.66	89.78	54.00
HGW	1.80	0.19-2.65	0.18	0.05	23.57	12.42	27.78	13.49
BMY	33.24	15-71	130.82	115.24	34.41	32.30	88.09	62.44
RL	15.89	9.2-21.2	8.32	6.47	18.15	16.01	77.76	29.08
DRW	14.98	5.93-30.21	29.93	22.64	36.52	31.76	75.64	56.91
RS	0.61	0.12-0.98	0.57	0.50	29.49	27.62	87.72	53.29
HI	0.45	0.05-0.75	0.56	0.41	54.23	46.40	73.21	77.84
GY	7.31	1.99-14.89	6.86	3.64	35.83	26.10	53.06	39.16

Table 3: Genetic variability parameters in F_3 - Nootripathu/PMK 2

	Mean	Range	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA (%)
RWC	7.99	5-10	3.30	1.65	22.74	16.08	50.00	23.42
LR	2.11	1-9	0.39	0.11	29.60	15.72	28.21	17.20
LD	1.8	1-9	0.25	0.15	27.78	21.52	60.00	34.33
DRR	2.22	1-9	0.64	0.12	36.04	15.60	18.75	13.92
DF	79.89	74-85	4.71	2.56	2.72	2.00	54.35	3.04
PH	93.81	59.5-126.2	268.82	223.65	17.48	15.94	83.20	29.95
PT	9.87	6-19	4.48	2.14	21.44	14.82	47.77	21.10
PL	21.43	16.4-26.8	5.08	3.31	10.52	8.49	65.16	14.12
GP	90.76	26-163	963.58	827.22	34.20	31.69	85.85	60.49
SF	58.68	0-94.06	506.91	412.30	38.37	34.60	81.34	64.29
HGW	1.92	0.29-2.65	0.16	0.06	20.83	12.76	37.50	16.09
BMY	42.34	12-130	492.16	400.56	52.40	47.27	81.39	87.85
RL	17.19	10.2-26.8	12.11	9.17	20.24	17.62	75.72	31.58
DRW	14.91	5.64-27.99	21.61	18.45	31.18	28.81	85.38	54.84
RS	0.63	0.09-0.96	0.82	0.34	29.89	19.24	41.46	25.53
HI	0.46	0.03-0.68	0.46	0.22	47.76	33.03	47.83	47.06
GY	8.71	1.89-16.2	12.90	10.64	41.24	37.45	82.48	70.06

Heritability serves as a good index for transmission of characters from one generation to next and it should be considered in terms of selection concept (Hanson, 1959). Improvement of heritability

Table 4: Genetic variability parameters in RILs under both Stress and Irrigated condition

		Mean	Range	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA (%)
RWC	(S)	15.80	12-19	46.25	20.84	11.15	7.49	45.07	10.35
LR	(S)	5.22	2.12-8.97	2.15	1.64	22.42	19.56	76.15	35.16
LD	(S)	3.94	0.84 -7.69	2.86	1.96	43.00	35.60	68.51	60.69
CT	(S)	35.75	31.95-39.05	62.35	52.22	5.47	5.01	83.75	9.43
DRR	(S)	5.34	1-9	3.12	1.76	51.42	38.62	56.41	59.76
DF	(S)	99.62	84-108	10.50	2.40	5.26	2.52	22.83	2.47
	(I)	99.95	84-108	10.22	6.25	5.54	5.5	61.15	11.24
PH	(S)	86.83	53.65-124.35	185.64	38.97	17.63	8.08	20.99	7.62
	(I)	116.24	85.20 -144.5	250.65	200.63	20.56	20.53	80.04	42.24
PT	(S)	7.12	2.20-15.90	12.65	7.43	38.62	29.60	58.73	46.72
	(I)	9.16	4.00 – 17.00	6.23	3.34	28.31	27.29	53.61	54.1
PL	(S)	22.29	14.05-28.95	24.24	2.69	11.03	3.67	11.08	2.52
	(I)	23.84	16.70-29.30	10.28	6.17	20.11	19.9	60.02	40.56
GP	(S)	90.22	84.84-98.70	925.64	525.65	22.16	16.72	56.79	25.96
	(I)	112.10	83.66-143.9	753.36	324.25	22.16	16.96	44.09	18.55
HGW	(S)	2.68	1.86-3.91	0.41	0.31	23.89	20.78	75.61	55.41
	(I)	2.68	1.86-3.91	0.23	0.18	17.89	15.83	78.26	42.95
BMY	(S)	68.90	17.00-180.30	265.48	50.57	26.10	11.40	19.05	10.24
	(I)	70.31	37.11-128.67	400.56	325.67	20.09	19.85	81.30	40.39
RL	(S)	13.65	7.70-24.45	16.98	6.48	25.77	15.93	38.19	20.27
DRW	(S)	7.12	2.23-17.48	42.15	13.77	48.51	27.74	32.68	32.66
RS	(S)	0.30	0.09-0.70	1.36	0.30	52.74	24.74	22.01	23.91
HI	(S)	0.29	0.12-0.75	1.23	0.12	35.73	11.19	9.80	7.22
	(I)	0.45	0.23-0.87	0.42	0.18	34.6	32.74	42.86	63.82
GY	(S)	18.62	4.60-36.76	16.45	4.68	34.72	18.51	28.43	20.33
	(I)	27.92	10.50-56.98	12.35	6.67	33.83	33.44	54.01	68.11

(S)- Stress condition (I)-Irrigated condition, RWC-Days to 70% Relative Water Content, LR-Leaf Rolling (in score), LD-Leaf Drying (in score), CT-Canopy Temperature (°C), DRR-Drought Recovery Rate (in score), DF-Days to Flowering PH-Plant Height (cm), PT-Productive Tillers per plant, PL-Panicle Length (cm), GP-Grains per Panicle, SF-Spikelet Fertility (%), HGW-Hundred Grain Weight (g), BMY-Biomass Yield (g), RL-Root Length (cm), DRW-Dry Root Weight (g), RS-Root/Shoot ratio, HI-Harvest Index, GY-Grain Yield (g)

values for yield and its components is particularly of interest to the breeder, as it enhances the breeding value and improves the selection response for characters (Yunus and Paroda, 1982). Heritability alone does not give any clear picture about the nature of inheritance of traits. Heritability estimates in conjunction with genetic advance over mean gives the nature of inheritance of a trait. Genetic advance being the product of heritability and selection differential, it indicates the potentiality of selection intensity. The estimates of high heritability do not always signify an increased genetic advance. In the present study (Table 1-4), BIPs showed high heritability coupled with high genetic advance for days to 70% RWC and leaf drying and moderate heritability with high genetic advance for leaf rolling and low heritability with high genetic advance was observed in root/shoot ratio, spikelet fertility, biomass yield, harvest index and grain yield. In F_3, high or moderate or low heritability coupled with high or moderate genetic advance was observed for days to 70% RWC, leaf rolling, leaf drying, drought recovery rate, plant height, productive tillers per plant, grains per panicle, panicle length, spikelet fertility, biomass yield, root length, root/shoot ratio, dry root weight, harvest index and grain yield in both the crosses. In RIL population, high heritability with high genetic advance was observed for leaf drying, leaf rolling and hundred grain weight under stress condition and for plant height, biomass yield, panicle length and hundred grain weight under controlled condition. In stress, moderate heritability with high genetic advance was expressed for productive tillers per plant, grains per panicle, drought recovery rate, root length and dry root weight, whereas in controlled condition it was noticed for grain yield, productive tillers per plant and harvest index, whereas days to flowering registered high heritability with moderate genetic advance and moderate heritability with moderate genetic advance was observed for grains per panicle.

Based on the above results of three genetic materials it was concluded that, the traits viz., days to 70% RWC, leaf rolling, leaf drying, harvest index, biomass yield and grain yield recorded high or moderate heritability along with high genetic advance. These characters also had high genotypic coefficient of variation. Hence, these characters offer much scope for drought tolerance improvement by way of simple selection techniques. This is in accordance with the finding of Lokaprakash *et al.* (1992).

In BIPs, the traits viz., drought recovery rate, days to flowering, plant height and panicle length showed moderate heritability with low genetic advance. While in F_3, only days to flowering exhibited low heritability with low genetic advance. The RILs under stress condition expressed low heritability with low genetic advance for plant height, harvest index, panicle length, canopy temperature and days to flowering. From these results, it was observed that only three traits viz., days to flowering, panicle length and plant height showed low heritability with low genetic advance. It showed environment playing a major role on these traits and those traits also showed low genotypic coefficient of variation. Thakur *et al.* (2000) recorded low heritability with low genetic advance for plant height and panicle length. Hence it showed that these traits are very hard to be improved under drought condition.

Effects of BIP Mating

To know the effect of biparental mating, the BIPs were compared with their respective F_3 (Norungan/ASD 16). It showed that the genotypic coefficient of variation was high for days to flowering, plant height and root length in BIPs when compared to F_3. Gurdevsingh *et al.* (1986) observed that genotypic coefficient of variation was higher in intermating population than F_2 and F_3 generations. This may be due to biparental mating which released more variability than mere selfing of single plants in F_2. Contrarily, for some of the traits viz., drought recovery rate, root/shoot ratio, grains per panicle, spikelet fertility and leaf drying low coefficients of variation was observed in BIPs when compared to F_3. This observation is in line with the findings of Altman and Busch (1984) who observed that intermating within single cross populations resulted in less useful recombination and reduced genetic variance. For the remaining traits the variability was more or less same in both the genetic materials. This suggests that single cycle of biparental mating alone could not make wider genetic variability when compared to F_3. When comparing for heritability and genetic advance, three traits viz., drought recovery rate, plant height and panicle length recorded high heritability coupled with high genetic advance in F_3. But in BIPs these traits recorded low heritability along with low genetic advance. However, for other traits both the genetic materials had similar trend of heritability and genetic advance. It showed that the intermating of segregants in F_2 had only very little effect on recombination. This is in accordance with Yunus and Paroda (1982) in wheat. Therefore more cycles of intermating of selected segregants is suggested to release more variability.

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