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Identification of Important Traits in Rice (*Oryza sativa* L.) For Lowland Drought Situation by Association Analyses

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Abstract: Rice is the principle food crop and is drastically affected by drought. Breeding for drought tolerance is a challenging task because of the complexity of the component traits, screening technique, environmental factors and their interaction. The major set back in drought tolerance breeding is the poor understanding of genetics and inheritance of drought tolerance traits and complete ignorance about the relationship between traits of physiological drought tolerance and plant productivity under stress. Present study consisted of BIPs, F_3 and RIL population screnned under drought condition to know the association nature. Association analysis in BIPs revealed that, if selection pressure is given on the positive side for days to 70% RWC, dry root weight, harvest index, root/shoot ratio and biomass yield and negative side for leaf rolling and leaf drying, it will result in high grain yield under drought situations. From F_3 studies it is concluded that selection pressure should be given on harvest index and productive tillers per plant in positive direction and plant height and leaf drying in negative direction for yield improvement in drought resistance breeding programme. The association analysis of RILs showed that, to harness high yield combined with drought tolerance, breeders should give selection pressure on days to 70% RWC, panicle length, grains per panicle, harvest index, biomass yield, root/shoot ratio and root length in positive direction and leaf rolling, leaf drying and drought recovery rate in negative direction. Association studies in three breeding materials combinedly pointed out that there is much scope for selecting high yielding genotypes with drought tolerance in rice, if selection pressure is exerted on days to 70% RWC, root/shoot ratio, biomass yield and harvest index and low scores of leaf rolling and leaf drying.

Key words: Rice, drought, correlation, path analysis

Introduction

Rice is cultivated in a wide range of ecosystems under varying temperatures and water regimes. About 27% of the world's rice land is rainfed lowlands characterized by alternating flooding and drying due to irregular rainfall patterns. Varietal improvement still remains the major strategy for increasing production and productivity under rainfed lowland condition. A major reason for the slow progress in breeding for drought resistance is the complexity of the drought characters in rice (Fukai and Cooper, 1996). Breeders create new gene recombinations and useful variants among genotypes through hybridization and selection (Atlin, 2003). Tyagi *et al*. (1999) suggested that selection on the basis of a single parameter could not provide the true picture of a genotype that response to stress and therefore at least two or three parameters should be used for identifying drought tolerant genotypes. Information on the nature and strength of association between grain yield and its component traits as

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well as their inter-correlation among component traits under moisture stress will be helpful for a breeder in prioritizing the character for selection. Path analysis has been used to organize the relationship between predicted variables and responsible variables. To understand the direct and indirect effects of each character on grain yield under stress condition and apply selection pressure in a better way for yield improvement, partitioning of the genotypic correlation coefficient into direct and indirect effects through path coefficient analysis is very important.

Earlier reports have suggested the importance of many traits for drought tolerance in rice. Jeena and Mani (1990) pointed out that early genotypes with high root volume and root length density at maturity gave higher yields. Therefore, a deep root system with high root volume would assist in developing drought resistant upland cultivars (Lilley and Fukai, 1994). Negative association between leaf rolling and drought tolerance was reported by Tomar and Prasad (1996). Spikelet fertility percentage was highly correlated with grain yield under water stress during reproductive stage (Rao and Saxena, 1999). Jongdee *et al*. (2002) reported that under water limited conditions around flowering, grain yield reduction was mainly due to increased spikelet sterility. Rao and Saxena (1999) suggested that harvest index could be one of the major selection criteria for yield improvement in upland rice, since water stress reduced the harvest index apparently. Shanmugasundaram *et al*. (2002) suggested that while selecting superior genotypes for cultivation under rainfed situations, relative water content, grain yield, harvest index and straw yield should be considered as selection criteria.

But limited study has been done on evaluating the contribution of putative traits to grain yield in rice which is more important since the survival alone during drought is not sufficient and crop needs to produce a reasonable yield for subsistence requirements or for economic reasons. Hence the present investigation was carried out to know the desirable traits of interest for plant breeding programme of rice under lowland drought condition.

Materials and Methods

The present study consisted of three breeding materials viz., Biparental Progenies (BIPs) from Norungan/ASD 18, F_3s from Norungan/ASD 18 and Nootripathu/PMK 2 and Recombinant Inbred Lines (RILs). 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).

Biparental Progenies (BIPs)

The F_2 of Norungan/ASD 16 was collected from Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Madurai and raised in non-replicated rows of 500 single plants. Two sets of four males and five females were randomly selected and mated in North Carolina Design II (NCD II) (Comstock and Robinson, 1948). Thus, 20 crosses were made in each set and totally 40 crosses (BIPs) were obtained. Forty BIPs were raised in randomized block design with two replications adopting a spacing of 20 cm between rows and 10 cm between plants. In each replication, two sets of BIPs were randomized and in each set, individual BIPs were randomized. In each BIP, 20 plants were raised with a row length of two meters in each replication. 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_2 population of Norungan/ASD 16 and Nootripathu/PMK 2 were obtained from Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Madurai and 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.

Recombinant Inbred Lines (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. The seeds of 148 RILs were obtained from the Center for Plant Molecular Biology, Tamil Nadu Agricultural University, Coimbatore. 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. Chandrababu *et al.* (1999) reported that RWC 70% was the best indicator for studying the drought stress. RWC 70% 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 at regular intervals in all populations. When most of the populations attain 70% RWC, the drought tolerant parameters viz., leaf rolling and leaf drying were scored and the field was reirrigated. 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.

Correlation between yield and its components including drought tolerant traits were estimated as per the method suggested by Goulden (1952). The path coefficient analysis was worked out as suggested by Dewey and Lu (1959). In the present study, grain yield was treated as dependent variable and all other components including drought tolerant traits were treated as independent variables. The simultaneous equation which expresses the basic relationship between the path coefficients were solved to obtain the path coefficients. The direct and indirect effects were classified based on the scales given by Lenka and Mishra (1973).

Results and Discussion

The study on the relationship of yield with other traits is of greater importance for formulation of selection programme in the improvement of yield in any crop. Because of such interrelationship, exercise of selection pressure on one character may bring with it change in other components. So the net improvement achieved is more than anticipated (Unnikrishnan, 1986). As the present study is oriented towards breeding for drought tolerance, much emphasize was given to understand the association between drought tolerant traits with yield and its components. Through correlation studies, it is desirable to obtain exposition of certain relationship as may be present between a set of characters. Correlation and path analysis are the two statistical tools, which are mostly employed by the breeders to understand the character association. The relationship of a particular trait or drought tolerant trait with yield would be of immense use to the breeders when they exercise simultaneous selection for both drought tolerant and yield characters. The path coefficient analysis suggested by Dewey and Lu (1959) provides a view into the interrelationships by further partitioning the correlation coefficients into direct and indirect effects.

Table 1: Correlation coefficients between grain yield and all other traits in BIPs

	RWC	LR	LD	DRR	DF	PH	PT	PL	GP
RWC	1.00	-0.83*	-0.71*	-0.64*	0.24	0.25	0.48*	0.24	0.53*
LR		1.00	0.73*	0.53*	-0.12	-0.29	-0.29	-0.42*	-0.44*
LD			1.00	0.65*	-0.26	-0.17	-0.39*	-0.36*	-0.44*
DRR				1.00	-0.42*	-0.10	-0.51*	-0.28	-0.25
DF					1.00	-0.02	0.06	0.05	-0.06
PH						1.00	0.06	0.44*	0.05
PT							1.00	0.07	0.44*
PL								1.00	0.26
GP									1.00
SF									
HGW									
BMY									
RL									
DRW									
RS									
HI									

	SF	HGW	BMY	RLD	RW	RS	HI	GY
RWC	0.49*	0.66*	0.42*	-0.01	0.25	0.18	0.32*	0.44*
LR	-0.40*	-0.57*	-0.35*	0.18	-0.14	-0.17	-0.36*	-0.38*
LD	-0.48*	-0.67*	-0.47*	0.01	-0.23	-0.18	-0.29	-0.43*
DRR	-0.32*	-0.51*	-0.35*	-0.17	-0.21	-0.11	0.00	-0.13
DF	0.00	0.16	-0.12	0.22	-0.10	-0.08	-0.16	-0.12
PH	0.06	0.20	0.24	-0.28	0.16	0.11	0.00	0.03
PT	0.36*	0.51*	0.63*	0.43*	0.31*	0.08	0.09	0.32*
PL	0.26	0.31*	0.26	-0.17	0.10	0.08	-0.05	0.03
GP	0.84*	0.42*	0.20	-0.08	0.21	0.18	0.33*	0.32*
SF	1.00	0.40*	0.21	-0.17	0.20	0.18	0.31*	0.29
HGW		1.00	0.45*	0.27	0.18	0.06	0.23	0.36*
BMY			1.00	0.20	0.42*	0.20	0.25	0.51*
RL				1.00	-0.13	-0.24	-0.04	0.09
DRW					1.00	0.75*	0.34*	0.46*
RS						1.00	0.57*	0.37*
HI							1.00	0.84*

*Significant at 5% level

BIPs

In BIPs, days to 70% RWC, productive tillers per plant, grains per panicle, hundred grain weight, biomass yield, dry root weight, root/shoot ratio and harvest index expressed significant and positive correlation with grain yield in BIPs (Gomez and Rangasamy, 2002). The intercorrelation among the yield components showed the nature and extent of relationship with each other that help in the breeding programme for simultaneous improvement of different traits along with yield. Days to 70% RWC was intercorrelated with all other traits, except dry root weight and harvest index. Productive tillers per plant had significant relationship with all traits except root/shoot trait. Grains per panicle was intercorrelated with hundred grain weight, harvest index and productive tillers per plant. Hundred grain weight showed intercorrelation with days to 70% RWC, productive tillers per plant, grains per panicle and biomass yield. Biomass yield expressed positive relation with productive tillers per plant, hundred grain weight and dry root weight. Dry root weight was interrelated with root/shoot ratio, harvest index, productive tillers per plant and biomass yield. Root/shoot ratio showed interrelationship with harvest index and dry root weight. Harvest index showed positive intercorrelation with days to 70% RWC, grains per panicle, dry root weight and root/shoot ratio. From the results, it is noticed that the traits viz., days to 70% RWC, productive tillers per plant, hundred grain weight, dry root weight and harvest index were well intercorrelated with each other (Raju *et al*., 2003) (Table 1). Hence selection of any one of these traits will improve the other traits simultaneously finally increasing the grain yield.

Partitioning the genotypic correlation coefficient into direct and indirect effects will throw light on the actual contribution of an attribute and its influence through other characters. Therefore, it is

Table 2: Path coefficients between grain yield and all other traits in BIPs

	RWC	LR	LD	DRR	DF	PH	PT	PL	GP
RWC	**0.30**	-0.22	0.17	-0.08	0.00	-0.02	0.07	0.04	-0.08
LR	-0.25	**0.26**	-0.17	0.07	-0.01	0.02	-0.04	-0.06	0.07
LD	-0.21	0.19	**-0.23**	0.08	-0.02	0.01	-0.05	-0.06	0.06
DRR	-0.19	0.14	-0.15	**0.13**	-0.03	0.01	-0.07	-0.04	0.04
DF	0.07	-0.03	0.05	-0.05	**0.07**	0.01	0.01	0.01	0.01
PH	0.07	-0.08	0.04	-0.01	0.01	**-0.07**	0.01	0.07	-0.01
PT	0.14	-0.08	0.04	-0.05	0.01	-0.01	**0.14**	0.01	-0.06
PL	-0.11	0.08	-0.04	-0.03	0.01	-0.03	0.01	**0.15**	-0.04
GP	0.16	-0.12	0.10	-0.03	-0.02	-0.01	0.06	0.04	**-0.15**
SF	0.14	-0.10	0.11	-0.04	0.03	-0.01	0.05	0.04	-0.12
HGW	0.20	-0.15	0.16	-0.07	0.01	-0.01	0.07	0.05	-0.06
BMY	0.13	-0.09	0.11	-0.05	0.01	-0.02	0.09	0.04	-0.03
RL	0.00	0.05	0.00	-0.02	0.02	0.02	0.06	-0.03	0.01
DRW	0.07	-0.04	0.05	-0.03	-0.01	-0.01	0.04	0.01	-0.03
RS	0.05	-0.04	0.04	-0.01	-0.01	-0.01	0.01	0.01	-0.03
HI	0.09	-0.09	0.07	0.00	-0.02	0.00	0.01	-0.01	-0.05

	SF	HGW	BMY	RL	DRW	RS	HI	Correlation with GY
RWC	-0.03	-0.07	0.02	0.01	0.12	-0.11	0.33	0.44*
LR	0.03	0.06	-0.02	-0.01	-0.07	0.10	-0.37	-0.38*
LD	0.03	0.07	-0.03	-0.01	-0.11	0.11	-0.30	-0.43*
DRR	0.02	0.05	-0.02	0.01	-0.11	0.07	-0.02	-0.13
DF	0.00	-0.02	-0.01	-0.01	-0.05	0.05	-0.16	-0.12
PH	-0.01	-0.02	0.01	0.01	0.08	-0.07	0.01	0.03
PT	-0.02	-0.05	0.04	-0.01	0.16	-0.05	0.10	0.32*
PL	-0.02	-0.03	0.01	0.01	0.05	-0.05	-0.05	0.03
GP	-0.05	-0.04	0.01	0.01	0.11	-0.12	0.34	0.32*
SF	**-0.07**	-0.04	0.01	0.01	0.10	-0.11	0.32	0.29
HGW	-0.03	**-0.10**	0.03	-0.01	0.09	-0.04	0.24	0.36*
BMY	-0.01	-0.05	**0.06**	-0.01	0.21	-0.13	0.25	0.51*
RL	-0.01	-0.03	0.01	**-0.02**	-0.07	0.15	0.04	0.09
DRW	-0.01	-0.03	0.02	0.01	**0.51**	-0.48	0.36	0.46*
RS	-0.01	-0.01	0.01	0.01	0.38	**0.38**	0.60	0.37*
HI	-0.02	-0.02	0.01	0.01	0.17	0.17	**1.03**	0.84*

Residual effect = 0.046. Diagonal values denote direct effects, *Significant at 5% level

important to partition the correlation into components of direct and indirect effects through path coefficient analysis. The traits viz., days to 70% RWC, dry root weight and harvest index revealed high positive direct effect on grain yield (Venkataramana and Hittalmani, 2000). Eventhough the two traits viz., biomass yield and root/shoot ratio did not show high direct effect on grain yield but they contributed indirectly through dry root weight and harvest index. One of the yield component traits viz., hundred grain weight showed high indirect effect on grain yield through harvest index. Hence, selection based on days to 70% RWC, dry root weight, hundred grain weight and harvest index will result in genotypes with good grain yield combined with drought tolerance. Negative association of traits with grain yield should also be taken into consideration for any selection programme. It is noticed in the present investigation that the traits viz., leaf rolling and leaf drying showed significant negative correlation with grain yield. This is in accordance with the findings of Thangaraj and Sivasubramanian (1990) for leaf rolling. Moreover these traits also showed negative interrelationship with grains per panicle, spikelet fertility, hundred grain weight, biomass yield and harvest index. In path analysis, leaf drying alone showed high negative direct effect on grain yield, but leaf rolling expressed their high negative indirect contribution on grain yield through days to 70% RWC and harvest index (Table 2). Hence, for drought screening, low scores of leaf rolling and leaf drying should be given importance in any selection programme.

The overall observation of BIPs revealed that, if selection pressure is given on the positive side for days to 70% RWC, dry root weight, harvest index, root/shoot ratio and biomass yield and low scores of leaf rolling and leaf drying will result in high grain yield under drought situations.

Table 3: Correlation coefficients between grain yield and all other traits in F_3 – Norungan/ASD 16

	RWC	LR	LD	DRR	DF	PH	PT	PL	GP
RWC	1.00	-0.14	-0.06	0.02	0.42*	-0.34*	0.39*	0.27*	0.45*
LR		1.00	0.72*	0.17*	-0.10	0.17*	-0.15*	-0.13	-0.15*
LD			1.00	0.25*	0.05	0.16*	-0.05	0.04	-0.05
DRR				1.00	0.09	0.04	0.20*	0.02	0.07
DF					1.00	-0.21*	0.20*	0.18*	0.37*
PH						1.00	-0.27*	-0.11	-0.38*
PT							1.00	0.26*	0.26*
PL								1.00	0.04
GP									1.00
SF									
HGW									
BMY									
RL									
DRW									
RS									
HI									

	SF	HGW	BMY	RL	DRW	RS	HI	GY
RWC	0.61*	0.13	-0.06	-0.11	0.21*	0.19*	0.29*	0.40*
LR	-0.16*	-0.21*	-0.16*	-0.03	-0.18*	-0.03	-0.17*	-0.14
LD	-0.10	-0.21*	-0.19*	-0.06	-0.11	0.04	-0.09	-0.15*
DRR	0.03	0.03	0.10	0.16*	0.01	0.00	0.13	0.09
DF	0.45*	0.20*	-0.09	0.01	-0.10	-0.04	0.29*	0.46*
PH	-0.32*	-0.21*	0.12	0.07	-0.04	-0.13	-0.38*	-0.28*
PT	0.56*	0.11	-0.07	-0.05	0.15*	0.21*	0.40*	0.42*
PL	0.19*	-0.14	0.02	-0.14	-0.03	-0.05	0.13	0.02
GP	0.55*	0.15*	-0.12	0.02	-0.07	0.05	0.39*	0.45*
SF	1.00	0.22*	-0.01	0.01	-0.04	0.01	0.41*	0.47*
HGW		1.00	0.19*	0.16*	-0.04	-0.19*	0.27*	0.28*
BMY			1.00	0.05	0.17*	-0.50*	-0.14	-0.11
RL				1.00	-0.01	-0.06	0.13	0.05
DRW					1.00	0.70*	0.02	-0.01
RS						1.00	0.09	0.04
HI							1.00	0.39*

*Significant at 5% level

F_3

Correlation studies in F_3 populations resulted that (Table 3 and 4), days to 70% RWC, days to flowering, productive tillers per plant, grains per panicle, spikelet fertility, hundred grain weight and harvest index in Norungan/ASD 16 and productive tillers per plant, grains per panicle, spikelet fertility, root/shoot ratio and harvest index in Nootripathu/PMK 2 showed significant positive correlation with grain yield. Similar trend was observed by Singh *et al*. (1994), Balan *et al*. (1999) and Raju *et al*. (2003). The intercorrelation among the drought tolerant and yield components revealed that, in Norungan/ASD 16, all the above mentioned seven traits showed interrelationship with each other, whereas, in Nootripathu/PMK 2, productive tillers revealed positive relation with grain per panicle, root/shoot ratio and harvest index. Also, harvest index showed positive relation with productive tillers per plant, grains per panicle and root/shoot ratio. The trait, root/shoot ratio also expressed significant positive relation with productive tillers per plant and harvest index. Hence, in both crosses the traits viz., productive tillers per plant, grains per panicle and harvest index showed intercorrelation among themselves which have already showed significant correlation with grain yield. Therefore, selection of genotypes for any one of the above three traits will automatically improve the other traits besides grain yield.

Dissecting out the correlation into direct and indirect effects through path coefficient analysis showed that (Table 5 and 6), in Norungan/ASD 16, days to flowering, productive tillers per plant, grains per panicle, spikelet fertility, hundred grain weight, dry root weight and harvest index and in Nootripathu/PMK 2, productive tillers per plant, root/shoot ratio and harvest index revealed high

Table 4: Correlation coefficients between grain yield and all other traits in F_3-Nootripathu/PMK 2

	RWC	LR	LD	DRR	DF	PH	PT	PL	GP
RWC	1.00	-0.48*	-0.56*	0.03	0.10	0.05	0.11	0.30*	0.15
LR		1.00	0.67*	-0.17	-0.14	0.02	-0.09	-0.19	-0.11
LD			1.00	-0.13	-0.13	0.01	-0.08	-0.15	-0.09
DRR				1.00	0.14	-0.17	-0.01	0.08	0.003
DF					1.00	-0.03	0.20*	0.16	0.20*
PH						1.00	-0.29*	-0.04	-0.30*
PT							1.00	-0.04	0.53*
PL								1.00	0.09
GP									1.00
SF									
HGW									
BMY									
RL									
DRW									
RS									
HI									

	SF	HGW	BMY	RL	DRW	RS	HI	GY
RWC	-0.16	-0.25*	0.26*	0.001	-0.29*	-0.41*	-0.09	0.15
LR	0.04	0.18	-0.41*	-0.19	0.22*	0.45*	0.21*	-0.09
LD	-0.06	0.13	-0.38*	-0.04	0.25*	0.46*	0.19	-0.09
DRR	0.02	0.02	-0.01	-0.13	-0.10	-0.02	0.09	0.08
DF	-0.07	-0.01	0.10	0.07	0.06	0.01	-0.02	0.02
PH	-0.13	-0.17	0.19	0.11	-0.03	-0.24*	-0.28*	-0.33*
PT	0.18	0.12	-0.16	-0.03	0.11	0.23*	0.51*	0.75*
PL	-0.20*	-0.06	0.04	-0.01	-0.15	-0.13	-0.20*	-0.17
GP	0.07	-0.02	-0.05	-0.16	0.00	0.07	0.35*	0.55*
SF	1.00	0.09	-0.06	0.01	0.04	0.06	0.13	0.25*
HGW		1.00	-0.15	-0.04	0.13	0.26*	0.14	0.08
BMY			1.00	0.004	0.11	-0.68*	-0.66*	-0.18
RL				1.00	0.11	0.01	-0.05	-0.01
DRW					1.00	0.54*	0.01	0.07
RS						1.00	0.61*	0.21*
HI							1.00	0.72*

*Significant at 5% level

direct effect on grain yield. The result of indirect effect showed that, panicle length expressed its contribution through grains per panicle; root/shoot ratio through dry root weight on grain yield in Norungan/ASD 16. Bateshwarkumar and Ramesh (1998) observed a similar trend. Whereas in Nootripathu/PMK 2, days to 70% RWC showed indirect effect through root/shoot ratio and grains per panicle through harvest index on grain yield. In general, selection based on productive tillers per plant, grains per panicle and harvest index will result in high yielder along with drought tolerance. Studies on negative contribution of some of the traits with grain yield revealed that, in Norungan/ASD 16, leaf rolling and plant height and in Nootripathu/PMK 2 plant height showed significant negative relation with grain yield. Bala (2001) reported similar result. The intercorrelation study showed that, leaf drying exhibited significant negative relation with hundred grain weight and biomass yield, whereas plant height in both the crosses expressed negative correlation with productive tillers per plant, grains per panicle and harvest index. Path analyses study showed that, in Norungan/ASD 16, leaf drying alone showed high negative direct effect, but the traits viz., days to flowering, productive tiller per plant and hundred grain weight registered negative indirect effect on grain yield through plant height. In Nootripathu/PMK 2, leaf rolling, days to flowering and plant height revealed high negative direct effect on grain yield. This is in accordance with the findings of Sreedhar (2000). Hence selection should be based on dwarf plant types with low score of leaf drying for improving drought tolerance with high grain yield.

From the foregoing discussion of association analysis in F_3 it is inferred that, selection pressure should be given on harvest index and productive tillers per plant in positive direction and reduced plant height and low leaf drying score for yield improvement in drought resistance breeding programme.

Table 5: Path coefficients between grain yield and all other traits in F_3-Norungan/ASD 16

	RWC	LR	LD	DRR	DF	PH	PT	PL	GP
RWC	**0.06**	-0.12	0.02	0.01	0.12	-0.01	0.11	-0.02	0.12
LR	-0.01	**0.16**	-0.18	1.21	-0.03	0.00	-0.31	0.01	-0.26
LD	-0.01	0.11	**-0.25**	0.01	-0.30	0.00	-0.01	-0.01	0.31
DRR	0.00	-0.17	-0.36	**0.05**	0.03	0.05	0.06	-0.01	0.18
DF	0.03	-0.02	-0.01	0.01	**0.29**	-0.26	0.06	-0.12	0.18
PH	-0.02	0.03	-0.04	0.00	-0.06	**0.01**	-0.07	0.01	-0.08
PT	0.02	-0.29	0.01	0.01	0.06	-0.32	**0.28**	-0.02	0.05
PL	0.02	-0.29	-0.31	0.00	0.05	0.00	0.12	**-0.09**	0.41
GP	0.03	-0.02	0.01	0.01	0.11	-0.01	0.07	-0.01	**0.21**
SF	0.04	-0.02	-0.17	0.00	0.13	-0.01	0.16	-0.02	0.11
HGW	0.01	-0.03	0.52	0.01	0.06	-0.34	0.03	0.01	0.03
BMY	-0.17	-0.03	0.05	0.01	-0.02	0.00	-0.02	0.00	-0.03
RL	-0.01	-0.17	-0.37	0.01	0.01	0.02	-0.02	0.01	0.01
DRW	0.01	-0.21	-0.13	0.00	-0.11	0.00	0.14	0.01	-0.02
RS	0.01	-0.01	-0.01	0.00	-0.01	0.00	0.06	0.01	0.01
HI	0.02	-0.08	-0.19	0.01	0.08	-0.01	0.11	-0.01	0.08

	SF	HGW	BMY	RL	DRW	RS	HI	Correlation with GY
RWC	0.02	0.01	0.02	-0.01	0.12	-0.07	0.01	0.40*
LR	-0.01	-0.31	0.05	0.00	-0.47	0.01	-0.01	-0.14
LD	-0.01	-0.02	0.06	0.00	-0.03	-0.01	-0.01	-0.15*
DRR	0.00	0.01	-0.03	0.00	0.28	0.00	0.01	0.09
DF	0.02	0.02	0.24	0.00	-0.03	0.05	0.01	0.46*
PH	-0.01	-0.02	-0.04	0.00	-0.01	0.05	-0.01	-0.28*
PT	0.02	0.45	0.15	0.00	0.04	-0.07	0.03	0.42*
PL	0.00	-0.02	-0.01	0.00	-0.01	0.15	0.01	0.02
GP	0.02	0.02	0.04	0.00	-0.02	-0.02	0.01	0.45*
SF	**0.22**	0.03	0.00	0.00	-0.01	-0.01	0.01	0.47*
HGW	0.01	**0.47**	-0.06	0.00	-0.01	0.41	0.01	0.28*
BMY	0.00	0.02	**-0.31**	0.06	0.16	0.18	-0.01	-0.11
RL	0.04	0.02	-0.02	**0.15**	0.00	0.37	0.01	0.05
DRW	0.00	-0.01	-0.05	0.00	**0.29**	-0.25	0.16	-0.01
RS	0.00	-0.02	0.16	0.00	0.20	**-0.36**	0.01	0.04
HI	0.01	0.03	0.23	0.00	0.01	-0.03	**0.19**	0.39*

Residual effect = 0.252, Diagonal values denote direct effects, * Significant at 5% level

RILs

The drought tolerant and yield traits of RILs under stress condition resulted that, most of the traits viz., days to 70% RWC, days to flowering, plant height, productive tillers per plant, panicle length, grains per panicle, hundred grain weight, biomass yield, root length, harvest index and root/shoot ratio showed significant positive correlation with grain yield. Studies on the same RIL population under fully moisture regime condition only for yield and its components showed that, the traits viz., productive tillers per plant, grains per panicle, hundred grain weight, biomass yield and harvest index registered significant relation with grain yield. Interrelationship among the traits under stress condition showed that, most of the above said traits were interlinked well with each other. Among these traits, biomass yield was intercorrelated with days to flowering, panicle length, grains per panicle, hundred grain weight, root length, dry root weight and root/shoot ratio. Panicle length showed significant correlation with days to flowering, productive tillers per plant, biomass yield, dry root weight, harvest index and root/shoot ratio. Root/shoot ratio exhibited significant relation with days to flowering, plant height, panicle length, biomass yield, root length and dry root weight. Under controlled condition, the five yield components viz., productive tillers per plant, grains per panicle, hundred grain weight, biomass yield and harvest index expressed interrelationship with each other (Table 7). In overall view, the traits viz., days to 70% RWC, biomass yield, panicle length, root length, grains per panicle, harvest index and root/shoot ratio under stress condition, the traits viz., grains per

Table 6: Path coefficients between grain yield and all other traits in F_3 – Nootripathu/PMK 2

	RWC	LR	LD	DRR	DF	PH	PT	PL	GP
RWC	**0.07**	0.01	-0.13	-0.21	-0.01	-0.01	0.15	-0.01	0.08
LR	-0.03	**-0.32**	0.00	-0.01	0.01	0.00	-0.03	0.01	-0.01
LD	-0.04	-0.01	**0.00**	-0.01	0.09	0.00	-0.26	0.01	-0.01
DRR	0.17	0.00	0.01	**0.03**	-0.01	0.02	-0.01	-0.01	0.00
DF	0.01	0.04	0.00	0.01	**-0.27**	0.01	0.14	-0.07	0.02
PH	0.01	0.00	0.00	-0.01	0.01	**-0.19**	-0.10	0.12	-0.05
PT	0.01	-0.13	0.00	0.00	-0.02	0.16	**0.33**	0.00	0.05
PL	0.02	0.01	0.00	-0.27	-0.01	0.01	-0.01	**-0.02**	0.19
GP	0.21	0.00	0.00	0.00	-0.25	0.03	0.18	-0.01	**0.10**
SF	-0.01	-0.22	0.00	0.01	0.01	0.01	0.05	0.19	0.01
HGW	-0.02	0.00	-0.34	0.00	0.00	0.03	0.27	0.00	0.01
BMY	0.21	0.01	0.00	0.00	-0.01	-0.23	-0.03	0.00	-0.01
RL	-0.17	0.00	-0.20	-0.01	-0.01	-0.01	0.15	0.00	-0.02
DRW	-0.02	-0.32	0.01	-0.01	-0.01	0.04	0.04	0.01	0.00
RS	-0.03	-0.01	0.00	0.00	0.00	0.02	0.08	0.01	0.01
HI	-0.41	0.00	0.00	0.01	0.01	0.03	0.17	0.01	0.35

	SF	HGW	BMY	RL	DRW	RS	HI	Correlation with GY
RWC	-0.01	-0.01	0.18	0.00	-0.09	0.21	-0.07	0.15
LR	0.01	0.01	-0.03	-0.01	0.30	-0.23	0.18	-0.09
LD	-0.01	0.09	-0.03	0.00	0.09	-0.24	0.16	-0.09
DRR	0.00	0.02	0.00	-0.01	-0.21	0.01	0.07	0.08
DF	-0.01	0.00	0.01	0.01	0.17	-0.01	-0.02	0.02
PH	-0.01	-0.01	0.01	0.01	-0.01	0.12	-0.24	-0.33*
PT	0.01	0.01	-0.01	-0.01	0.03	-0.12	0.43	0.75*
PL	-0.02	0.00	0.06	0.00	-0.05	0.07	-0.17	-0.17
GP	0.01	0.00	-0.01	-0.01	0.05	-0.38	0.30	0.55*
SF	**0.11**	0.01	-0.01	0.00	0.01	-0.03	0.11	0.25*
HGW	0.01	**0.02**	-0.01	-0.01	0.04	-0.13	0.11	0.08
BMY	-0.01	-0.01	**0.07**	0.00	0.04	0.35	-0.56	-0.18
RL	0.01	0.00	0.22	**0.04**	0.04	-0.01	-0.04	-0.01
DRW	0.01	0.01	0.28	0.01	**0.31**	-0.28	0.01	0.07
RS	0.01	0.01	-0.05	0.00	0.17	**0.51**	0.52	0.21*
HI	0.09	0.01	-0.05	-0.01	0.00	-0.31	**0.84**	0.72*

Residual effect = 0.123, Diagonal values denote direct effects, *Significant at 5% level

panicle, hundred grain weight and biomass yield under controlled condition showed interrelationship with each other besides positive correlation with grain yield. Hence improvement of any one of these traits will enhance the effect of other traits and finally improving the grain yield.

Partitioning of correlation coefficient into direct and indirect effect resulted that, the traits viz., days to 70% RWC, productive tillers per plant, panicle length, grains per panicle, hundred grain weight, biomass yield, dry root weight, harvest index and root/shoot ratio showed high direct effect on grain yield under stress condition. The traits viz., grains per panicle, hundred grain weight and harvest index also expressed indirect contribution of grain yield through root length. In controlled condition, grains per panicle, biomass yield and harvest index showed high direct effect on grain yield. Hence, the traits viz., days to 70% RWC, productive tillers per plant, panicle length, grains per panicle, biomass yield, harvest index and root/shoot ratio showed positive effect on grain yield. Negative association of some components with grain yield in RIL population under stress condition showed that, the traits viz., leaf rolling, leaf drying and drought recovery rate had significant negative correlation with grain yield. Pantuwan *et al.* (2002) also observed negative correlation of leaf rolling and leaf drying with grain yield. Interrelationship among the traits revealed that, the two traits viz., leaf rolling and leaf drying showed significant negative relation with panicle length, hundred grain weight, biomass yield and root length. In path analysis, all the above mentioned traits showed high negative direct effect on grain yield. Meanwhile the traits viz., days to 70% RWC, plant height, productive

Table 7: Correlation coefficients between grain yield and all other traits in RILs under both water stress and controlled condition

	RWC	LR	LD	CT	DRR	DF	PH	PT	PL
RWC	1.00	-0.67*	-0.55*	0.11	-0.77*	0.23*	0.46*	0.14	0.30*
LR		1.00	0.89*	0.26*	0.83*	-0.22*	-0.70*	-0.09	-0.38*
LD			1.00	0.31*	0.90*	-0.06	-0.87*	-0.24*	-0.48*
CT				1.00	0.09	-0.02	0.49*	0.47*	0.58*
DRR					1.00	0.03	-0.58*	-0.31*	-0.62*
DF						1.00	0.16*	-0.53*	0.49*
(C)						1.00	0.15*	-0.04	0.13
PH							1.00	0.85*	-0.18
(C)							1.00	-0.06	0.49
PT								1.00	0.32*
(C)								1.00	-0.15*
PL									1.00
(C)									1.00
GP									
(C)									
HGW									
(C)									
BMY									
(C)									
RL									
DRW									
HI									
(C)									
RS									

	GP	HGW	BMY	RL	DRW	HI	RS	GY
RWC	-0.04	0.04	0.04	-0.03	0.08	0.69*	0.11	0.32*
LR	0.03	-0.15*	-0.42*	-0.30*	0.08	0.21*	0.28*	-0.30*
LD	0.03	-0.15*	-0.47*	-0.41*	0.00	-0.09	0.19*	-0.40*
CT	0.06	0.03	-0.29*	-0.29*	0.20*	0.46*	0.38*	0.07
DRR	0.05	-0.12	-0.22*	-0.04	0.13	0.22*	0.34*	-0.17*
DF	-0.03	-0.04	0.41	0.11	0.48*	-0.18*	0.35*	0.18*
(C)	-0.10	-0.03	0.04	-	-	-0.10	-	-0.15*
PH	0.03	-0.23	0.09	0.54*	0.29*	0.03	0.24*	0.23*
(C)	-0.06	-0.07	0.16	-	-	-0.15*	-	-0.10
PT	0.10	-0.34	-0.10	0.03	0.03	0.20*	0.03	0.18*
(C)	0.23*	0.17	0.23*	-	-	0.03	-	0.31*
PL	-0.02	-0.02	0.52*	-0.10	0.27*	0.19*	0.24*	0.48*
(C)	-0.03	-0.04	0.20*	-	-	-0.08	-	0.05
GP	1.00	0.54	0.40*	0.11	0.16*	0.66*	0.13	0.88*
(C)	1.00	0.31	0.23*	-	-	0.44*	-	0.75*
HGW		1.00	0.26*	-0.01	0.09	0.31*	0.09	0.85*
(C)		1.00	0.28*	-	-	0.27*	-	0.41*
BMY			1.00	0.62*	0.79*	-0.31*	0.51*	0.73*
(C)			1.00	-	-	0.33*	-	0.27*
RL				1.00	0.79*	-0.31*	0.51*	0.37*
DRW					1.00	-0.21*	0.94*	0.06
HI						1.00	-0.38*	0.62*
(C)						1.00	-	0.52*
RS							1.00	0.16*

*Significant at 5% level (C) -Controlled condition

tillers per plant, panicle length and biomass yield revealed indirect effect on grain yield through drought recovery rate (Table 8). It illustrated the negative influence of leaf rolling and leaf drying with other yield component traits along with grain yield. Based on the above findings of RILs, it was concluded that, to harness high yield combined with drought tolerance, breeders should give selection pressure on days to 70% RWC, panicle length, grains per panicle, harvest index, biomass yield, root/shoot ratio and root length in positive direction and low scores of leaf rolling, leaf drying and drought recovery rate.

Table 8: Path coefficients between grain yield and all other traits in RILs under both water stress and controlled condition

	RWC	LR	LD	CT	DRR	DF	PH	PT	PL
RWC	**0.32**	-0.32	-0.12	-0.01	-0.49	-0.15	-0.23	0.21	0.24
LR	1.58	**-0.98**	0.12	-0.02	0.23	0.14	-0.50	-0.14	-0.70
LD	1.29	-1.23	**-1.02**	-0.19	0.61	0.22	0.46	-0.37	-0.89
CT	-0.25	-0.92	-0.49	**-0.08**	0.15	0.02	-1.16	0.74	1.08
DRR	1.83	-1.02	-0.46	-0.01	**-0.56**	-0.02	0.74	-0.48	-1.15
DF	-0.55	0.69	0.10	0.01	0.05	**-0.66**	-0.37	-0.84	0.90
(C)	-	-	-	-	-	**-0.07**	-0.01	-0.01	0.02
PH	-0.45	0.23	0.12	-0.04	-0.47	-0.01	**-0.31**	0.33	-0.34
(C)	-	-	-	-	-	-0.01	**-0.09**	-0.01	0.06
PT	-0.32	0.31	-0.38	-0.23	-0.50	0.35	-1.01	**1.31**	0.30
(C)	-	-	-	-	-	0.01	0.01	**0.14**	-0.02
PL	-0.71	0.12	0.08	-0.05	-1.01	-0.32	0.43	0.50	**0.92**
(C)	-	-	-	-	-	-0.01	-0.04	-0.02	**0.13**
GP	-0.12	-0.08	-0.05	-0.45	0.01	-0.13	-0.02	0.25	0.31
(C)	-	-	-	-	-	0.01	0.01	0.03	-0.01
HGW	0.03	-0.05	-0.03	-0.12	-0.06	-0.21	-0.03	0.11	0.09
(C)	-	-	-	-	-	0.00	0.01	0.03	-0.01
BMY	-0.08	1.47	0.74	0.02	-0.36	-0.27	-0.20	-0.15	0.96
(C)	-	-	-	-	-	-0.01	-0.01	0.03	0.03
RL	0.07	1.06	0.64	0.02	-0.06	-0.07	-1.27	0.04	-0.18
DRW	-0.19	-0.26	-0.06	-0.02	0.06	-0.32	-0.70	0.05	0.50
HI	-0.46	-0.72	0.15	-0.56	0.35	0.12	-0.24	0.31	0.35
(C)	-	-	-	-	-	0.01	0.01	0.01	-0.01
RS	-0.26	-0.33	-0.30	-0.23	0.47	-0.23	-0.56	0.78	0.44

	GP	HGW	BMY	RL	DRW	HI	RS	Corr. with GY
RWC	0.04	-0.01	0.23	0.02	-0.29	0.30	0.58	0.32*
LR	0.03	0.01	-0.59	0.22	-0.26	-0.09	0.66	-0.30*
LD	0.03	0.03	-0.65	0.30	-0.01	0.04	0.97	-0.40*
CT	0.06	0.06	-0.41	0.21	-0.70	-0.20	1.96	0.07
DRR	0.05	-0.01	-0.31	0.03	-0.12	-0.10	1.42	-0.17*
DF	-0.03	0.12	0.57	-0.08	-1.02	0.08	1.21	0.18*
(C)	-0.05	-0.01	0.01	-	-	-0.03	-	-0.15*
PH	0.03	-0.01	0.18	-0.39	0.23	-0.01	1.23	0.23*
(C)	-0.03	-0.01	0.04	-	-	-0.05	-	-0.10
PT	0.31	-0.01	-0.14	-0.02	-0.12	0.22	0.14	0.18*
(C)	0.11	0.01	0.05	-	-	0.01	-	0.31*
PL	-0.02	0.01	0.26	0.07	-0.96	-0.08	1.24	0.48*
(C)	-0.02	-0.01	0.04	-	-	-0.03	-	0.05
GP	**0.86**	0.01	0.01	0.26	0.01	0.09	-0.08	0.88*
(C)	**0.49**	0.02	0.05	-	-	0.15	-	0.75*
HGW	0.46	**0.33**	0.01	0.25	0.05	0.15	-0.13	0.85*
(C)	0.15	**0.08**	0.06	-	-	0.10	-	0.41*
BMY	0.41	-0.16	**0.67**	-0.45	-0.41	-0.13	-1.33	0.73*
(C)	0.11	0.02	**0.21**	-	-	-0.11	-	0.27*
RL	0.11	0.16	0.50	**-0.73**	-0.35	0.13	0.32	0.37*
DRW	0.16	-0.23	0.16	-0.58	**0.48**	0.11	0.91	0.06
HI	0.39	0.11	0.41	0.22	0.73	**0.44**	-0.98	0.62*
(C)	0.21	0.02	-0.07	-	-	**0.35**	-	0.50*
RS	0.13	0.01	-0.36	-0.37	0.48	0.18	**0.32**	0.16*

Residual effect: 0.043. Diagonal values denote direct effects (C) -Controlled condition, RWC - Days to 70% Relative Water Content LR - Leaf Rolling, LD - Leaf Drying, CT - Ca nopy Temperature, DRR -Drought Recovery Rate, DF - Days to Flowering, PH - Plant Height, PT - Productive Tillers per plant, PL -Panicle Length, GP-Grains per Panicle, SF - Spikelet Fertility, HGW - Hundred Grain Weight, BMY - Biomass Yield, RL - Root Length, DRW - Dry Root Weight, RS - Root/Shoot ratio, HI - Harvest Index, GY - Grain Yield

Overall observation of association studies in three breeding materials pointed out that there is much scope for selecting high yielding genotypes with drought tolerance in rice, if selection pressure is exerted on days to 70% RWC, root/shoot ratio, biomass yield and harvest index and low scores of leaf rolling and leaf drying.

Comparison of BIPs and F_3

Understanding of desirable traits in lowland genotypes and breaking linkage barriers between drought and grain yield are very much essential to make significant achievement. Breeders usually retain desirable linkages after breaking undesirable linkages between drought and yield traits to improve the selection efficiency in discriminating genotypes. Biparental mating is one of the simplest random mating designs available to effect forced recombination and breaking down undesirable linkages as pointed out by Comstock and Robinson (1948). Reports on deployment of this technique for the genetic enhancement of rice genotypes provide an impetus to exploit for lowland rice improvement, where the productivity is low. The comparison of correlation of characters among BIPs and F_3 in the present study revealed that intermating in F_2 caused shifts of associations from F_3 to BIPs both in magnitude and direction. Shanthi (1989) in rice observed that biparental mating had frequently increased the genetic recombination and changed the magnitude and direction of character associations. The traits viz., dry root weight, root/shoot ratio and biomass yield, which are indicators of drought tolerance, did not show significant relationship with grain yield in F_3. But in BIPs, these traits showed significant positive association with grain yield. Thus an unfavorable linkage between drought tolerance traits and grain yield was broken down by way of intermating in F_2 and resulted in favourable linkages. Yunus and Paroda (1982) viewed that breakage of coupling phase linkages tented to increase the correlations. Thus it could be suggested that for drought tolerance breeding programme in rice, intermating of selected segregants in F_2 is recommend as an alternate method to pedigree breeding programme. Similarly, the unfavorable tight linkage of days to flowering and spikelet fertility with grain yield in F_3 was changed to favourable non-significant relationship in BIPs by way of intermating in F_2.

The change of direction is another aim of BIP, here the negative contribution of biomass yield and dry root weight in F_3 was converted to positive influence on grain yield in BIPs. For days to flowering and spikelet fertility, the positive significant influence on grain yield in F_3 was changed over to negative and/or non significant influence in BIPs. Days to flowering showed positive and significant association in F_3. It means that late types will give higher yield. But early flowering or early duration genotypes are preferable for drought situations to escape from drought. Normally in drought situation spikelet fertility decide the grain yield which showed the tight linkage between spikelet fertility and grain yield. Similar trend was observed in the present study of F_3. But in BIPs, spikelet fertility showed non-significant relation with grain yield, this showed breakage of linkage between these two traits. It resulted that grain yield will be improved irrespective of spikelet fertility. Hence, the breaking of positive association of days to flowering and significant association of spikelet fertility with grain yield in BIPs by way of intermating resulted in a situation where the grain yield could be improved irrespective of the flowering duration and spikelet fertility.

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