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Association analysis of grain yield and its component traits in backcross inbred lines (BILs) of rice (*Oryza sativa* L.) under reproductive stage moisture stress conditions

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Abstract
A set of twenty four BILs of rice (*Oryza sativa* L.) were assessed to examine inter-relationships of moisture stress tolerance and yield related traits under reproductive stage moisture stress conditions. Association analysis revealed that grain yield per plant exhibited highly significant positive association with harvest index, plant height, filled grains per panicle, spikelet fertility, biological yield per plant, number of tillers per plant, number of panicles per plant and 1000 grain weight. Among moisture stress tolerance related traits, shoot length and SCMR showed high and significant positive association with grain yield per plant.

Keywords: Rice, association analysis, grain yield traits, reproductive stage moisture stress, backcross inbred lines (BILs)

Introduction
Rice is the most important cereal crop and a primary source of food for more than 60% of the people in India. The country has to increase its rice production by 2.5 million tons a year to meet its people requirement by 2050. In the current era of climate change, drought stress plays a vital role in affecting rice yields in rainfed rice areas. Drought stress affects rice yields particularly at reproductive stage. Drought tolerance in rice is a polygenically controlled trait with low inheritability and expected gain through conventional breeding has got its own limitations of response to selection. Marker-assisted selection may be more efficient than conventional breeding in situations where the trait to be improved shows a low heritability, or is expensive or time-consuming to measure (Jongdee *et al.*, 2002) [4]. Correlation analysis reveals the direction and extent of the genetic relationships between any given pair of traits without regards to cause/effect relationship. Therefore, an attempt has been made to assess inter-relationship between moisture stress tolerance traits and grain yield related traits in the present study.

Material and Methods
The material for the present study consisted of 24 backcross inbred lines (BC_2F_2) of rice derived through marker assisted backcross breeding of IR58025B with Apo. They were grown in a randomized block design with two replications at Indian Institute of Rice Research formerly known as Directorate of Rice Research, Hyderabad during *rabi* 2018. The seeds of BC_2F_2 of IR58025B X Apo were sown in nursery bed along with parents to raise the seedlings. Later single seedling of 17 days old were transplanted in an experimental plot in two rows of 2.4 m length. Inter and intra row spacing maintained as 30cm and 10cm respectively in transplanted field. Regular and need based operations were performed to grow a healthy crop.
Moisture stress was imposed by draining the field and withholding irrigation for 3 weeks at panicle initiation stage. After 3 weeks, BILs were irrigated. Tolerant genotypes were recovered from stress. Crop was harvested when the grains reached physiological maturity stage. Observations were recorded on randomly chosen five competitive plants for all characters *viz.*, plant height, number of tillers per plant, number of panicles per plant, panicle length, filled grains per panicle, unfilled grains per panicle, spikelet fertility, grain yield per plant, biological yield per plant, harvest index, shoot length, shoot dry weight, leaf rolling at reproductive stage stress, specific leaf area at harvest, relative water content and SCMR reading.

The characters *viz.*, days to 50% flowering and days to maturity were recorded on per plot basis. Correlation coefficients were calculated using the method given by Johnson *et al.* (1955) [3].

Results and Discussion

The analysis of variance indicated the existence of significant differences between the BILs in all the traits under reproductive stage moisture stress conditions (Table 1). Phenotypic correlation coefficients of grain yield per plant with its component traits under reproductive stage moisture stress are presented in the Table 2. In the present investigation, grain yield per plant showed highly significant positive association with harvest index (0.84**), plant height (0.72**), filled grains per panicle (0.56**), spikelet fertility (0.35*), biological yield per plant (0.35*), number of tillers per plant (0.34*), number of panicles per plant (0.32*) and 1000 grain weight (0.32*). These results were in confirmation with the reports of Bidinger *et al.* (1999) [1], Pantuwan *et al.* (2002) [7], Lafitte *et al.* (2004) [5] and Lanceras *et al.* (2004) [6]. This association indicates that these yield related parameters can be used as preliminary screening tools for selecting the high yielding BILs in the present material under moisture stress.

On contrary, grain yield per plant displayed highly significant negative association with unfilled grains per panicle (0.57*). Hence, improvement for grain yield could be effectively augmented through indirect selection of less number of unfilled grains per panicle. The strong correlations between single plant yield and harvest index under reproductive stage stress indicated the capacity of the plants to maintain seed set under moisture stress rather than biomass accumulation. Therefore the genetic improvement of harvest index would improve grain yield significantly (Lanceras *et al.*, 2004) [6]. The positive association of plant height with grain yield per plant in the present study showed that yield advantage under stress was not related to plant height *per se* but with the maintenance of plant height and biomass under stress conditions. Strong positive correlation of filled grains per panicle with grain yield revealed that the BILs with high filled grains per panicle will produce better grain yield under moisture stress. Strong positive correlation of biological yield per plant with grain yield per plant displayed the efficiency of BILs in utilizing stem reserves during grain filling under moisture stress (Lanceras *et al.*, 2004) [6]. Gopikannan and Ganesh (2013) [2] reported significant positive association of number of tillers per plant with grain yield per plant suggesting that individual plant selections can be made for plants with higher number of productive tillers per plant which ultimately leads to improvement in both number of productive tillers per plant and grain yield per plant in the present breeding material.

Inter correlation among yield components revealed significant and positive correlation of plant height with harvest index, biological yield per plant, 1000 grain weight and filled grains per panicle indicating that tall plants are capable to produce more biological and grain yield under moisture stress conditions. Number of tillers and panicles per plant displayed significant and positive with harvest index. Similarly, filled grains per panicle displayed significant and positive association with spikelet fertility and harvest index. Spikelet fertility exhibited significant and positive association with harvest index. Phenotypic correlation coefficients of physiological traits with grain yield per plant under reproductive stage moisture stress are presented in the Table 3. Grain yield per plant recorded highly significant positive association with shoot length (0.66**) and SCMR (0.40**). This finding suggests that shoot length and SCMR can be used as indirect selection criteria for higher grain yield. In contrast, it had highly significant negative correlation with leaf rolling (-0.96**). This association suggests that selection of individual plants with less leaf rolling will result in higher grain yield by maintaining adequate relative water content (Pantuwan *et al.*, 2002) [7].

Inter correlations among drought tolerance related traits revealed significant and positive correlation of shoot length with relative water content (0.32*) and negative association with leaf rolling (-0.71**) indicating that the traits like shoot length, SCMR, leaf rolling and relative water content reflects internal water status of the BILs under stress and these traits can be considered as integrative traits to identify drought resistant genotypes (Pantuwan *et al.*, 2002) [7].

Table 1: ANOVA of BILs for yield and its component traits under reproductive stage moisture stress conditions

S. No.	Traits	Mean sum of squares		
		Replications (d.f.=2)	Treatments (d.f.=23)	Error (d.f.=56)
1	Plant height (cm)	126.75**	43.26**	18.94
2	Days to 50% flowering (No.)	72.52**	7.38**	0.47
3	Days to maturity (No.)	82.68**	8.10**	1.25
4	Number of tillers per plant (No.)	114.08**	7.17**	0.30
5	Number of panicles per plant (No.)	80.08**	9.26**	0.60
6	Panicle length (cm)	12.17*	4.06	2.29
7	1000 grain weight (g)	196.02**	15.50**	0.84
8	Number of filled grains per panicle (No.)	2436.75**	998.20**	10.48
9	Number of unfilled grains per panicle (No.)	1344.08**	81.89**	2.90
10	Spikelet fertility (%)	105.52**	55.54**	1.31
11	Grain yield per plant (g)	65.33**	19.54**	2.94
12	Biological yield per plant (g)	48.00	52.91	0.01
13	Harvest index (%)	149.99**	84.64**	14.69
14	Shoot length (cm)	631.98**	46.12**	17.40
15	Relative water content (%)	244.80**	18.86	29.19
16	SPAD chlorophyll meter reading	115.75**	8.80**	2.76
17	Shoot dry weight (g)	38.73**	3.46**	0.06
18	Specific leaf area (cm^2g^{-1})	424.35**	162.15**	7.55

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

Table 3: Phenotypic correlation coefficients among grain yield and its physiological traits in 24 BILs of rice under reproductive stage moisture stress condition

Traits	Shoot length	Shoot dry weight	Leaf rolling	Specific leaf area	Relative water content	SPAD chlorophyll meter reading	Grain yield per plant
Shoot length	1.00	0.08	-0.71**	-0.04	0.32*	0.21	0.66**
Shoot dry weight		1.00	-0.16	0.03	0.04	0.25	0.09
Leaf rolling			1.00	0.10	-0.33*	-0.69**	-0.96**
Specific leaf area				1.00	0.06	0.01	-0.04
Relative water content					1.00	0.09	0.27
SPAD chlorophyll meter reading						1.00	0.40**

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

Table 2: Phenotypic correlation coefficients among grain yield and its component traits in 24 BILs of rice under reproductive stage moisture stress condition

Traits	PH	DFF	DTM	NTP	NPP	PL	1000GW	FGP	UFGP	SF	BYP	HI	GYP
PH	1.00	0.03	-0.17	0.18	0.13	0.12	0.30*	0.29*	-0.34*	0.09	0.34*	0.56**	0.72**
DFF		1.00	0.93**	0.08	0.24	-0.13	0.34*	-0.25	0.23	-0.29*	0.19	-0.17	-0.05
DTM			1.00	0.11	0.22	-0.07	0.34*	-0.28	0.26	-0.23	0.11	-0.14	-0.08
NTP				1.00	0.91**	0.21	0.11	0.22	-0.22	0.16	0.11	0.34*	0.34*
NPP					1.00	0.01	0.17	0.20	-0.17	0.16	0.08	0.32*	0.32*
PL						1.00	-0.14	0.20	-0.24	0.08	0.20	0.08	0.18
1000GW							1.00	-0.05	0.07	0.02	0.14	0.25	0.32*
FGP								1.00	-0.97**	0.86**	0.15	0.50**	0.56**
UFGP									1.00	-0.83**	-0.14	-0.52**	-0.57**
SF										1.00	-0.01	0.38*	0.35*
BYP											1.00	-0.19	0.35*
HI												1.00	0.84**

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

PH: Plant height (cm)
DFF: Days to 50% flowering
DTM: Days to maturity
NTP: Number of tillers per plant
NPP: Number of panicles per plant
PL: Panicle length (cm)
1000GW: Thousand grain weight (g)
FGP: Filled grains per panicle
SF: Spikelet fertility (%)
BYP: Biological yield per plant (g)
HI: Harvest index (%)
GYP: Grain yield per plant (g)

Conclusions

1. The traits to be given importance in selection in the present breeding material are harvest index, plant height, filled grains per panicle, spikelet fertility, biological yield per plant, number of tillers per plant, number of panicles per plant and 1000 grain weight as they exhibited highly positive correlation with grain yield and also a positive inter-correlations among themselves.
2. Selection based on shoot length and SCMR is highly suitable for identifying BILs for use in rice improvement for drought tolerance.
   Highly yielding BILs of IR58025B under reproductive stage moisture stress could be further utilized for the development of rice hybrids tolerance to drought stress.

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