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

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Abstract
A set of twenty six backcross inbred lines of rice (*Oryza sativa* L.) were assessed to study inter-relationships of phosphorus stress tolerance related traits and yield related traits under low phosphorus stress conditions. Correlation analysis revealed that grain yield per plant exhibited highly significant positive association with harvest index (0.90), spikelet fertility (0.66), number of tillers per plant (0.38), filled grains per panicle (0.29), number of panicles per plant (0.28) and leaf P (0.27).

Keywords: Rice, association analysis, phosphorus stress tolerance traits, grain yield traits, low p stress, backcross inbred lines (BILs)

Introduction
Rice is one of the most important staple food crops of the world and is a primary source of food for more than half of the world's population. India needs to increase its rice production by 2.5 million tons a year to meet the population requirement by 2050. One third of the agricultural land in the world does not have adequate amount of P in the soil for optimum plant growth and development (Mac. Donald *et al.*, 2011) [6]. Soil phosphorus deficiency has been identified as a major factor limiting rice yield. Application of phosphorus fertilizers can alleviate this problem but the lack of locally available P sources and the high cost of importing and transporting P fertilizers frequently prevent resource poor farmers in developing countries like India. Hence, there is a need to develop a cost effective solution for this problem. Conventional breeding for P-deficiency is slow in attaining progress and difficult in phenotyping. This requires several years of continuous cropping without application of P-fertilizer. Developing rice hybrids with tolerance to P-deficient soil by means of marker-assisted selection would be convenient and cost effective method as it helps to selectively incorporate desired genes or QTLs into the plant by getting rid of undesirable traits. Correlation analysis reveals the direction and magnitude of the relationships between any given pair of traits without regards to cause/effect relationship. Therefore, an attempt has been made to assess inter-relationship of low phosphorus stress tolerance related traits with grain yield in a set of twenty six backcross inbred lines of rice (*Oryza sativa* L.) to formulate an effective selection strategy to isolate high yielding BILs under low P stress conditions.

Material and Methods
The material for the present study comprised of 26 backcross inbred lines of rice derived from the cross of KMR-3R with Kasalath 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. Each genotype was sown on low phosphorus stress field with P< 2ppm in two rows of 2.4 m length. Inter and intra row spacing maintained as 30cm and 10cm respectively in transplanted field. Recommended crop production and protection practices were followed to raise a healthy crop. 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, phosphorus content in leaf and phosphorus content in seed.

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) [2].

Results and Discussion

Analysis of variance revealed the existence of significant difference among the BILs for all traits except number of tillers per plant, number of panicles per plant and 1000 grain weight under low P conditions (Table 1). Phenotypic correlation coefficients among yield related traits with grain yield per plant under low P conditions are presented in the Table 2. Grain yield per plant was found to have highly significant positive association with harvest index (0.90**), spikelet fertility (0.66**), number of tillers per plant (0.38**), filled grains per panicle (0.29*), number of panicles per plant (0.28*) and leaf P (0.27*). These results were in conformity with the results of Koide *et al.*, (2013) [3] and Wang *et al*., (2014) [8] for grain yield per plant with leaf P. It indicates the ability of plants with high leaf phosphorus content to produce grain yield under phosphorus deficient conditions. Significant positive association of harvest index with grain yield per plant in the present study revealed the ability of the plants to maintain seed set under phosphorus stress rather than biomass accumulation. Significant positive association of tillers per plant with grain yield per plant is in agreement with work of Wissuwa and Ae (2001) [9]. They reported that plants with more number of tillers per plant were more efficient in phosphorus uptake and thereby produces higher grain yield under phosphorus stress. 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 low phosphorus stress. In contrast, unfilled grains per panicle (0.70) had significant negative correlation with grain yield per plant. Hence, indirect selection for grain yield could be effectively done through direct selection of genotypes that produces less number of unfilled grains per panicle.

Inter correlation among yield components revealed significant and positive correlation of number of tillers per plant with number of panicles per plant, spikelet fertility, harvest index and filled grains per panicle. It indicated that genetic improvement in tillers per plant leads to improvement of above correlated characters under low phosphorus stress conditions. Number of panicles per plant displayed significant and positive correlation with panicle length, spikelet fertility and harvest index. Filled grains per panicle and spikelet fertility displayed significant and positive association with leaf P and harvest index. These results indicated filled grains per panicle is a crucial trait for performance under low phosphorus stress as was detailed by Koide *et al.*, (2013) [3]. Leaf P displayed significant positive association with seed P indicating phosphorus content in leaf and seed can be used as indicators of P uptake in plants to demonstrate general P deficient adaptation and used as reliable criteria to identify tolerance in plants under phosphorus deficient conditions (Chankaew *et al.*, 2019) [1].

Table 1: ANOVA of BILs for yield and its component traits under low P conditions

S. No.	Traits	Mean sum of squares		
		Replications (d. f.=2)	Treatments (d. f.=25)	Error (d. f.=50)
1	Plant height (cm)	972.48**	229.48**	3.38
2	Days to 50% flowering (No.)	46.78**	6.16**	0.36
3	Days to maturity (No.)	49.20**	6.35**	0.41
4	Number of tillers per plant (No.)	4.66**	0.98	0.68
5	Number of panicles per plant (No.)	6.23**	0.77	0.64
6	Panicle length (cm)	46.89*	4.32**	1.79
7	1000 grain weight (g)	15.60*	3.38	2.62
8	Number of filled grains per panicle (No.)	738.10**	35.35**	12.89
9	Number of unfilled grains per panicle (No.)	622.29**	22.44**	1.10
10	Spikelet fertility (%)	44.52**	8.59*	0.79
11	Grain yield per plant (g)	15.57*	4.37*	2.12
12	Biological yield per plant (g)	55.08**	11.75**	4.45
13	Harvest index (%)	7.35	12.16	6.98
14	Leaf P content (%)	0.20**	0.03**	0.01
15	Seed P content (%)	0.11**	0.01**	0.01

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

Table 2: Phenotypic correlation coefficients among grain yield and its component traits in 26 BILs of rice under low P condition

Traits	PH	DFF	DTM	NTP	NPP	PL	1000GW	FGP	UFGP	SF	BYP	HI	Leaf P	Seed P	GYP
PH	1.00	-0.18	-0.16	0.05	0.07	0.57**	0.04	-0.03	-0.31*	0.23	0.15	0.11	-0.01	-0.01	0.18
DFF		1.00	0.99**	0.02	0.05	-0.19	0.09	0.11	0.12	-0.05	-0.17	-0.10	-0.03	-0.15	-0.19
DTM			1.00	-0.02	0.06	-0.19	0.11	0.12	0.09	-0.02	-0.15	-0.08	-0.07	-0.19	-0.16
NTP				1.00	0.82**	0.24	-0.07	0.28*	-0.38**	0.40**	-0.06	0.38**	0.11	0.06	0.38**
NPP					1.00	0.35**	0.07	0.25	-0.30*	0.33*	-0.08	0.29*	0.03	-0.09	0.28*
PL						1.00	0.03	0.11	-0.13	0.15	0.04	0.08	0.06	-0.04	0.10
1000GW							1.00	0.02	-0.08	0.07	0.03	0.02	-0.21	-0.22	0.03
FGP								1.00	-0.36**	0.69**	-0.05	0.29*	0.33*	0.21	0.29*
UFGP									1.00	-0.91**	-0.14	-0.60**	-0.18	-0.06	-0.73**
SF										1.00	0.10	0.56**	0.28*	0.13	0.66**
BY											1.00	-0.41**	-0.02	0.01	0.01

HI												1.00	0.25	0.19	0.90**
Leaf P													1.00	0.80**	0.27*
Seed P														1.00	0.22

*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 (%)Seed
BYP: Biological yield per plant (g)
HI: Harvest index (%)
Leaf P: Leaf phosphorus content (%)
P: Seed phosphorus content (%)
GYP: Grain yield per plant (g)

Conclusions

1. Selection based on the traits *viz.*, harvest index, spikelet fertility, number of tillers per plant, filled grains per panicle, number of panicles per plant and leaf P in the present breeding material is highly suitable for identifying BILs with high grain yield under low P stress since these traits exhibited highly positive correlation with grain yield and also positive inter-correlations among themselves.
2. High yielding BILs of KMR-3R under low phosphorus stress could be further utilized for development of rice hybrids tolerance to phosphorus stress.

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