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Research Article

Selection for drought tolerance in rice genotypes based on principal components and seletion indices

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Abstract

Rice being the hugely consumed crop worldwide is unfortunately facing a severe yield loss due to drought stress. In this view, the study was conducted at Pandit Jawaharlal Nehru College of Agriculture and Research Institue, Karaikal during late samba of 2018 using 48 rice genotypes with an objective to select discriminating rice genotypes for drought tolerance based on principal component analysis (PCA) and selection index. The field experiments were laid out in normal and drought conditions using RBD design with three replications. Traits such as days to 50 per cent flowering, plant height, productive tillers, panicle length, grains per panicle, grain weight, grain yield were observed under both the environments, additionally relative water content, leaf senescence, leaf rolling, leaf drying and stress percentage were observed under drought environment. The PCA had reduced the 12 traits into six traits *viz.,* days to 50 per cent flowering, plant height, panicle length, grains per panicle, grain yield and stress percentage across the environments. Selection index computed with the economic weights derived from PCA had registered the genotype IET-27693 with high index score for drought tolerance.

Keywords

rice, drought tolerant, PCA, selection index.

INTRODUCTION

Rice (*oryza sativa* L.) is the main crop in cauvery delta zone which is the rice bowl for the states of Tamil Nadu and Puducherry and it is cultivated in irrigated lowland under puddled flooded condition using Cauvery river water. In this sutiation, inadequate water supply from Cauvery river was witnessed in the past several years and declining water table due to frequent failures of monsoons resulted in water shortage leading to steady reduction or decrease in area under rice cultivation in this highly productive region. Therefore, water stress is a major factor limiting rice production that causes a great threat to rice production (Fellahi *et* al., 2013). To reduce yield losses of rice crops in water deficient areas and to increase the overall rice production, rice varieties with greater adaptation to drought stress are essential. Therefore, there is an urgent need to identify or develop suitable rice genotypes for drought tolerance in this zone. Drought tolerance is a complex trait, however the selection in many breeding program, seldom practiced on single trait *i.e.*, grain yield. Smith (1936) argued that the genetic worthiness could not be directly evaluated on single trait: rather it might be best estimated by a linear function of observable phenotypic values. Hence, the use of selection index would maximize the genetic gain for complex traits like drought tolerance. Considering these in view, the present study was aimed to evaluate the genetic variation among the rice genotypes using principal component analysis and to select the discriminating rice genotypes for drought tolerance based on multiple traits using selection index.

MATERIALS AND METHODS

The plant material includes forty eight rice genotypes comprised of 10 popular varieties and 32 advanced breeding lines along with 6 drought tolerant lines (**Table 1**).

Table 1. Details of rice genotypes used in the experiment.

G.No.	Genotype	Parentage
	Drought tolerant lines	
G1	DRR DHAN-42	Aday Sel / *3 IR 64
G2	DRR DHAN-44	IR 71700-247-1-1-2 / IR03L120
G3	DULAR	Landrace
G4	KALIUS	Landrace
G5	MOROBOREKEN	Landrace
G6	N-22	Landrace
	Varieties	
G7	ADT 39	IR 8 / IR 20
G8	ADT 43	IR 50 / White ponni
G9	ADT46	ADT 38 / CO 45
G10	ADT49	CR 1009 / Jeeragasamba
G11	CO(R)50	CO 43 / ADT 38
G12	CO(R)52	BPT 5204 / CO (R) 50
G13	CR1009	Pankaj / Jagannath
G14	IW PONNI	Taichung 65 / 2 / Mayang Ebos-80
G15	MDU 1010	MTU-077 / IR 64
G16	TKM 13	WGL 32100 / Swarna
	Advanced lines	
G17	IET-27717	MTU 1075 / Kavya
G18	IET-27712	IR 69702-52-3-3R / 1096
G19	IET-27687	Mahamaya / IRBB 59
G20	IET-27706	Swarna / MTU 1010
G21	IET-27684	Surendra / Annapurna
G22	IET-27696	MTU 1081 / A 69-1
G23	IET-27664	Swarna / RAU 3041
G24	IET-27659	OR 2060-5 / Indravati
G25	IET-27665	Swarna / RAU 3041
G26	IET-27682	Pusa 1121 / BM71
G27	IET-27666	JGL 11727 / MTU 1064
G28	IET-27705	MTU 1001 / KMP 150
G29	IET-27677	RP Bio-226 / JGL - 1798
G30	IET-27693	BPT 1768 / NLR 145
G31	IET-26968	CR 407 / Samba Mahsuri
G32	IET-27668	Pyzum / Sambha Mahsuri
G33	IET-27690	IR 58025A / KMR-3R
G34	IET-27685	SK-20 / Vandana / 69-3-2-1-1-1-1
G35	IET-27674	MTU 1010 / KMP 149
G36	IET-27678	IR 36 / Birupa
G37	IET-27713	Khandagiri / FL378
G38	IET-27702	Akshyadhan / PAU-201
G39	IET-27710	Heera // Subhadra
G40	IET-27676	Karma Mahsuri / IRBB59
G41	IET-27686	MTU 1075 / CR 3598-1-4-2-1
G42	IET-27691	MTU 1010 / HMT Sona
G43	IET-26979	CN 1039-9 / IR 85260-148
G44	IET-27675	IET-19389 / Badshabhog
G45	IET-27683	MTU 1010*2 / ST 12
G46	IET-27680	Malbhog / Bahadur
G47	IET-27660	AD 02233 / BPT 5204
G48	IET-27698	IR05N170 / MTU 1010

The experiments *viz*., normal and drought environment were conducted simultaneously in two adjacent plots at Pandit Jawaharlal Nehru College of Agriculture and Research Institute Karaikal. Forty eight rice genotypes were sown in three lines per entry under raised bed nursery. Twenty five days old seedlings were planted in the experimental blocks, where they were equally partitioned to two separate experiments one under normal environment and other under drought environment in randomized block design (RBD) with three replications. Each genotype was planted in three rows with the spacing of 20 x 10 cm within genotype and 30 cm spacing between two genotypes. Both the fields were in puddled condition during transplanting of seedlings.

The total amount of rainfall during the crop period was 96.9 cm (IMD, 2018) with dry spell of 4 weeks . The trial was under sufficient water stress during the vegetative period. After 15 days of planting, drought environment field was drained while the normal field was irrigated with 5 cm of water depth at frequent intervals. The drought environment was allowed for drying for the disappearance of water till the formation of fine cracks or hairline cracks indicating the moisture level below the soil surface (>15cm) and this condition was maintained up to peak tillering phase (20 days) until the drought symptoms appeared over the crop as reported by Manickavelu *et al*. (2006).

Relative water content (RWC) was previously demonstrated to be a relevant screening tool of drought tolerance in cereals, as well as good indicator of plant water status (Teulat *et al*., 2003). Hence the RWC was taken at regular intervals using the method suggested by Karmer (1969) in drought environment to monitor the drought stress.

Observations were recorded on five randomly selected plants of each genotypes per replication in both the experiments for yield component traits *viz*., days to 50% flowering (DF), plant height (PH), productive tillers (PT), panicle length (PL), grains per panicle (GP), grain weight (GW) and grain yield per plant (GY). Additionally, when most of the genotypes attained 70% RWC level, then the scoring of leaf rolling (LR), leaf drying (LD) and leaf senescence (LS) were observed according to Standard Evaluation System adopted for rice (IRRI, 1996) in drought environment.

The analysis of variance was carried out individually for each environment. Pooled analysis of variance was also performed for normal and drought environment to assess the significance of genotypes across the environments, between the environments and interaction of genotypes with environments as suggested by Singh and Chaudhary (1977). The mean data of the traits were used to perform principal component analysis (PCA) using software R v.3.4.4. Through PCA component traits which had the maximum contribution towards variability were identified. The weights derived from the eigen values were further considered for selection index analysis. Selection indices were constructed according to Smith (1936). The weightage for each trait was derived based on the PCA loading value. The scale of 1 to 10 was used for weights, in which grain yield had given the maximum weightage of 10. Selection index for the recorded data was computed using PBTools v. 1.4 (PBTool, 2014).

RESULTS AND DISCUSSION

The potentiality of a breeding method is judged on the extent of genetic variability generated in different quantitative traits (Allard, 1960), as it indicates the extent of recombination for effective selection. Analysis of variance for all the yield and drought related traits studied were found to be significant in both the environmental conditions (**Table 2**). The genotypes over the two environmental conditions

Table 2. Mean sun of square, mean and range for drought and normal environment.

Traits	Mean sum of square		Mean		Range	
	Normal	Drought	Normal	Drought	Normal	Drought
Days to 50 % flowering	278.32**	232.26**	86.20	84.75	60.0-123.0	74.0-118.0
Plant height (cm)	333.40**	280.15**	98.77	90.16	70.9-117.0	74.5-111.0
Productive tillers (nos)	5.37**	7.83**	9.91	7.90	7.3- 12.3	4.3- 11.3
Panicle length (cm)	13.28*	9.16**	23.24	21.97	17.3- 27.7	17.6- 25.6
Grains per panicle (nos)	7323**	5106.00**	172.34	121.94	83.0-295.7	49.6-295.7
Grain weight (g)	0.33**	0.42**	2.14	2.17	1.4- 2.9	1.4- 2.9
Grain yield (g)	111.11**	113.71**	26.28	16.96	12.2- 44.7	9.0- 32.0
RWC (%)	NA	101.71*	NA	77.96	NA	61.0 - 91.7
Leaf senescence (Score)	NA	8.21**	NA	4.08	NA	1.0- 5.0
Leaf rolling (Score)	NA	1.22	NA	1.14	NA	0.0- 3.0
Leaf drying (Score)	NA	1.18**	NA	0.70	NA	0.0- 3.0
Stress %	NA	1109.90**	NA	32.37	NA	3.6- 93.4

*significance at 5% level **significance at 1% level were significant for all the traits studied. The environmental conditions *viz*., normal and drought stress conditions differed significantly for all the traits except grain weight. Interaction between genotypes and environmental conditions was also significant for all the traits except panicle length.

Table 3. Principal component analysis under drought and normal environment.

Traits	PC1		PC2		PC3	
	Drought	Normal	Drought	Normal	Drought	Normal
Days to 50 % flowering	0.078	0.092	**0.116**	**0.806**	**0.424**	**0.564**
Plant height (cm)	0.072	0.039	0.018	**0.532**	**0.857**	**0.780**
Productive tillers (nos)	0.003	0.007	0.000	0.013	0.028	0.019
Panicle length (cm)	0.019	0.020	0.007	**0.159**	0.095	0.036
Grains per panicle (nos)	**0.992**	**0.993**	0.023	**0.108**	**0.110**	0.007
Grain weight (g)	0.002	0.002	0.002	0.015	0.010	0.001
RWC (%)	0.024	NA	0.018	NA	0.028	NA
Leaf senescence (Score)	0.001	NA	0.028	NA	0.031	NA
Leaf rolling (Score)	0.002	NA	0.009	NA	0.004	NA
Leaf drying (Score)	0.000	NA	0.017	NA	0.006	NA
Stress %	0.018	NA	**0.991**	NA	0.025	NA
Grain yield (g)	0.057	0.057	0.054	**0.170**	**0.249**	**0.268**
EV	4.147	4.940	1.983	1.091	1.055	1.074
PV	0.721	0.903	0.165	0.043	0.047	0.043
CuV	0.721	0.903	0.886	0.947	0.933	0.989

EV - Eigen value; PV - Proportion of variance; CuV - Cumulative variance;
Note: Traits with high loading value in the principal components are indicated with bold font

Table 4. Rice genotypes identified with high selection index score in drought environment.

Genotype No.	DF (Days)	PH (cm)	PT (No.)	PL (cm)	GP (No.)	GW (g)	RW (%)	LS (Score)	LR (Score)	LD (Score)	SP (%)	GY (g)	Selection Index
G30	82.00	108.33	10.33	24.53	295.73	2.13	77.99	5.00	0.67	0.00	21.48	25.14	**3.95**
G17	83.00	92.13	7.00	21.15	197.13	1.69	74.20	5.00	2.33	3.00	76.78	30.81	**3.31**
G5	84.67	103.87	4.33	24.60	157.33	2.99	79.72	5.00	1.00	0.00	40.26	32.00	**2.89**
G31	97.00	100.41	7.00	24.00	132.13	2.58	81.95	5.00	1.00	0.00	26.85	31.30	**2.34**
G47	105.00	99.33	8.33	25.67	205.53	1.98	66.21	2.33	1.33	1.00	12.15	23.15	**2.13**
G18	83.00	103.07	6.00	21.14	130.40	2.76	76.18	5.00	0.00	2.33	75.23	22.56	**1.81**
G24	91.67	99.01	7.00	24.77	157.93	1.87	73.80	5.00	0.67	0.00	17.11	25.21	**1.72**
G27	83.00	81.17	9.00	21.43	99.13	1.56	76.20	5.00	1.00	1.00	93.37	22.86	**1.34**
G46	96.33	96.47	11.33	23.80	117.13	2.48	84.71	5.00	1.33	0.00	14.63	24.68	**1.30**
G39	86.33	98.21	8.67	23.68	116.53	2.04	85.66	5.00	0.67	1.00	50.00	18.98	**1.10**
MSI	**89.20**	**98.20**	**7.90**	**23.48**	**160.90**	**2.21**	**77.66**	**4.73**	**1.00**	**0.83**	**42.79**	**25.67**	NA
MAI	**84.75**	**90.16**	**7.90**	**21.97**	**121.40**	**2.17**	**77.96**	**4.08**	**1.14**	**0.70**	**32.37**	**16.96**	NA
SDi	**4.45**	**8.04**	**0.00**	**1.51**	**39.50**	**0.04**	**-0.30**	**0.65**	**-0.14**	**0.13**	**10.41**	**8.71**	NA
EGG	**4.30**	**5.63**	**0.22**	**1.06**	**53.91**	**-0.07**	**-0.99**	**0.30**	**-0.05**	**0.10**	**6.91**	**5.16**	NA

MSI: Mean of selected individuals SDi: Selection differential MAI: Mean of all individuals
EGG: Expected genetic gain

PCA was carried out using the mean data of the traits studied. The percent of variation explained by first three PCs in normal and drought environments were 98.9 per cent and 93.3 per cent respectively (**Table 3**). The eigen value for first three PCs were more than one in both the environments. This was in accordance with Brejda *et al*. (2000) in which he has explained that the data with eigen value more than one determines at least 10 per cent of the variation. The PC1 explains 90.2 per cent of total variation under normal environment, whereas under drought environment it accounts for 72.1 per cent. The PC2 and PC3 were contributes for 4.4 per cent and 4.3 per cent of variation respectively under normal environment, whereas under drought environment PC2 and PC3 accounts for 16.5 per cent and 4.7 per cent of total variation. It was found that, the trait grains per panicle had highly loaded in PC1 in both normal and drought environments. This trend was same as reported by Gana *et al*. (2013). It was clearly shown in the Table 3 that, the PC2 and PC3 for normal environment was highly loaded with traits such as days to 50 per cent flowering, plant height, panicle length, grains per panicle and grain yield. Mahendran *et al*. (2015) also reported that PC2 was loaded with grain yield. In drought environment, PC2 was loaded with days to 50 per cent flowering and stress percentage while PC3 was loaded with plant height, grains per panicle and grain yield. Traits with high variability are expected to provide high level of gene transfer during breeding programs (Gana *et al*., 2013).

Selection of genotypes is based on grain yield alone in many breeding programs. However, the economic value of a plant depends on the values of its different traits, plant breeders should consider simultaneous selections for several traits to maximize the economic value of a plant. Selection index (Smith, 1936) will help us in computing these traits in order to develop a best genotype. The calculated index scores for all forty eight genotypes grown under drought environment ranged from -3.67 to 3.95 for 48 genotypes. Ten best genotypes were selected based on high selection index score in which IET-27693, a advanced breeding line registered first rank for drought tolerance (**Table 4**). Similar to our study, Rahimi *et al.* (2017) also used selection indices for selecting best rice varieties under drought stress and non-stress conditions. The use of selection index based on multivariate analysis for improving grain yield in rice is also demonstrated by Sabouri *et al*. (2008).

Overall, drought stress reduced significantly the yield of some genotypes and some of them revealed tolerance to drought, which suggested the genetic variability for drought tolerance in this material. The results derived through various analyses had made visible the most efficient genotypes among the forty eight genotypes undertaken in our study. These results have shown that index based selection is the most efficient method to achieve aggregate genetic progress with any other direct single trait selection method. Moreover, indexing via PCA selected traits would improve the reliability of selection.

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