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Evaluation of drought tolerance in backcross inbred lines of rice genotypes based on selection indices

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Abstract

Drought tolerant lines of Improved White Ponni (IWP) were developed by marker assisted back crossing of IWP with Apo. Three drought tolerant backcross inbred lines (BILs), developed by introgressing the drought tolerance QTLs from Apo were evaluated for drought tolerance along with their parents based on drought indices. Twenty drought indices were calculated based on grain yield under drought and irrigated conditions. Yield in drought and irrigated conditions were significantly and positively correlated with mean productivity index, harmonic mean, geometric mean of productivity and stress tolerance index. Ranking method and three dimensional plot discriminated IWP-4-2 as the most drought tolerant genotype, which was placed in group A (Genotypes, which performed good under drought and irrigated conditions), and outperformed the drought tolerant parent, Apo. IWP-4-2 possessed medium slender grains similar to the recurrent parent, IWP. Based on its drought tolerance and grain type IWP-4-2 can also be used as donor parent for developing climate resilient rice variety suitable to conditions obtaining in Tamil Nadu.

Key words: Rice, drought indices, ranking method, correlation analysis, grain type

Introduction

Rice is India's staple food consumed by more than half of the Indian population. India is the second leading producer of rice in the world. Drought is a major production constraint and frequently reduces the grain yield in rice growing areas around the globe. In the climate change scenario, dry spells can occur at any time during the rice growth period leading to drought stress of varying intensity both in upland and lowland cultivation. Breeding drought-tolerant rice is, therefore, an important goal for plant breeders. In rice, spikelet fertility is an important component of yield and it is highly sensitive to drought. Improving resilience to drought at reproductive stage is an important target (Richards et al. 2010).

Several experiments have been done to standardize the procedures for uniform screening of segregating populations under reproductive stage drought, considering grain yield as a selection criteria (Venuprasad et al. 2008). Moderate heritability of grain yield under drought confirms the suitability of grain yield as a selection criterion (Kumar et al. 2009). It was also reported that, in large mapping populations, the correlation of yield under drought and control condition was low but always positive (Kumar et al. 2008), suggesting the possibility of considering yield as a selection criteria to screen rice genotypes for drought tolerance. Also according to Richards (1996), selection for yield ultimately integrates all the known and unknown factors that contribute to drought tolerance.

In the state of Tamil Nadu, Improved White Ponni (IWP) is a very popular rice variety but it is sensitive to drought with yield reduction of upto 40 % under dry sown conditions (Subramanian et al. 2013). Hence, developing drought tolerant Improved White Ponni helps the state farmers to grow IWP in water limiting conditions. Therefore, a study was conducted to evaluate the drought tolerant ability of backcross inbred lines (BILs) derived by crossing drought susceptible Improved White Ponni with drought tolerant Apo, so that suitable genotypes can be developed for their utilization for breeding climate resilient rice varieties.

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Materials and methods

Plant material

The genetic material for the study consist of three back cross inbred lines (BC_1F_4) *viz.*, IWP-4-2, IWP-1-52, IWP-1-57 of Improved White Ponni, which were introgressed with QTLs for yield under drought located on chromosomes 2, 3 and 6 with combinations of QTLs originally derived from Apo, an *indica* cultivar in the genetic background of IWP. Three SSR markers namely, RM 240 (chromosome 2; 31.4 Mb), RM 520 (chromosome 3; 30.9 Mb), RM 3414 (chromosome 6; 2.8 Mb), exhibiting polymorphism between IWP and Apo were used for foreground selection of target QTLs *viz*., *qDTY 2.2, qDTY3.1* and *qDTY6.1* (QTLs for grain yield under drought stress), respectively. The BILs, IWP-1-57 and IWP-1-52 consist of two QTLs (*qDTY* 3.1+ *qDTY* 6.1) and the BIL IWP-4-2 consists of three QTLs (*qDTY* 2.2 + *qDTY* 3.1+ *qDTY* 6.1). The BILs were evaluated for their performance under both irrigated and drought conditions along with their parents.

Conduct of experiments

The experiment was conducted in rain out shelter facility at the Paddy Breeding Station, Tamil Nadu Agricultural University (TNAU), Coimbatore located at latitude of 11^o N and longitude of 77^o E and an altitude of 426.7 m above msl. Five genotypes were raised in randomized block design with four replications in a plot size of 1.44 m^2. Cultural practices were followed as per the TNAU crop production guide. Screening for drought tolerance was done at reproductive stage (Garrity and O'Toole 1994). Terminal drought stress was imposed by withholding the irrigation 25 days before heading. Soil moisture was recorded at 15 and 30 cm depth by gravimetric method at weekly intervals (Reynolds 1970). The moisture level in the field at which the observation were recorded are described here as under. The soil moisture steadily decreased from 85.0 per cent at 15 cm depth and 90.0 per cent at 30 cm depth. At harvest the soil moisture was 25 percent at both the depths.

Biometric observations and yield

At physiological maturity, five uniform plants were tagged per replication. For each plant, height was measured from the base to the tip of the plant. Simultaneously, total no. of tillers and total productive tillers were counted for the measured plants. After these observations, the same plant was sampled for biomass and grain yield. From the measured plant, primary and secondary panicles were sampled separately. After sampling the panicles, the remaining plant parts were sampled for biomass estimation. The dried plant parts was weighed and recorded as straw yield. The corresponding unthreshed primary panicle and secondary panicle were weighed separately and recorded. The sum of straw weight, unthreshed primary and secondary panicle weight constitute the total dry matter production (TDMP) (except root). The primary panicle and secondary panicle were subjected to threshing. Only the filled grains were retained. Grains from primary and secondary panicles were collected separately and weighed. The sum of primary and secondary panicles grain weight constitute the yield per plant. Likewise total dry matter production and yield of five plants per replication were recorded. The mean of five plants constitute the grain yield(g) per plant for replication. The mean grain yield(g) of four replications constitutes the yield per plant for the genotype.

Grain length, breadth and volume

Length, breadth and thickness of the brown rice were measured using digital Vernier caliper (Model: Shinwasokutei 19979, China). Brown rice shape was scored according to the scale given in Standard Evaluation System for Rice (SES) using length and L/B ratio (IRRI, 2014). Grain volume was measured using the formula given below:

Volume of ellipsoid (Cubic units) = $4/3\ \pi abc$

Where,

a = Length of the grain (mm); b = Breadth of the grain (mm) and c = Thickness of the grain (mm)

Drought indices and statistical analysis

The estimation of drought tolerant indices based on various methods are enumerated namely Yield index (YI) (Gavuzzi et al., 1997), Yield stability index (YSI) (Bouslama and Schapaugh, 1984), Relative Drought Index (Fischer and Maurer, 1978), Relative Efficiency (REI) (Hossain et al.,1990), Mean Relative Performance (MRP) (Hossain et al.,1990), Mean Productivity Index (MPI) (Hossain et al.,1990), Harmonic mean (HM) (Rosielle and Hamblin, 1981), Geometric Mean of Productivity (GMP) (Ramirez-Vallejo and Kelly, 1998), Stress Tolerance Index (STI) (Fernandez, 1992), Drought tolerance efficiency (DTE) (Fischer and Wood, 1981), Drought resistance Index (DI) (Blum A 1988), Stress Non-Stress Production Index (SNPI) (Moosavi et al., 2008), Drought Yield

Index (DYI) (Raman et al., 2012), Relative decrease Yield (RDY) (Ýlker, 2011), Drought susceptibility index (S) (Fischer and Maurer, 1978), Stress Susceptibility Index (SSI) (Fischer and Maurer,1978), Schneider's Stress Severity Index (SSSI) (Schneider et al., 1997), Stress Susceptibility Percentage Index (SSPI) (Moosavi et al., 2008), Stress Tolerance (TOL) (Rosielle and Hamblin, 1981) and Abiotic Tolerance Index (ATI) (Moosavi et al., 2008) were calculated using standard formulas. Y_s and Y_{ns} represent the mean yield of a genotype evaluated under drought and irrigated conditions, respectively

Analysis of variance (ANOVA), Pearson correlation between indices and grain yield in two conditions, cluster analysis, three-dimensional plots drawing were performed by SPSS ver. 20.

Results and discussion

Ranking method

Selection of drought tolerant genotype based on single index may be contradictory. To determine the most desirable drought tolerant genotype by considering all the calculated indices, mean rank, standard deviation of ranks and rank sum of all drought tolerant (Tables 1a and 1b) and drought susceptible (Tables 2a and 2b) indices were calculated and based on these two criteria the most desirable drought tolerant genotypes were identified. Ranking method was used to select drought tolerant genotypes in bread wheat (Farshadfar et al. 2012 a, b).spring canola (Khalili et al. 2012), maize (Naghavi et al. 2013) and rice (Abbasian et al. 2014). In all the previous studies drought tolerant and drought susceptible indices were ranked together to identify the drought tolerant genotypes based on rank sum. But in the present study the indices were grouped into two categories *viz.,* tolerant indices and susceptible indices. The tolerant genotype should have low rank sum in the drought tolerant indices; should have high rank sum among the drought susceptible indices. For the susceptible genotype this scenario is reversed. The BIL, IWP-4-2 recorded lowest rank sum of 1.64 among drought tolerant indices (Table 1b) and the second highest rank sum of 4.55 among the drought susceptible indices next to Apo (5.22) (Table 2b). The highest score of Apo among drought susceptible indices clearly reflects the drought tolerant ability of Apo. Under drought, yield reduction in Apo was 22.2 per cent, whereas IWP-4-2 had the yield reduction of 25.0 per cent. Although IWP-4-2 had higher yield reduction compared to Apo, the actual yield recorded

Table 1a. Drought Tolerant indices of rice genotypes under irrigated and drought conditions

Genotype	Y_{ns}	Y_s	YI	YSI	RDI	REI	MRP	MPI	HM	GMP	STI	DTE	DI	SNPI
IWP-4-2	20.16	15.11	0.84	0.75	1.13	1.41	2.38	17.63	17.23	17.43	0.93	74.82	0.95	32.71
IWP-1-52	17.53	11.28	0.62	0.64	0.97	0.91	1.91	14.40	13.66	14.03	0.61	64.24	0.62	22.27
IWP-1-57	19.06	12.99	0.72	0.68	1.03	1.15	2.14	16.03	15.39	15.70	0.76	68.00	0.75	26.50
IWP	19.64	9.62	0.53	0.49	0.74	0.87	1.89	14.63	12.91	13.74	0.58	48.94	0.39	17.43
Apo	14.04	10.92	0.60	0.78	1.17	0.91	1.99	15.48	13.28	14.38	0.67	77.84	0.71	23.79

Y_s and Y_{ns} represents the grain yield of all genotypes evaluated under drought stress and irrigated conditions. YI = Yield Index, YSI = Yield Stability Index, RDI = Relative Drought Index, REI = Relative Efficiency, MRP = Mean Relative Performance, MPI = Mean Productivity Index, HM = Harmonic mean, GMP = Geometric Mean of Productivity, STI = Stress Tolerance Index, DTE = Drought Tolerance Efficiency, DI = Drought Resistance Index and SNPI = Stress Non-Stress Production Index

Table 1b. Rank (R), rank mean (RM), standard deviation of ranks (SDR) and rank sum (RS) of drought tolerant indices

Genotype	Y_{ns}	Y_s	YI	YSI	RDI	REI	MRP	MPI	HM	GMP	STI	DTE	DI	SNPI	RM	SDR	RS
IWP-4-2	1	1	1	2	2	1	1	1	1	1	1	2	1	1	1.21	0.43	1.64
IWP-1-52	4	3	3	4	4	3	4	5	3	4	4	4	4	4	3.79	0.58	4.36
IWP-1-57	3	2	2	3	3	2	2	2	2	2	2	3	2	2	2.29	0.47	2.75
IWP	2	5	5	5	5	5	5	4	5	5	5	5	5	5	4.71	0.83	5.54
Apo	5	4	4	1	1	4	3	3	4	3	3	1	3	3	3.00	1.24	4.24

Y_s and Y_{ns} represents the yields of all genotypes evaluated under drought stress and irrigated conditions. YI = Yield Index, YSI = Yield Stability Index, RDI = Relative Drought Index, REI = Relative Efficiency, MRP = Mean Relative Performance, MPI = Mean Productivity Index, HM = Harmonic mean, GMP = Geometric Mean of Productivity, STI = Stress Tolerance Index, DTE = Drought Tolerance Efficiency, DI = Drought Resistance Index, SNPI = Stress Non-Stress Production Index, RM = Rank Mean, SDR = Standard Deviation of Ranks and RS = Rank Sum

Table 2a. Drought susceptibility indices of rice genotypes under irrigated and drought conditions

Genotype	Y_{ns}	Y_s	DYI	RDY	S	SSI	SSSI	SSPI	TOL	ATI
IWP-4-2	20.16	15.11	0.28	25.18	0.25	0.75	-0.09	13.96	5.05	57.30
IWP-1-52	17.53	11.28	0.33	35.76	0.36	1.06	0.02	17.28	6.25	56.97
IWP-1-57	19.06	12.99	0.31	32.00	0.32	0.95	-0.02	16.77	6.06	61.73
IWP	19.64	9.62	0.42	51.06	0.51	1.51	0.17	27.72	10.03	91.32
Apo	14.04	10.92	0.27	22.16	0.22	0.66	-0.12	8.64	3.13	25.77

Table 2b. Rank (R), rank mean (RM), standard deviation of ranks (SDR) and rank sum (RS) of drought susceptible indices

Genotype	Y_{ns}	Y_s	DYI	RDY	S	SSI	SSSI	SSPI	TOL	ATI	RM	SDR	RS
IWP-4-2	1	1	4	4	4	4	4	4	4	3	3.30	1.25	4.55
IWP-1-52	4	3	2	2	2	2	2	2	2	4	2.50	0.85	3.35
IWP-1-57	3	2	3	3	3	3	3	3	3	2	2.80	0.42	3.22
IWP	2	5	1	1	1	1	1	1	1	1	1.50	1.27	2.77
Apo	5	4	5	5	5	5	5	5	5	5	4.90	0.32	5.22

Y_s and Y_{ns} represents the grain yield of all genotypes evaluated under drought stress and irrigated conditions. DYI = Drought Yield Index, RDY = Relative Decrease Yield, S = Drought Susceptibility Index, SSI = Stress Susceptibility Index, SSSI = Schneider's Stress Severity Index, SSPI = Stress Susceptibility Percentage Index, TOL = Stress Tolerance, ATI = Abiotic Tolerance Index, RM = Rank Mean, SDR = Standard Deviation of Ranks and RS = Rank Sum

by IWP-4-2 was higher in both control and drought conditions. The best rank sum of IWP- 4-2 out of drought tolerant and drought susceptible indices was due to the higher yield of IWP-4-2 in control and drought conditions. Hence, IWP-4-2 has been identified as drought tolerant genotype among the back cross inbred lines and its performance was also superior compared to tolerant genotype, Apo.

Three dimensional plot

Three dimensional plot with STI, Y_{ns} and Y_s was used to group high yielding and drought tolerant genotypes in rapeseed (Yarnia et al. 2011) wheat (Drikvand et al. 2012 and Farshadfar, 2013), sunflower (Abdi et al. 2013) soybean (Kargar et al. 2014) maize (Kumar et al. 2015) and barley (Dorostkar et al. 2016). Three dimensional plot is presented to show the interrelationships among STI, Y_{ns} and Y_s and used to separate the cultivars of group A (high yielding genotypes in both irrigated and drought conditions) from the other groups (B, C and D) and to illustrate the advantage of STI index as selection criterion for identifying high-yielding and drought tolerant genotype (Fig. 1). In three dimensional plot, IWP-4-2 was included in group A, this genotype had stable grain

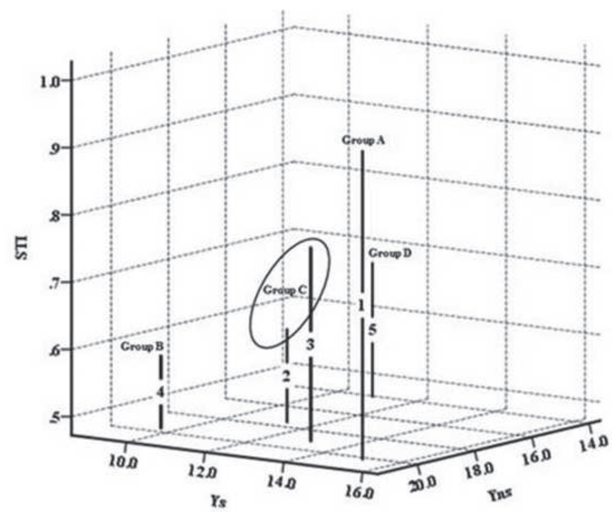

Fig. 1. The three dimensional plot between STI, Y_{ns} and Y_s. (1) IWP-4-2, (2) IWP-1-52, (3) IWP-1-57, (4) IWP and (5) Apo

yield in irrigated and drought conditions. IWP was included in group B, which had high yield in irrigated conditions but very poor in drought conditions. The backcross inbred lines, IWP-1-52 and IWP-1-57 were included in group C, which had yield advantage in drought conditions. The drought tolerant donor, Apo was placed in Group D because of low yield in both conditions, when compared with backcross inbred lines.

Cluster analysis

Cluster analysis showed that the genotype, based on indices tended to group into three groups (Fig. 2). In this analysis, the genotype IWP-1-52 and IWP-1-57 are placed in single cluster and has the rank sum of 4.36 and 2.75, respectively in the drought tolerant indices, 3.35 and 3.22 in drought susceptible indices and considered to be semi-tolerant. The genotype, IWP-4-2 and Apo are placed in single cluster and have the rank sum of 1.64 and 4.24, respectively in the drought tolerant indices; 4.55 and 5.22 in drought susceptible indices and considered to be tolerant. The genotype, IWP has the rank sum of 5.54 in the drought tolerant indices and has rank sum of 2.77 in drought susceptible indices and considered to be susceptible. The results obtained from cluster analysis were confirmed by three dimensional plots.

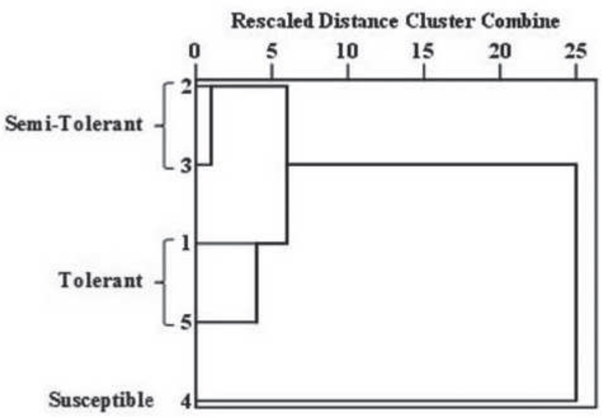

Fig. 2. Dendrogram using ward method between groups showing classification of cultivars based on tolerant/susceptible indices. (1) IWP-4-2, (2) IWP-1-52, (3) IWP-1-57, (4) IWP and (5) Apo

Correlation analysis

To determine the suitable drought tolerant/susceptible index for selection, correlation analysis was done between Y_{ns}, Y_s and drought tolerant (Table 3a), drought susceptible indices (Table 3b). A suitable index must have a significant correlation with grain yield (Mitra 2001). The indices which showed significant correlation with yield under irrigated and drought conditions can be used to evaluate genotypes of group A and D. The indices which showed significant correlation with yield under irrigated condition can be used to evaluate genotypes of group B in contrast to the indices which showed significant correlation with

Table 3a. Correlation coefficient between Y_{ns}, Y_s and drought tolerant indices

Indices	Y_{ns}	Y_s	YI	YSI	RDI	REI	MRP	MPI	HM	GMP	STI	DTE	DI	SNPI
Yns	1.000													
Ys	0.404	1.000												
YI	0.415	1.000**	1.000											
YSI	-0.474	0.610	0.602	1.000										
RDI	-0.465	0.620	0.611	1.000**	1.000									
REI	0.747	0.910*	0.915*	0.230	0.241	1.000								
MRP	0.787	0.882*	0.888*	0.168	0.179	0.998**	1.000							
MPI	0.894*	0.890*	0.817	0.032	0.044	0.980**	0.991**	1.000						
HM	0.890*	0.945*	0.949*	0.319	0.331	0.995**	0.987**	0.957*	1.000					
GMP	0.874*	0.892*	0.897*	0.187	0.198	0.999**	1.000**	0.988**	0.990**	1.000				
STI	0.895*	0.905*	0.910*	0.218	0.229	1.000**	0.999**	0.982**	0.994**	0.999**	1.000			
DTE	-0.477	0.609	0.600	1.000**	1.000**	0.228	0.166	0.030	0.318	0.185	0.216	1.000		
DI	0.044	0.931*	0.926*	0.857	0.863	0.697	0.650	0.541	0.761	0.665	0.688	0.857	1.000	
SNPI	0.217	0.978**	0.976**	0.756	0.762	0.810	0.771	0.678	0.859	0.782	0.803	0.754	0.984**	1.000

**Correlation is significant at the 0.01 level; *Correlation is significant at the 0.05 level. Y_s and Y_{ns} represents the grain yield of all genotypes evaluated under drought stress and irrigated conditions. YI = Yield Index, YSI = Yield Stability Index, RDI = Relative Drought Index, REI = Relative Efficiency, MRP = Mean Relative Performance, MPI = Mean Productivity Index, HM = Harmonic mean, GMP = Mean of Productivity, STI = Stress Tolerance Index, DTE = Drought Tolerance Efficiency, DI = Drought Resistance Index, SNPI = Stress Non-Stress Production Index

Table 3b. Correlation coefficient between Yns, Ys and drought susceptible indices

Indices	Y_{ns}	Y_s	DYI	RDY	S	SSI	SSSI	SSPI	TOL	ATI
Yns	1.000									
Ys	0.404	1.000								
DYI	0.441	-0.642	1.000							
RDY	0.477	-0.609	0.996**	1.000						
S	0.474	-0.610	0.995**	1.000**	1.000					
SSI	0.478	-0.608	0.996**	1.000**	1.000**	1.000				
SSSI	0.474	-0.610	0.995**	1.000**	1.000**	1.000**	1.000			
SSPI	0.638	-0.447	0.972**	0.980**	0.978**	0.980**	0.978**	1.000		
TOL	0.637	-0.447	0.972**	0.980**	0.978**	0.980**	0.978**	1.000**	1.000	
ATI	0.806	-0.214	0.885*	0.901*	0.899*	0.902*	0.899*	0.969**	0.969**	1.000

** Correlation is significant at the 0.01 level; *Correlation is significant at the 0.05 level; Y_s and Y_{ns} represents the yields of all genotypes evaluated under drought stress and irrigated conditions. DYI = Drought Yield Index, DRY = Relative Decrease Yield, S = Drought Susceptibility Index, SSI = Stress Susceptibility Index, SSSI = Schneider's Stress Severity Index, SSPI = Stress Susceptibility Percentage Index, TOL = Stress Tolerance and ATI = Abiotic Tolerance Index

yield under drought condition which can be used to evaluate genotypes of group C as was discussed by Fernandez (1992) in mung bean.

The drought tolerant indices, YI, REI, MRP, DI, and SNPI showed significant positive correlation with yield under drought (Y_s). YSI, RDI and DTE displayed non-significant negative correlation with yield under irrigated (Y_{ns}) conditions. MPI, HM, GMP, STI showed significant positive correlation (p >0.05) with yield under irrigated conditions (Y_{ns}) and drought (Y_s). Correlations have been recorded between Y_{ns} and MPI (r = 0.894), HM (r = 0.890), GMP (r = 0.874), and STI (r = 0.895) and the correlation between Ys and MPI (r = 0.890), HM (r = 0.945), GMP (r = 0.892), and STI (r = 0.905) (Table 3b). In the present study majority of the drought tolerant indices significantly associated with yield under stress rather than yield under control insisting the significance of performance under drought in the cumulative estimation of drought tolerant indices. Jafari et al. (2009) had also reported in maize that STI, GMP shown positive correlation with yield under drought (Y_s) and irrigated conditions (Y_{ns}). Similar results were also reported by Dorostkar et al. (2016) in barley.

All the drought susceptible indices had non-significant positive and negative correlation with yield under irrigated (Y_{ns}) and drought (Y_s) conditions respectively. Ehdaie and Shakiba (1996) reported that there was no correlation between stress susceptibility and yield under irrigated conditions in wheat. This explains the reducing influence of productivity potential as the susceptibility under drought.

Overall, MPI, HM, GMP and STI can be used to screen high yielding and drought tolerant genotypes as it showed significant positive correlation with yield under irrigated (Y_{ns}) and drought (Y_s) conditions. The observed relations between Y_{ns}, Y_s, MPI, HM, GMP, STI were consistent with those reported by Fernández (1992) in mungbean, Farshadfar and Sutka (2002a) in wheat, Farshadfar and Sutka (2002b) in maize, Golabadi et al. (2006) in durum wheat, Mehrabi et al. (2011) in maize and Farshadfar et al. (2012) in wheat landraces. In canola, positive correlation existed between Y_s, Y_{ns}, MPI and GMP (Toorchi et al. 2012), Y_s, Y_{ns}, MPI, GMP and STI (Khalili et al. 2012). MPI, GMP and STI were effective in selecting high yielding genotypes under drought and irrigated conditions in corn (Khayatnezhad and Gholamin, 2010) and wheat (Ýlker et al. 2011).

Grain type

The grains of back cross inbred lines were compared with the recurrent parent, IWP to select grain type similar to IWP. There exists a significant difference in the grain volume between the genotypes and treatments. The drought tolerant genotype has high grain filling under drought conditions (Pieters and Souki 2005). The IWP-4-2, which is identified as drought tolerant genotype compared to other genotypes show 9% reduction in grain volume under drought conditions, whereas IWP-1-52 and IWP-1-57 showed 11.3, 14.7 per cent reduction in grain volume under drought compared to irrigated conditions, respectively (Table 4) . The parents, IWP and Apo display 26.0, 18.6 per

Table 4. L/B ratio, Grain volume and 100g weight of rice genotypes grown in irrigated and drought conditions

	Genotype	Length	Breadth	Thickness	L/B ratio	Volume	100 grain weight	Shape
Irrigated	IWP-4-2	6.29^{a}	2.07	1.57^{b}	3.03	85.52^{b}	1.715^{d}	MS
	IWP-1-52	6.11^{c}	2.04	1.46^{c}	3.00	76.27^{d}	1.697^{d}	MM
	IWP-1-57	6.22^{ab}	2.05	1.53^{b}	3.04	81.42^{bc}	1.775^{c}	MS
	IWP	6.13^{e}	1.99	1.53^{a}	3.08	78.51^{cd}	1.696^{a}	MS
	Apo	5.50^{bc}	2.30	1.65^{b}	2.48	90.93^{a}	2.205^{d}	SM
Drought	IWP-4-2	6.25^{bc}	2.05	1.45^{c}	3.04	77.82^{cd}	1.399^{e}	MS
	IWP-1-52	6.10^{c}	2.04	1.30^{e}	2.99	67.66^{f}	1.270^{f}	MM
	IWP-1-57	6.11^{c}	1.98	1.37^{d}	3.09	69.48^{ef}	1.362^{e}	MS
	IWP	5.93^{f}	1.93	1.21^{b}	3.07	58.12^{de}	1.241^{b}	MS
	Apo	5.22^{d}	2.15	1.57^{f}	2.42	74.01^{g}	2.051^{f}	SM

L/B – Length breadth; MS - Medium slender; MM - Medium medium; SM - Short medium

cent reduction in grain volume under drought compared to irrigated conditions, respectively. The L/B ratio of genotypes does not show any significant difference between irrigated and drought conditions and the differences in 100 grain weight are due to the difference in length and thickness of rice grains. Based on length and L/B ratio, the BILs IWP-4-2 and IWP-1-57 were classified in to medium slender group which is similar to grain type of IWP. By considering the drought tolerance ability IWP-4-2 has been identified as a superior drought tolerant genotype among the back cross inbred lines with grain type similar to IWP. Among different drought tolerant/susceptible indices evaluated MPI, HM, GMP and STI had significant positive correlation with grain yield under irrigated and drought conditions indicating more suitability of these indices for selection of tolerant/susceptible genotypes. Although, Apo is drought tolerant as depicted in three dimensional plots between Yns, Ys and STI placed Apo in the group D because of low yield compared to BILs. The BILs, IWP-4-2, IWP-1-52 and IWP-1-57 outperformed Apo under drought. Based on the present study, IWP-4-2 is recommended to be used as parent for developing climate resilient medium slender rice varieties.

Authors' contribution

Coceptualization of research (DD, SR, AK); Designing of the experiments (DD, AK, MR, SR); Contribution of experimental materials (MR); Execution of field/lab experiments and data collection (DD); Analysis of data and interpretation (DD); Preparation of the manuscript (DD, SR).

Declaration

The authors declare no conflict of interest.

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