Received : 25 Mar 2019 | Revised : 04 Feb 2020 | Accepted : 06 Feb 2020

Electronic Journal of Plant Breeding

Research Article

Studies on indices and morphological traits for drought tolerance in rainfed rice (O*ryza sativa* L.)

S. Muthuramu* and T. Ragavan

Agricultural Research Station, Tamil Nadu Agricultural University, Paramakudi – 623 707.
Tamil Nadu, India.
***E-Mail:** smuthuramu@gmail.com

Abstract
The present experiment comprised of 48 rice genotypes was conducted to identify stress-tolerant genotypes under reproductive stage drought stress and controlled conditions during *Rabi* 2017-18. Drought tolerance indices like stress susceptibility index (SSI), drought tolerance efficiency (DTE), stress tolerance index (STI) and stress tolerance (TOL) and morphological traits responses were employed in screening of the genotypes. Significant yield reduction was observed under drought stress in the majority of the rice genotypes studied. Drought stress at reproductive stage caused a reduction in grain yield (51%), a number of panicles per square metre (15%), panicle length (13%), spikelet fertility (17%), plant height (9%) and harvest index (26%). The variation in SSI values ranged from 0.83 – 1.33, DTE from 36.90-66.67%, STI ranged from 0.39-1.02 and TOL varied from 0.98 -2.97. The genotypes with high DTE and STI and low SSI and TOL were identified as drought-tolerant genotypes. Based on screening, rice genotypes PM 17015 and PM 15048 showed low SSI and TOL and high DTE and STI values were identified as drought-tolerant genotypes. The present study indicates that selection based on stress tolerance indices likes DTE, SSI, STI and TOL will result in the identification of drought-tolerant genotypes for the rainfed ecosystem.

Keywords
Rainfed rice, water stress, drought tolerance indices, morphological and yield traits.

INTRODUCTION

Rice is one of the principal food crops and one-third of the world population and two-thirds of the Indian population is utilizing rice as a staple food. It contributes 43 per cent of caloric requirement and 20-25% of agricultural income. Rainfed rice accounts for around 45% of the world's rice area and around 40 million ha of the rainfed area is concentrated in South and South-East Asia alone (Maclean *et al*., 2002). Among the different stresses, drought is the single largest yield-reducing factor in rainfed areas of South and Southeast Asia, affecting more than 23 million ha area (Huke *et al*., 1997). Rice crop is highly sensitive to soil moisture deficit and high/low-temperature stresses at the reproductive stage. Losses due to reproductive-stage drought stress are most severe. Most of the high yielding varieties are highly susceptible to drought, particularly reproductive stage drought. The higher frequency and intensity of drought spells necessitates the development of rice cultivars, which are able to survive underwater deficit stress at the reproductive stage and quickly recover after the drought spells, by rapid growth upon improved availability of soil moisture (Kamoshita *et al*., 2008). Mean yield and relative yield performance under stressed and controlled environments are the most widely used criteria for selecting genotypes for stress-prone environments. Higher relative yield shows that the genotype performed relatively well under drought stress condition. The ability of crop cultivars to perform reasonably well in drought-stressed environments is paramount for stable production. The combination of high yield stability and high relative yield under drought has been proposed as useful selection criteria for characterizing genotypic performance under varying degrees of water stress (Pinter *et al*. 1990).

There are some indices to determine drought-tolerance *i.e.* stress tolerance level (TOL), stress tolerance index

(STI), stress susceptibility index (SSI) and drought-tolerance efficiency (DTE), which may be useful as an indicator to identify drought-tolerant genotypes that perform well in stress environments. These indices are yield stability parameters which are based on how much reduction are realized under drought-stress condition. Leaf rolling is one of the visible morphological responses to plant water deficit. It is an adaptive response to water deficit which helps in maintaining favorable water balance within plant tissues under conditions of water scarcity and depleting soil moisture. Plant recovery from desiccation in agricultural crops is primarily dependent on the capacity for maintaining higher relative water content during desiccation (Blum *et al*., 1999). In this context, the objective of the present study was to screen and identify rice genotypes having high yield potential and stability under drought stress conditions, particularly at the reproductive stage by analyzing drought tolerance indices and to investigate the effect of water stress on morphological traits associated with drought tolerance under rainfed condition.

MATERIALS AND METHODS

The experimental material comprised of forty-eight advanced rice cultures collected from various research institutes which were evaluated in an alpha lattice design with three replications at Agricultural Research Station, Tamil Nadu Agricultural University, Paramakudi during Rabi 2017-18. The experimental site is located at 9" 21' N latitude, 78" 22' E longitudes and an altitude of 242 m above mean sea level with an average annual rainfall of 840 mm. This site has clay loam soil texture with a pH of 8.0. The field experiments were conducted under stress (reproductive stage drought) and non-stress (irrigated) condition. The field was thoroughly prepared and levelled before transplanting. Twenty-five days old seedlings were transplanted at 20 x 15 cm spacing. In each plot a uniform plant stand was maintained and standard agronomic practices were followed for raising and maintenance of plants.

In non-stress experiments, standing water was maintained from transplanting to 20 days before maturity by providing water by rain or by supplementary irrigation as and when required. The reproductive stage drought-stress experiment was irrigated like the non-stress (control) experiments by keeping standing water up to 28 days after transplanting. Thereafter, the field was drained to allow them dry and for stress to develop. The drought-stress experiments were not provided with any supplemental irrigation after drainage until the susceptible checks showed permanent wilting. During the reproductive stage stress period soil moisture content was monitored through periodical soil sampling at 15 and 30 cm soil depth after suspension of irrigation. Water table depth was also monitored during the stress period. The drought scores, leaf rolling, leaf drying and stress recovery observations were taken as per SES method, 1 to 9 scales (IRRI, 1996). Observations of yield and yield contributing traits were recorded on ten randomly selected plants per genotype per replication. The relative yield (yield potential) under drought stress was calculated as the yield of specific genotypes under drought divided by that of the highest yielding genotype in the sample.

Several drought tolerance indices have been suggested on the basis of a mathematical relationship between yield under drought-stress and non-stressed conditions. Based on the mean grain yield across trials under stress and non-stress conditions, drought tolerance indices including stress tolerance level (TOL), stress tolerance index (STI), stress susceptibility index (SSI), drought tolerance efficiency (DTE) were calculated. Rosielle and Hamblin (1981) defined stress tolerance (TOL) as the differences in yield between the stress and non-stress environments, *i.e.,* TOL= (Yi)NS - (Yi)S. Let (Yi)S and (Yi)NS denote the yield of the ith genotype under stress and non-stress (irrigated) condition, respectively. The higher value of TOL indicates the susceptibility of a given genotype. Fernandez (1992) defined a stress tolerance index (STI) as STI = [(Yi)NS*(Yi)S] /(YNS)2, which can be used to identify genotype that produces high yield under both stress and non-stress conditions. A high value of STI implies higher tolerance to drought stress. Fischer and Maurer (1978) proposed stress susceptibility index (SSI), which assesses the reduction in yield caused by unfavourable (stress) compared to favourable irrigated environments SSI is expressed as SSI = [1- ((Yi)S / (Yi) NS] / SI.
SI, the stress intensity is estimated as SI = 1- (YS/YNS). YS and YNS denote the mean yield of all genotypes evaluated under stress and non-stress environments, respectively. Lower SSI values indicate a lower difference in yield across stress level, in other words, more tolerance to drought. SSI has often been used for identifying genotypes with yield stability in moisture limited environment (Puri *et al*., 2010; Raman *et al*., 2012). Drought tolerance efficiency (DTE) is estimated by the equation of Fischer and Wood (1981). According to this equation: DTE (%) = (Yield under stress /Yield under non-stress) * 100. The higher value of DTE indicates higher drought tolerance ability of genotypes.

RESULTS AND DISCUSSION

The results related to yield attributes of promising rice genotypes under drought stress at the reproductive stage and irrigated condition, as well as morphological reaction under drought stress, has been presented in **Table 1**. Rice genotypes grown under water stress condition produced significantly lower grain yield than irrigated condition. Yield decline was observed almost in all the rice genotypes grown under drought stress condition. The range of yield decline was 1.21 to 3.17 t ha^{-1} under water stress condition in comparison with non-stress (irrigated) condition. Genotype means yields ranged from 3.34 t ha^{-1} to 4.98 t ha^{-1} under non-stress irrigated condition and from 1.85 t ha^{-1} to 3.23 t ha^{-1} under stress condition. The reduction in yield between drought-stressed and control treatment ranged between 33 and

69%. Ouk *et al.,* (2006) and Kumar *et al.,* (2014) reported 12 to 46% and 29 to 78% respectively reduction in grain yield under drought stress. Out of 48 rice genotypes evaluated, 14 were identified as promising genotypes which performed better than check variety Anna (R) 4. The difference in grain yield between drought stress and non-stress treatment was 35 % in PM 15048 and 33% in PM 17015 whereas it was 51 % in TM 13018, 50% in TM 12039 and 37% in Anna (R) 4. Under non-stress condition, maximum grain yield was observed in PM 15048 (4.98 t ha^{-1}) followed by TR 15053 (4.90 t ha^{-1}) and TR 09030 (4.89 t ha^{-1}).

In general, across genotypes a slight but non-significant delay in fifty per cent flowering was observed under water stress condition as compared to non-stress irrigated situation; however, the responses varied among genotypes. A similar finding was also reported by Kumar *et al*., (2009). Significant decrease in plant height was also observed in rice genotypes grown under drought stress condition. The Similar trends were also observed for the number of panicles per square metre area, panicle length and harvest index. Drought tolerant genotypes CB 14530 (87.7%) followed by PM 15048 (87.3%) and PM 17026 (86.7%) showed high per cent spikelet fertility than susceptible lines and check variety, which is similar to findings reported by Garrity *et al.* (1994) and Kumar *et al*., (2014). This result suggests that spikelet fertility is a reliable parameter for the screening of genotypes for yield response subjected to water deficit stress at the reproductive stage. Depletion of soil moisture during the reproductive stage increased the per cent spikelet sterility, which may result in decreased grain yield under stress condition.

Significant variations were observed among genotypes for drought tolerance parameters leaf rolling, leaf drying and stress recovery. Drought tolerant genotypes *viz.,* PM 17026 and TR 05031 had lesser leaf rolling, leaf drying and better stress recovery (**Table 1**), as well as delayed leaf, rolling and drying. Leaf rolling was induced by the loss of turgor and poor osmotic adjustment in rice and delayed leaf rolling is an indication of turgor maintenance and dehydration avoidance (Blum, 1989). Beena *et al.,* (2012) and Kumar *et al.,* (2014) also reported similar results in rice.

Table 1. Yield and yield attributes of promising rice genotypes and check variety in drought stress and irrigated condition and morphological reaction under reproductive stage drought stress.

S. No.	Promising lines	DFF		PH (cm)		NPSM		PL (cm)		SF (%)		HI		GY (t/ha)		Morphological reaction under drought stress		
		DS	IC	DS	IC	DS	IC	DS	IC	DS	IC	DS	IC	DS	IC	LR	LD	SR
1	PM 15048	78	75	78	85	275	304	18.5	20.3	87.3	94.1	0.41	0.47	3.23	4.98	1.3	1.7	6.7
2	PM 17015	81	83	76	85	249	278	18.8	19.9	83.2	92.6	0.36	0.43	3.10	4.65	1.3	1.7	6.3
3	PM 17026	81	78	74	88	228	245	18.7	20.1	86.7	94.3	0.37	0.46	3.03	4.87	1.0	1.3	6.7
4	TR 05031	93	90	95	112	249	283	20.9	21.9	82.5	90.9	0.38	0.43	3.00	4.59	1.0	1.7	6.7
5	TR 09030	80	76	94	110	251	278	18.0	18.3	85.9	93.7	0.37	0.45	2.97	4.89	1.7	2.3	6.3
6	TR 13069	79	75	91	107	224	240	17.9	18.7	84.5	91.8	0.35	0.42	2.93	4.75	2.0	2.0	5.7
7	TR 15053	84	78	87	91	265	290	18.1	19.0	85.1	93.3	0.38	0.46	2.90	4.90	2.3	3.3	5.7
8	IET 25106	84	81	98	102	221	234	19.9	21.4	83.0	91.9	0.36	0.44	2.83	4.61	3.0	3.7	4.7
9	PM 14042	80	77	74	90	265	287	18.5	20.1	81.3	93.1	0.33	0.42	2.83	4.86	3.0	3.7	4.7
10	CB 14530	93	90	90	110	234	260	19.5	21.7	87.7	95.9	0.39	0.47	2.80	4.87	3.7	3.0	7.0
11	CB 14756	93	91	97	112	220	250	19.0	20.5	85.7	94.3	0.40	0.47	2.67	4.73	4.3	4.3	5.7
12	TM 12039	89	86	95	109	235	254	18.3	19.7	83.1	92.7	0.35	0.44	2.63	4.85	4.3	2.7	5.7
13	TM 12077	84	83	88	98	215	225	19.0	19.3	83.2	93.1	0.39	0.48	2.40	4.76	3.0	3.0	6.3
14	TM 13018	85	81	91	101	213	230	19.7	20.1	82.7	92.3	0.38	0.43	2.37	4.81	3.7	4.3	6.3
15	Anna(R)4	84	82	71	83	178	198	17.3	18.1	78.3	89.6	0.32	0.41	2.30	3.70	4.3	4.3	4.7
	Check Mean	89	81	87	103	177	213	15.9	19.2	73.7	91.7	0.31	0.39	2.39	3.98	3.8	4.0	5.0
	CV	1.51	1.73	4.53	4.23	7.56	8.72	7.37	4.89	9.45	7.52	7.27	8.52	9.75	6.67	5.67	6.90	4.3
	LSD (5%)	2.15	2.35	8.40	9.62	6.23	9.34	0.92	1.05	2.10	1.94	0.03	0.05	0.24	0.35	0.15	0.13	0.57

Note: DS – Drought Stress; IC-Irrigated Condition; DFF-Days to 50% Flowering; PH-Plant Height; NPSM-Number of panicles per square metre area;
PL-Panicle Length; SF-Spikelet Fertility; HI-Harvest Index; GY-Grain Yield; LR-Leaf Rolling; LD-Leaf drying and SR-Stress Recovery.

The drought tolerance indices and relative yield for reproductive stage drought stress are presented in **Table 2.** A significant difference was observed between the mean grain yield of control and stress condition for all entries which implies that the performance under stress and non-stress was considerably different. PM 15048 ranked first in cases of REI, MPI, MRP and STI. Lowest TOL value (1.40) recorded surprisingly in check variety Anna(R)4 followed by PM 17015 (1.55), TR 05031 (1.59) and PM 15048 (1.75) whereas TM 13018 showed its higher value (2.44). The lower value of TOL (stress tolerance) indicates the high-stress tolerance ability of a given cultivar. Similar findings were reported by Raman *et al.,* (2012) and Kumar *et al*., (2014). Stress susceptibility index assesses the reduction in yield caused by unfavorable environment compared to a favorable

environment. Lower SSI values indicate the lower differences in yield between non-stress and stress condition, in other words more tolerance to drought. SSI is a measure of yield stability. PM 17015 recorded lowest SSI value of 0.83, followed by TR 05031 (0.87) and PM 15048 (0.88) whereas TM 13018 showed its higher value (1.27). Timing of drought stress in relation to the development of different genotypes or lack of adaptation to unfavorable environments could be other possible reason for variation in SSI. The results of this study are in good agreement with the earlier finding (Prakash, 2007; Raman *et al.*, 2012; Kumar *et al.,* 2014). Genotypes with low SSI values (less than 1) can be considered to be drought resistant (Chauhan *et al.,* 2007) because they exhibited smaller yield reductions under water stress compared with well-watered conditions. Based upon the value and direction of desirability, the ranking was done for different genotypes as highly drought-tolerant (SSI < 0.50), drought-tolerant (SSI: 0.51-0.75), moderately drought tolerant (SSI: 0.76-1.00) and drought susceptible (SSI > 1.00). On the basis of SSI index, nine genotypes out of 48 genotypes were identified as drought-tolerant rice genotypes (SSI<1) while, rest of the genotypes were susceptible (SSI>1) for grain yield. An overall appraisal revealed that PM 17015 possessed a high level of drought tolerance (**Table 2**). Drought indices TOL and SSI ensure genotypes with good yield under drought stress condition. Therefore, they are more useful for identifying genotypes that perform well in a stressful environment.

Stress tolerance index (STI) was used to identify genotypes that produce high yield under both drought stress and non-stress irrigated condition. A high value of STI implies higher tolerance to stress. Rice genotype PM 15048 showed the highest value of STI (1.02). With respect to STI drought index, PM 15048, PM 17026, TR 09030, PM 17015 and TR 15053 were the top five performing rice genotypes under stress condition. Drought tolerance efficiency (DTE) is a measure of drought resistance mechanisms and determines the consistency of selected genotypes in response to drought stress having of different severity, timing and duration and thus may be helpful in identifying genotypes that possess drought resistance capability in rainfed lowland ecosystem of rice. Highest DTE value for grain yield was recorded in PM 17015 (66.67%) followed by TR 05031 (65.36%) and PM 15048 (64.86%).

The mean relative grain yield values under drought stress and non-stress irrigated treatments were 0.81 and 0.93, respectively (**Table 2**). Mean relative yield in case of water stress was less than that non-stress irrigated. Drought tolerant genotypes *viz.* PM 15048, PM 17015, PM 17026, TR 05031 and TR 09030 showed relatively high yield under water stress (RY > mean RY), while Anna(R)4, TM 13018 and TM 12077 were relatively low yielding (RY < mean RY) in this treatment. This was in agreement with the results of Kumar *et al.,* (2014).

Table 2. Grain yield and drought tolerance indices of promising rice genotypes and check variety in drought stress and irrigated condition.

S.No.	Promising lines	GY (t/ha)		RY_C	RY_S	REI	MPI	MRP	TOL	STI	SSI	DTE
		IC	DS									
1	PM 15048	4.98	3.23	1.00	1.00	1.69	4.11	2.60	1.75	1.02	0.88	64.86
2	PM 17015	4.65	3.10	0.93	0.96	1.52	3.88	2.47	1.55	0.91	0.83	66.67
3	PM 17026	4.87	3.03	0.98	0.93	1.55	3.95	2.49	1.84	0.93	0.94	62.22
4	TR 05031	4.59	3.00	0.92	0.92	1.45	3.80	2.41	1.59	0.87	0.87	65.36
5	TR 09030	4.89	2.97	0.98	0.91	1.53	3.93	2.47	1.92	0.92	0.98	60.74
6	TR 13069	4.75	2.93	0.95	0.90	1.46	3.84	2.42	1.82	0.88	0.96	61.68
7	TR 15053	4.90	2.90	0.98	0.89	1.49	3.90	2.44	2.00	0.90	1.02	59.18
8	IET 25106	4.61	2.83	0.92	0.86	1.37	3.72	2.34	1.78	0.82	0.97	61.39
9	PM 14042	4.86	2.83	0.98	0.86	1.45	3.85	2.41	2.03	0.87	1.04	58.23
10	CB 14530	4.87	2.80	0.98	0.85	1.43	3.84	2.40	2.07	0.86	1.06	57.49
11	CB 14756	4.73	2.67	0.95	0.79	1.33	3.70	2.31	2.06	0.80	1.09	56.45
12	TM 12039	4.85	2.63	0.97	0.77	1.34	3.74	2.32	2.22	0.81	1.14	54.23
13	TM 12077	4.76	2.40	0.95	0.65	1.20	3.58	2.20	2.36	0.72	1.24	50.42
14	TM 13018	4.81	2.37	0.96	0.64	1.20	3.59	2.20	2.44	0.72	1.27	49.27
15	Anna(R)4	3.70	2.30	0.65	0.60	0.89	3.00	1.89	1.40	0.54	0.95	62.16
	Check											

Note: GY-Grain Yield; DS – Drought Stress; IC-Irrigated Condition; RY_C – Relative Yield under control; RY_S – Relative Yield under Stress; REI – Relative Yield Index; MPI- Mean Productive Index; MRP- Mean Relative Performance TOL – Stress Tolerance Level; STI- Stress Tolerance Index; SSI- Stress Susceptibility Index and DTE – Drough Tolerance Efficiency.

From this study, it was concluded that moisture stress imposed during reproductive stage significantly reduced rice yield in all genotypes. The differential responses of genotypes to imposed water stress condition indicate the drought tolerance ability of rice genotypes. This study also indicated that selection based on drought tolerance indices DTE, SSI, STI and TOL will result in the identification of drought-tolerant genotypes with a

significantly superior and stable performance of yield and yield attributes under water stress condition in rainfed lowland drought-prone ecosystem. PM 17015 and PM 15048 showed high DTE and STI values and low SSI and TOL values, identified as high yielding drought-tolerant genotypes. They showed the highest yield under the normal irrigated condition and good yield under drought condition through better maintenance of internal water balance under drought stress situation. These drought-tolerant rice genotypes can be adopted in the large area in a rainfed lowland ecosystem where drought is frequent.

REFERENCES

Beena R., Thandapani V. and Chandrababu R. 2012. Physio-morphological and biochemical characterization of selected recombinant inbred lines of rice for drought resistance. *Indian J. Plant Physiol.* **17(2)**: 189-193.

Blum A. 1989. Osmotic adjustment and growth of barley cultivars under drought stress. Crop Sci. **29**: 230-233.

Blum A., Mayer J., Golan G. and Sinmera B. 1999. Drought tolerance of a doubled- haploid line population of rice in the field. In: Genetic improvement of rice for water limited environment. Ito, P., O'Toole, J.C. and Hardy, B. (ed.). IRRI, pp. 319-330.

Chauhan J.S., Tyagi M.K., Kumar A., Nashaat N.I., Singh M., Singh N.B., Jakhar M.L. and Welham S.J. 2007. Drought effects on yield and its components in Indian mustard (*Brassica juncea* L.). Plant Breeding **126**: 399-402

Fernandez G.C.J. 1992. Effective selection criteria for assessing plant stress tolerance. In: Kus EG (ed) Adaptation of Food Crop Temperature and Water Stress. Proceeding of 4th International Symposium, Asian Vegetable and Research and Development Center, Shantana, Taiwan, pp 257–270.

Fischer K.S. and Wood G. 1981. Breeding and selection for drought tolerance in tropical maize. In: Proc. Symp. on Principles and Methods in Crop Improvement for Drought Resistance with Emphasis on Rice, IRRI, Philippines.

Fischer R.A. and Maurer R. 1978. Drought resistance in spring wheat cultivars. I. Grain yield responses in spring wheat. Australian. J. Agric. Sci. **29**: 892-912.

Garrity D.P. and Toole J.C. 1994). Screening rice for drought resistance at the reproductive phase. Field Crop Res. **39:**99-110.

Huke R.E. and Huke E.H. 1997. Rice Area by Type of Culture: South, Southeast and East Asia. International Rice Research Institute, Los Banos, Philippines.

International Rice Research Institute.1996. Standard Evaluation System for Rice, International Rice Research Institute, Los Banos, The Philippines, 4th Edn.

Kamoshita A., Babu R.C., Boopathi N.M. and Fukai S. 2008. Phenotypic and genotypic analysis of drought-resistance traits for development of rice cultivars adapted to rainfed environments. Field Crop Res. **109**: 1-23

Kumar A., Verulkar S., Dixit S., Chauhan B., Bernier J., Venuprasad R., Zhao D. and Shrivastava M.N. 2009. Yield and yield-attributing traits of rice (*Oryza sativa* L.) under lowland drought and suitability of early vigour as a selection criterion. Field Crop Res. **114**: 99-107.

Kumar S., Dwivedi S.K., Singh S.S., Jha S.K., Lekshmy S., Elanchezhian R., Singh O.N. and Bhatt B. P. 2014. Identification of drought tolerant rice genotypes by analysing drought tolerance indices and morpho-physiological traits. SABRAO J. Breed. and Genet.**46 (2)**: 217-230.

Maclean J.L., Dawe D.C., Hardy B. and Hettel G.P. (eds.) 2002. Rice almanac (third Edition), Philippines, IRRI, WARDS, CIAT and FAO.

Ouk M., Basnayake J., Tsubo M., Fukai S., Fischer K.S., Cooper M. and Nesbitt H. 2006. Use of drought response index for identification of drought tolerant genotypes in rain-fed lowland rice. Field Crop Res. **99**: 48-58.

Pinter Jr P.J.G., Zipoli R.J., Reginato R.D., Jackson, Idso S.B. Idso. 1990. Canopy temperature as an indicator of differential water use and yield performance among wheat cultivars. Agric Water Manag. **18**: 35– 48.

Prakash V. 2007. Screening of wheat (*Triticum aestivum* L.) genotypes under limited moisture and heat stress environments. Ind J. Genet. **67 (1)**: 31-33.

Puri R.R., Khadka K. and Paudyal A. 2010. Separating climate resilient crops through screening of drought tolerant rice land races in Nepal. Agronomy J Nepal. **1**:80-84.

Raman A., Verulkar S., Mandal N.P., Varrier M., Shukla V.D., Dwivedi J.L., Singh B.N., Singh O.N., Swain P., Mall A.K., Robin S., Chandrababu R., Jain A., Ram T.R., Hittalmani S., Haefele S., Piepho H.S. and Kumar A. 2012. Drought yield index to select high yielding rice lines under different drought stress severities. Rice: **5(31)**: 1-12.

Rosielle A.A. and Hamblin J. 1981. Theoretical aspects of selection for yield in stress and non-stress environment. Crop Sci. **21**: 943–946.