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Analysis of yield stability of rice (*Oryza sativa* L.) landraces under drought conditions with three different approaches

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Abstract

A set of sixty landraces along with checks were taken from core group of rice germplasm was studied stability of the genotypes under water stress condition following three different statistical approaches. The three analytical measures of stability namely, Eberhart and Russel model, Yield Index and Drought Susceptibility Index identified only four genotypes *viz*., Jhitpiti, Angurguchcha, E-1702 and Elayachi (PMBB) with stable mean performance in irrigated, rainfed and terminal stage drought (TSD) condition over two years. Drought intensity index showed high degree of stress in rainfed and TSD conditions. Hence, these four genotypes are said to be stable genotypes under all the three conditions. The four promising genotypes with high genetic stability and stable yield under diverse environments may prove useful in rice breeding programs for enhancing the yield under water stress conditions.

Key words: Rice, stability, rainfed, yield index, DSI

Introduction

Rice (*Oryza sativa* L.) is the grain foodstuff which frames a vital place among three billion individuals eating rice around the globe. It has molded the way of life, diets, and economies of thousands of people world over. The conceivably yielding capacity at present of accessible rice assortments must be expanded twice by 2020, to take care of the current demand by using profitable yield and qualities containing protection from the biotic and abiotic stress. Drought and high temperatures are expected to become more frequent due to climatic changes that may affect the yield in future agriculture.

A large proportion of farm land is utilized for production of paddy which leads Chhattisgarh to top ten rice producing states of India. The rice germplasm collected from different places and over 20,000 rice germplasm have been prevailing in the state. Diverse rice germplasm have been found to sustain optimal growth in different environmental conditions like the variety of soil and amount of water present in the field. The presently available biodiversity has showed a significant role in the growth of not only rice but other crops too. About 80% of populaces in the state are provincial and the principal control of the villagers is rice agribusiness. The atmosphere is ideal for the development of rice and the yield fundamentally relies on the water, which is satisfied by the south-west storm and rest is from water system of rivers namely, Mahanadi, Shivnath, Pairi, Sodhur, Jonk, Kelo and Indravati. Besides, temperature increase and drought incidences, which adversely affect spikelet sterility and accumulation of assimilates, rice is highly prone to water stress during the reproductive stage, leading to significant decrease in grain yield and therefore, developing drought tolerant rice varieties is often challenging because of the complexity of drought (Korres et al. 2017).

The response of the crops to varying environments will depend on the phenology, crop variety, and growth stage of the crop species. Different physiological responses of genotypes across environments are the main challenge facing plant breeders. This is termed as genotype-environment interaction (G x E) (Comestock and Moll 1963). Significant G × E interaction indicates that all phenotypic responses of genotypes to varying agro-ecological conditions are not consistent. These would

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be due to rank change of the genotypes from location-to-location and/or from year-to-year. G x E interactions have greater importance in plant breeding as they reduce the stability of genotypic values under diverse environments (Zewdu et al. 2020).

To identify stable genes and yield of the grain under different environment conditions has been analyzed by Acuña et al. (2008) in backcross lines of rice in upland condition. But Bose et al. (2012) found that genotypic and environmental interactions often contribute to the germplasm line stability. Another methodology involves the usage of regression coefficients to determine stability by Eberhart and Russell (1966), and the stable variety can be screened by using the obtained unit regression coefficients, minimum deviation from regression and high grand mean yield which can be further utilized for cultivating in several environmental conditions and attaining high yield. To increase commercial cultivation over a wide range of agro-climatic conditions in Chhattisgarh, stable crop varieties are needed. Stability analysis has been used by many researchers to decide whether the performance of the genotype is satisfactory? Stability and adaptation studies are useful for releasing a genotype to cultivate in wide range of environments (Shrestha et al. 2020). Therefore, the main objective of this study is to assertion the degree of genetic stability and environmental acclimatization of some rice germplasm using three different stability analysis through different statistical procedures.

Materials and methods

Sixty landraces along with six checks of rice available Chhattisgarh were selected for this study. Nurseries were raised and twenty-one days old seedlings of both the *kharif* seasons of 2017 and 2018 were subsequently transplanted in the field, in Randomized Block Design (RBD) with two replications. The row-to-row and plant-to-plant spacing of 25cm×25cm was maintained with net plot size of 3 m x 1.5 m. The crop was maintained under three conditions that is irrigated, rainfed and terminal stage drought (TSD).

Statistical analysis

Analysis of variance of genotypic mean was computed for yield and its component traits in each condition. The data were pooled over environments as the coefficients of variation values in each environment were generally low. The stability model proposed by Eberhart and Russell (1966) was implemented to analyze the data over six conditions (environment). The model includes the assessment of stability parameters like mean, regression coefficient (b_i) and deviation from regression (S^2d_i). Analysis was done by using SPAR 2 software. Stability parameters and their estimation was carried out by subjecting the data to the condition that G × E interaction is significant when tested against pooled error the stability parameter are figured. The yield index has been calculated by using mean of all the environment of grain yield (Table 4). It is based on the mean value and standard error of each of the genotype as well as the condition, a new mean value is calculated for each of the genotype and ranking is done on the basis of new mean value, top ranking is given to the genotype having highest mean yield index.

The measure of yield stability (DSI) and relative yield potential were calculated from mean yield. DSI (Fischer and Maurer 1978) was as DSI = (1-Yd/Yw)/D where Yd = mean yield under drought, Yw = mean yield under transplanted/aerobic conditions, and D = environmental stress intensity = 1-(mean yield of all genotypes under drought/mean yield of all genotypes under transplanted conditions). The relative yield under drought was calculated as the yield of a specific genotype under drought divided by that of the highest yielding genotype in the population.

Results and discussion

Stability by Eberhart and Russell model

The present investigation was carried out to evaluate sixty landraces of rice including checks in three different conditions namely, irrigated, rainfed and TSD and over two seasons, *kharif* 2017 and *kharif* 2018. Estimation of the performance of the genotypes for grain yield over the location and over the years were done using appropriate methodology. The pooled analysis of variance for stability of grain yield in rice over three different conditions is given in Table 1. Pooled analysis of variance showed that the mean square difference among the genotypes and the environment were highly significant for grain yield. It indicated the presence of high degree of variability among the sixty selected landraces as well as different environments. Variance due to genotype x environment was highly significant which encouraged for further analysis to be performed to estimate stability parameters. Genotype x environment (G x E) interaction arises when different genotypes react differently to the different environments and are paramount in the identification and development of genotypes that perform well over a wide range of growing conditions (Malosetti et al. 2013; Dou et al. 2016). It also indicated that the genotypes interacted considerably with the environmental condition for grain yield. The sum of squares due to Environment + Genotype x Environment was portioned into environment (Linear), Genotype x Environment (Linear) and the remaining part was distributed to the residue called pooled deviation. The pooled deviation is further partitioned into component associated with genotypes. The significant of different effects was tested by variance ratio as per Eberhart and Russell (1966).

The linear component of environment was found to be highly significant for grain yield. The environment x genotype (linear) interaction also exhibited significant difference in grain yield. Non-linear components of G x E interaction were found to be significant for grain yield as indicated by highly significant mean square due to G x E (linear) interaction and pooled deviation. Above results showed significant differences among the genotypes studied for linear response to environment. The result of ANOVA in present study is similar to the results obtained by different researchers (Ghrilahre and Sarial 2011; Krismawati et al. 2013; Jain et al. 2018). The existing variability may be due to the variability in topography; soil types, fertility and organic matter turn over, soil nutrient dynamics, water regime, nutrient cycle, nutrient availability and uptake (Sandhu et al. 2019).

Table 1. Pooled analysis of variance and stability parameters for grain yield

Source	df	MSS
Genotype	59	99625.04**
Environment	2	7239709.28**
Genotype X Environment	118	8229.61**
Environment +Genotype x Environment	120	128754.27**
Environment (Linear)	1	14479418.57**
Genotype X Environment (Linear)	59	15191.27**
Pooled deviation	60	1246.82**
Pooled Error	180	1683.024
Total	179	

Eberhart and Russell (1966) defined a stable variety as one which shows high mean yield, regression co-efficient (b_i) around unity and deviation from regression near to zero. In the stability parameters of sixty rice landraces, three parameters *viz*., grand mean over environment, the regression coefficient (bi) and the squared deviation from the regression are considered to be important. The regression coefficient around unity and deviation from regression around zero indicate that the selected rice genotypes possessing these attributes are stable over different conditions.

The statistical analysis identified, Jhitpiti, Angur Guchcha, E-1702, Muni Bhog, Elayachi (PMBB), Bodi, Silipat, Baisur, Kotte (II), Danwar and Bhainsa Punchhi landracers with high genetic stability and unrivaled form under all environments (Table 2). The results obtained in present study are supported by earlier reports of stability analysis carried out in upland and basmati rice under diverse environments (Mosavi et al. 2012; Lakew et al. 2014; Seyou et al. 2016; Sadimantara et al. 2018) adopting different approaches. All these researchers have emphasized on the importance of genetic stability with high value and the efficiency associated with high yield and widespread environmental acclimatization.

Genotypes with high mean, b_i=1 with non-significant S^2d_i are suitable for general adaptation *i.e.* suitable for over all the environmental conditions and they are considered as stable genotypes. The computed data indicated that on comparing with check variety MTU-1010 none of the genotype was found stable whereas on comparing with the grand mean (326.23 g/m^2) genotypes Jhitpiti, Angur Guchcha, E-1702, Muni Bhog, Elayachi (PMBB), Bodi, Silipat, Baisur, Kotte (II), Danwar and Bhainsa Punchhi had higher mean with regression coefficient (b_i) around unity (1) with non-significant S^2d_i. Hence, they performed stable in all the three condition i.e., irrigated, rainfed and TSD, during both the years (Table 3).

The genotypes with high mean, bi >1 with non-significant S^2di are considered as below average in stability such genotypes tend to respond favorably to better environments but give poor yield in unfavorable conditions. Hence, they are suitable for favorable environments (irrigated). On comparing with the check variety MTU 1010, only genotype Chapti gurmatia is found stable, because it has higher mean than the check variety, the squared deviation from the regression is non-significant but, the value of regression coefficient is more than one, so genotype Chaptigurmatia performs stable only for favorable irrigated condition. On the basis of the grand mean (326.23 g/m^2) checks, IR64, Swarna, R-RF-75 and Danteshwari are highly responsive and genotypes, IR

Table 2. Estimate of different stability parameters for grain yield

S. No.	Genotype	Mean	Regrassion coefficient (bi)	Stability parameter (S^2_{di})
35	Chaptigurmatia	478.69	1.4995**	-292.1641
56	MTU-1010	477.50	1.5952**	776.3661
57	IR64	447.74	1.5089**	928.4462
59	IGKV R1	426.37	1.5329**	5120.49*
55	Swarna	413.08	1.6302**	684.1777
29	IR 42253	396.37	1.3793**	2044.2353
58	R-RF-75	392.71	1.3349**	-1109.2819
32	Jhitpiti	392.60	1.0721**	3177.1365
25	Sonapan	382.28	1.4155**	-1100.8109
60	Danteshwari	379.82	1.1902**	-519.7267
9	Angur Guchcha	378.68	1.0605**	-857.3761
7	Kohaka	367.41	1.1727**	-879.6861
27	Cross 116	367.04	1.3146**	-1017.8275
14	PeeleeLuchai	365.67	1.2722**	-657.84
20	Bylao	365.02	1.1791**	-1030.8512
34	E-1702	360.39	0.9848**	-1099.2952
45	Muni Bhog	355.29	0.9806**	353.3202
43	Elayachi	354.27	0.9258**	-1109.4056
36	Elayachi	347.41	0.8516**	1716.1736
37	Bisni-I	345.86	0.8335**	83.8891
13	Bodi	339.00	0.9997**	-254.7546
16	Silipat	337.76	0.9891**	-900.2329
19	Baisur	335.64	1.037**	-1094.6895
4	Kotte (II)	335.12	1.0313**	-633.2114
41	KadamPhool	333.13	0.6701**	1933.2813
50	Danwar	332.20	1.0359**	-1036.3505
47	BhainsaPunchhi	326.88	0.9018**	-788.7067
39	Nagina-22	322.13	0.707**	12927.911**
30	Lalmati	322.10	0.9418**	-777.6592
2	Hardichudi	320.90	0.8883**	-700.472
17	Unknown	320.17	0.9041**	-441.2185
10	Basigal(ii)	318.69	0.8565**	-1077.9177
52	HunumanLangur	315.99	1.0475**	-872.9135
6	Karhani	313.13	0.8714**	-1065.7179
22	Kanak Jira	312.79	0.9093**	-760.5649
18	AmaDhul	312.51	1.0282**	-1020.048
26	Bakal	312.15	0.7908**	-176.1554
8	Luchai(A)	308.08	0.7064**	-1018.4728
54	Sindursenga	308.02	1.0046**	1213.2114
23	TebarooMundaria	304.09	0.8922**	-1104.8018
49	Bhejari	302.01	1.1083**	-1082.1886
53	NariyalChudi	300.73	1.2619**	860.9837
40	R-RF-75	294.57	0.6624**	1839.0419
12	Bhulau	292.82	0.8662**	-998.4084
42	Koudidhull	290.43	0.9172**	-1103.4353
15	TulsiPhool	290.38	0.7312**	-343.9702
24	Kalajira	280.63	0.9623**	-993.7514
46	JouPhool	279.14	0.924**	-769.2575
11	Bhejari	275.49	0.9839**	-400.0753
48	Lahsun Bhog	274.17	1.0358**	-1035.588
33	WR99	272.14	0.9487**	-1008.5206
44	LoktiMachhi	270.62	0.812**	-334.2035
21	Bhaniya	268.30	0.8478**	-727.8063
51	Karhani	253.61	0.7904**	4.9797
31	Laloo-14	246.32	0.7755**	-1085.7735
28	Deshilaldhan	244.21	0.7394**	2270.8101
38	Moroberekan	243.81	0.7545**	2444.6524
5	Sathadhan	235.47	0.7515**	-1109.2424
1	Bagri	225.09	0.5756**	5262.9418*
3	Koto	209.45	0.6041**	360.4251
Pooled Mean		**326.23**		
Check Mean (MTU 1010)		**477.50**		

Blue = Stable for Favourable condition (Based on Check mean)
Green = Favourable, Purple = Stable, Orange = Unfavourable condition (Based on Pooled mean)

42253, Sonpan, Kohka, Cross 116, Peelee Luchai, and Byalo showing $b_i$value more than 1 with mean value (in terms of grain yield) more than the grand mean they may be suitable for favorable environment (irrigated condition) only. Several workers have used Eberhart and Russel model to study the stability of genotypes of different crops for different environments. While studying sorghum mutants following Eberhart and Russel (1966) model, Girish et al. (2020) found stability of certain genotypes under rainfed conditions showed higher mean values than population mean with regression coefficient greater than unity (b-1) and minimum S2 di values indicated their stability and adaptation to specific favorable environment. Kumar et al. (2020) analysed stability parameters of seed

Table 3. Stability analysis of sixty genotypes based on yield index

S.No.	Rank	Genotypes	I	RF	TSD	Mean by crop yield index
1	35	Chaptigurmatia	1074.317	105.750	256.000	12.188
2	56	MTU-1010	1117.510	129.500	185.500	10.893
3	57	IR64	1053.460	121.250	168.500	8.244
4	32	Jhitpiti	814.555	96.250	267.000	7.642
5	41	KadamPhool	595.650	138.500	265.250	7.060
6	9	AngurGuchcha	803.022	138.750	194.250	6.730
7	37	Bisni-I	675.336	126.250	236.000	5.880
8	43	Elayachi	723.550	135.750	203.500	5.654
9	36	Elayachi	682.488	111.250	248.500	5.535
10	34	E-1702	752.917	125.750	202.500	5.333
11	59	IGKV R1	1044.593	116.500	118.000	4.972
12	45	Muni Bhog	743.109	98.500	224.250	4.266
13	39	Nagina-22	593.885	77.000	295.500	3.970
14	60	Danteshwari	852.464	82.750	204.250	3.827
15	29	IR 42253	951.355	107.750	130.000	3.371
16	8	Luchai(A)	588.995	135.000	200.250	3.130
17	58	R-RF-75	925.124	77.250	175.750	3.086
18	7	Kohaka	836.471	100.500	165.250	2.786
19	40	R-RF-75	563.450	174.000	146.250	2.736
20	47	BhainsaPunchhi	688.129	125.750	166.750	2.279
21	13	Bodi	740.236	122.250	154.500	2.229
22	16	Silipat	733.525	113.750	166.000	2.091
23	20	Bylao	834.560	80.750	179.750	2.032
24	26	Bakal	624.945	105.250	206.250	1.790
25	10	Basigal(ii)	659.825	112.750	183.500	1.716
26	2	Hardichudi	676.935	124.500	161.250	1.693
27	17	Unknown	683.022	123.750	153.750	1.329
28	4	Kotte (II)	748.364	106.000	151.000	0.931
29	30	Lalmati	699.305	111.750	155.250	0.769
30	19	Baisur	748.910	88.250	169.750	0.604
31	6	Karhani	660.135	103.000	176.250	0.579
32	15	TulsiPhool	584.392	136.000	150.750	0.427
33	55	Swarna	1065.085	41.750	132.390	0.380
34	50	Danwar	746.110	93.250	157.250	0.257
35	14	PeeleeLuchai	871.272	51.250	174.500	0.110
36	25	Sonapan	947.099	50.000	149.750	-0.047
37	22	Kanak Jira	673.867	85.750	178.750	-0.373
38	27	Cross 116	890.548	50.315	160.250	-0.412
39	23	TebarooMundaria	659.757	92.000	160.500	-1.130
40	12	Bhulau	639.211	95.250	144.000	-2.131
41	52	HunumanLangur	732.452	58.500	157.000	-2.651
42	18	AmaDhul	721.786	63.500	152.250	-2.709
43	54	Sindursenga	704.547	39.000	180.500	-3.337

Contd ....

S.No.	Rank	Genotypes	I	RF	TSD	Mean by crop yield index
44	42	Koudidhull	656.029	72.250	143.000	-3.662
45	44	LoktiMachhi	592.109	60.500	159.250	-4.762
46	21	Bhaniya	608.159	81.000	115.750	-5.294
47	46	JouPhool	646.106	48.785	142.535	-5.654
48	49	Bhejari	744.530	43.750	117.750	-5.719
49	24	Kalajira	665.400	60.500	116.000	-5.877
50	51	Karhani	571.756	89.000	100.063	-6.156
51	28	Deshilaldhan	544.135	108.000	80.500	-6.238
52	38	Moroberekan	549.901	105.000	76.535	-6.587
53	11	Bhejari	670.210	60.750	95.500	-6.895
54	33	WR99	649.670	41.500	125.250	-7.095
55	1	Bagri	447.770	36.500	191.000	-7.323
56	31	Laloo-14	555.202	60.000	123.750	-7.366
57	48	Lahsun Bhog	688.063	35.250	99.185	-8.344
58	5	Sathadhan	535.168	57.750	113.500	-8.439
59	53	NariyalChudi	807.886	32.065	62.250	-8.566
60	3	Koto	447.094	41.500	139.750	-9.749

yield/plant in urdbean (*Vigna mungo* L.) indicated that genotypes that showed regression coefficient greater than unity (b-1) with non-significant S2 di values and higher mean values than population mean which exhibited their stability and adaptation to specific favorable environment only.

Genotypes with high mean, b_i<1 with non-significant S^2d_i do not respond favorably to improved environmental conditions and hence, are suitable for unfavorable environment. Among sixty lines based on check MTU-1010, none of the genotypes is found stable for rainfed and TSD conditions on the contrary based on grand mean (326.23 g/m^2) only genotype, Elayachi (RG 25) and Bisni-I revealed b_i values lower than unity but showed a higher mean than grand mean. Therefore, these two lines are suitable for unfavorable environment and in the present case these two lines are suitable for rainfed and TSD conditions. Similar results were reported by Girish et al (2020) in sorghum mutants and by Kumar et al. (2020) in uradbean, in which some genotypes recorded higher mean values than population mean with non-significant deviation from the regression coefficient S^2di and therefore, recommended for unfavourable environments. Zewdu et al. (2020) carried out multi-environment evaluation of rice genotypes following AMMI analysis and identified appropriate genotypes for suitable production areas based on stability analysis. In present study all the genotype excluding IGKV R1, Nagina-22 and Bagri deviated non-significantly from zero (S^2d_i=0). Therefore, these genotypes are performing stable for grain yield under all the conditions. Among these genotypes, Jhitpiti, Angur Guchcha, E-1702, Muni Bhog, Elayachi (PMBB), Bodi, Silipat, Baisur, Kotte (II), Danwar, Bhainsa Punchhi, Lalmati, Hanuman Langur, Ama Dhul, Sindursenga, Koudidhul, Kalajira, Jouphool, Bhejari, Lahsun Bhog and WR99 are average responsive. Hence, these genotype are suited to all the environmental conditions (irrigated, rainfed and TSD). However, unfortunately genotypes, Lalmati, Hanuman Langur, AmaDhul, Sindursenga, Koudidhul, Kalajira, Jouphool, Bhejari, Lahsun Bhog and WR99 were recorded to have less mean value than the grand mean, and therefore, these genotypes cannot be recommended.

Based on the positive response, only 12 genotypes, namely, Chaptigurmatia, MTU-1010, R64, Swarna, IR 42253, R-RF-75, Sonpan, Danteshwari, Kohka, Cross 116, Peelee Luchai and Baylo recorded high mean value than the grand mean. Therefore, these genotypes are recommended for favorable (irrigated) environments. The genotypes Elayachi (RG25) and Bisni-I are low responsive and recorded higher mean than grand mean. Therefore, these two genotypes are recommended for unfavorable (rainfed and TSD) conditions. Based on the regression coefficient using Eberhart and Russel model several stable genotypes in rice suitable for specific environments have been reported (Hasan et al. 2014). The good yield advantage of the selected genotypes over the presently existing locally adapted varieties, indicates the suitability of these genotypes to be released as variety for cultivation under aerobic conditions.

Stability by yield index

Crop yield index are widely used to compare yields of a number of crops on a given farm with the average yields of the same crops on another farm or on a number of farms. They are also used in year-to-year comparisons to relate the yields in a given year to the yields in some other base year or period of years. Such crop-yield index numbers consequently are summery number intended to indicate how the yields of several different crops vary on the average, between farms, between geographical areas, or between years. The results from present study showed that the genotype, Chaptigurmatia followed by MTU-1010, IR-64, Jhitpiti, Kadam Phool, Angur Guchcha, Bisni-I, Elayachi (PMBB), Elayachi (RG25) and E-1702 had high mean and performed stable in all the conditions over the years. However, on the contrary, according to the Eberhart and Russel model, Chaptigurmatia, IR 64 and MTU-1010 showed b_i more than one and significant S^2d_i. But the genotype Jhitpiti, Angurguchcha, E-1702, Elayachi (RG 25) and Elayachi (PMBB) showed stable performance in both the methods. Hence, it is clear that the above mentioned genotypes performed stable and are suitable for irrigated, rainfed as well as terminal stage drought conditions.

Drought susceptibility index (DSI) and drought intensity index (DII)

The DSI suggested by Fischer and Maurer (1978) for estimating the yield stability that detailed the changes in both potential and actual yields in variable environments. According to DSI parameters, the resistant genotypes from year to year were not consistent. In other words, similar to other indices, the DSI gave different ranks to genotypes in different years. The genotypes with DSI less than one (unit) are drought resistant, since their yield reduction recorded for all the genotypes (Babu et al. 2011). Whereas the higher value of DSI i.e., DSI>1 revealed that the genotypes are relatively prone to drought stress. In the present investigation the genotypes with the least DSI value in rainfed condition based on pooled data which is having higher mean grain yield than the overall mean, were R-RF-75 followed by Angur Guchcha, Jhitpiti, Kadam Phool, Tulsiphool, Luchai (A), Elaychi (PMBB), Bisni-I, E-1702 and Bhainsa Punchi (Table 4).

The DSI value based on the pooled data of two years, under TSD condition was found less than one in genotypes Nagina-22 followed by Jhitpiti, Kadamphool, Chaptigurmatia, Elayachi (PMBB), Bisni-I, Muni Bhog, Bakal, Elayachi (RG 25), E-1702 and Luchai (A) and grain yield more than the grand mean. The present findings are corroborated with the findings of Meena et al. (2015) in chickpea and Babu et al. (2011) in rice who reported that genotypes with a DSI of less than 1 unit are drought tolerant. The drought susceptibility index helps in identifying the genotypes which has less grain yield reduction under water stress condition as compared to non-stress condition. Drought intensity index (DII) tells the optimum level of stress in a particular environment or condition. The DII formula clearly shows that higher the severity of stress, the closer the value of DII is to 1.0, because under severe stress, the yield of a stressed environment will be reduced significantly and its ratio to yield under a controlled environment will be less than 1.0 and nearer 0.0. In the present investigation the DII value for rainfed condition was 0.876 whereas for TSD condition 0.775.

The ideal value of DII should be 0.5, and in our study the DII value is found more than 0.5 that clearly means the stress severity of rainfed and TSD conditions are higher. It reveals that the DII value more than 0.5 (meaning a loss of more than 50% yield from a controlled or normal environment to a stressed one) indications higher limits of stress. The reason for the connection between DII and the DSI in selecting the stress tolerant lines is that, when the stress influence is very severe in a targeted environment, the selection pressure for stress tolerance screening should be increased so that "the more tolerant genotypes which can succeed in that environment can be selected".

Overall based on three different analytical measures of stability i.e Eberhart and Russel model, Yield index and Drought susceptibility index (DSI) out of sixty genotypes on comparing with check variety MTU-1010 genotype Chaptigurmatia performs stable under irrigated condition and on the other hand when comparing to grand mean only four namely, Jhitpiti, Angurguchcha, E-1702 and Elayachi (PMBB) were found to have stable performance in irrigated, rainfed and TSD conditions over two years (Table 5). This clearly indicates that four genotypes are performing superior with high means for grain yield, estimate of bi

Table 4. DSI values under Rainfed and TSD condition

S.No.	Genotypes	DSI (RF)	DSI (TSD)	S.No.	Genotypes	DSI (RF)	DSI (TSD)
1	Bagri	1.049	0.740	31	Laloo-14	1.019	1.003
2	Hardichudi	0.932	0.984	32	Jhitpiti	0.807	0.868
3	Koto	1.036	0.888	33	WR99	1.069	1.042
4	Kotte (II)	0.980	1.031	34	E-1702	0.901	0.844
5	Sathadhan	1.019	1.017	35	Chaptigurmatia	1.010	0.983
6	Karhani	0.964	0.946	36	Elayachi	0.956	0.821
7	Kohaka	1.005	1.036	37	Bisni-I	0.908	0.840
8	Luchai(A)	0.880	0.852	38	Moroberekan	0.924	1.111
9	AngurGuchcha	0.865	0.879	39	Nagina-22	0.994	0.649
10	Basigal(ii)	0.927	0.932	40	R-RF-75	0.789	0.956
11	Bhejari	1.038	1.107	41	KadamPhool	0.876	0.716
12	Bhulau	0.972	1.000	42	Koudidhull	1.016	1.010
13	Bodi	0.953	1.022	43	Elayachi	0.908	0.852
14	PeeleeLuchai	1.075	1.033	44	LoktiMachhi	1.025	0.944
15	TulsiPhool	0.876	0.958	45	Muni Bhog	0.991	0.902
16	Silipat	0.965	0.999	46	JouPhool	1.056	1.006
17	Unknown	0.935	1.000	47	BhainsaPunchhi	0.933	0.928
18	AmaDhul	1.041	1.019	48	Lahsun Bhog	1.083	1.105
19	Baisur	1.007	0.998	49	Bhejari	1.075	1.087
20	Bylao	1.031	1.013	50	Danwar	0.999	1.019
21	Bhaniya	0.990	1.045	51	Karhani	0.964	1.065
22	Kanak Jira	0.997	0.949	52	HunumanLangur	1.051	1.014
23	TebarooMundaria	0.983	0.977	53	NariyalChudi	1.097	1.192
24	Kalajira	1.038	1.066	54	Sindursenga	1.079	0.960
25	Sonapan	1.082	1.087	55	Swarna	1.097	1.131
26	Bakal	0.950	0.865	56	MTU-1010	1.010	1.017
27	Cross 116	1.077	1.059	57	IR64	1.010	1.085
28	Deshilaldhan	0.915	1.100	58	R-RF-75	1.047	1.046
29	IR 42253	1.013	1.115	59	IGKV R1	1.015	1.145
30	Lalmati	0.959	1.004	60	Danteshwari	1.031	0.982
					DII	**0.876**	**0.775**

DSI = Drought Susceptibility Index and DII = Drought Intensity Index

Table 5. Overall performance of the genotypes based on ER model of stability, yield index and DSI based on grand mean

Genotypes	Eberhart and Russel model			Yield index	DSI	
	Mean	(b_i)	S^2_{di}		RF	TSD
Jhitpiti	392.60	1.072**	3177.13	7.642	0.807	0.868
AngurGuchcha	378.68	1.060**	-857.37	6.730	0.865	0.879
E-1702	360.39	0.984**	-1099.29	5.333	0.901	0.844
Elayachi (PMBB)	354.27	0.925**	-1109.40	5.654	0.908	0.852

b_i = Reg Coefficient; S^2_{di} = Stability Parameter

near to 1 and with minimal deviation of S^2di. Therefore these four genotypes are said to be stable genotypes over the years for all three conditions. As aforesaid genotypes are germplasm lines so these lines can be used as donor for developing drought tolerant lines.

Authors' contribution

Conceptualization of research ( ); Designing of the experiments ( ); Contribution of experimental materials ( ); Execution of field/ lab experiments and data collection ( ); Analysis of data and interpretation ( ); Preparation of manuscript ( ).

Declaration

The authors declare no conflict of interest.

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