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Identification of drought-tolerant traditional cultivars of rice (*Oryza sativa* L.) under different terminal water stress environments

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ABSTRACT

Drought is one of the most important abiotic stresses causing considerable yield loss in local rice cultivars. Water stress at the reproductive phase is a common phenomenon in many long-duration rice-growing areas. Traditional rice cultivars pass through the terminal drought. In this endeavor, 59 local cultivars of rice were screened under terminal drought created by spraying potassium iodide, normal terminal drought, and a control block (irrigated condition) based on some of the drought tolerance indices. The study exhibited a reduction in mean grain yield in both drought conditions by 21.42% and 6.81%, respectively. The best ten performing cultivars under non-stress conditions were Jhagrikartik, Ghee Bora, Hatidat Komal, Panikuthi Shyamlal, Sial Bhomra, Garu Chakua, Silathia Bora, Tulsimukul, Tarapakri, Dudhekalam. Of those, Jhagrikartik, Ghee Bora, Panikuthi Shyamlal, and Tulsimukul also performed well under stress conditions created by spraying potassium iodide, however, the cultivars Hatidat Komal, Garu Chakua, and Silathia Bora also performed well under normal terminal drought environment. Nine drought-tolerant indices were used to find out the better-performing rice cultivars. Based on combination of different drought tolerant indices under different drought conditions Panikuthi shyamlal, Ghee Boraand Jhagrikartik were found to be promising under drought stress environments. Ladu and Kaltury were also found to be better under drought conditions. The novelty of this endeavour includes the use of potassium iodide to create a drought situation for screening tolerant genotypes in addition to the normal drought environment.

Keywords: *Drought tolerant indices,, Local cultivars, Potassium iodide, Rice, Terminal drought*

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INTRODUCTION

Rice is an important staple food crop of the world, particularly in Asian, African, and Latin American countries. A large number of traditional rice cultivars are being cultivated in India and occupied a considerable area. Usually, traditional cultivars are of long duration and photoperiod-sensitive. Water stress at the reproductive phase with special reference to the grain-filling phase is a common phenomenon in many long-duration rice-growing regions. Monsoon rains in northern and northeastern India naturally withdraw by end of September, however, the panicle emergence of long-duration rice cultivars starts by mid of October. Thus, the local long-duration genotypes of rice pass through the terminal drought. Drought during the reproductive phase directly affects grain yield and quality [31].

Drought stress at the anthesis stage slow down the rate of grain filling leading in a reduction in mean kernel weight and subsequently a reduction in grain yield and quality. Grain development of rice depends on photosynthesis ability and accumulated assimilates. During the vegetative phase, carbohydrates accumulate in the stems of rice plants [4, 24]. If current photosynthesis is limited by terminal drought, grain development is supported by the remobilization of previously accumulated stem reserves from vegetative tissues [32]. During the terminal, drought increases the remobilization of assimilates from the vegetative tissues to the grains [18] to compensate for the reduction in the mobilization of photsynthates from leaves.

Chemical desiccants, like KI (potassium iodide), have been suggested as an indirect method to induce terminal drought in rice. Spraying of KI solution under normal irrigated conditions immediately after panicle emergence causes destruction of the plant's photosynthetic activities [22]. Many researchers successfully used KI to screen rice cultivars for terminal drought [2, 26]. KI inhibits photosynthesis without any harmful effect on the translocation of reserve foods to the developing grains. KI primarily causes desiccation and it resembles the terminal drought subsequently it reduces the rate of photosynthesis and chlorophyll content and enhances senescence [23] leading in a reduction in grain dry weight.

Considering the importance of terminal drought in long-duration rice cultivars, an experiment was set to screen the drought-tolerant traditional rice cultivars using nine drought tolerance indices. Cultivars were screened under two drought situations- i) spraying of potassium iodide (KI) solution immediately after panicle emergence and ii) withdrawal of irrigation at the reproductive phase. Several drought tolerance indices, such as the stress tolerance index [7], geometric mean of productivity [19], stress tolerance [20], stress susceptibility index [9], stress tolerance efficiency [8], mean relative performance [12], relative efficiency index[12], yield index [11] and mean productivity index [12] have been used in this endeavor to find out the drought tolerant local cultivars of rice.

MATERIALS AND METHODS

Materials

Fifty-nine traditional cultivars of rice were received from the Repository of Farmers' Varieties of Rice, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India. Those cultivars were collected from West Bengal and the adjoining states of West Bengal (Table 2). Out of those 59 cultivars, 30 were aromatic and the remaining 29 were non-aromatic. All were long-duration and highly photoperiod-sensitive cultivars, the usual time of flowering is October-November.

Experimental Site and Design

The field experiment was carried out at the Instructional Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, during the *Kharif*season (June-November) of 2014 and 2015. The experimental field is situated at 26°19′86′′ N latitude and 89°23′53′′ E longitude, at an elevation of 43 meters above mean sea level. Single seedlings per hill of 30 days old were transplanted in four lines 5 m long in each set and each genotype in Randomized Block Design with two replications. The row-to-row distance was 25 cm and plant to plant was 20 cm. In each plot, a uniform plant stand was maintained and standard agronomic practices compatible with the humid tropic of the Tarai Zone (under the sub-tropical region) were followed to obtain good crop stand [21]. Transplanting was done during the second week of July 2014 and 2015.

Experimental Situation and Method

The field experiments were conducted in three different sets. i) Irrigated condition- standing water was maintained from 20 days after transplanting to the grain filling stage by providing rainwater or by water supplementation as and when required. ii) Artificial drought condition- was created at the reproductive stage just after panicle emergence by application of 0.6% KI solution as outlined by Tyagi et al. [30]. This set of experiments was irrigated as and when required. iii) Normal terminal drought condition- crops were transplanted under rain-fed conditions and no supplementary irrigation was given. In this set of experiments, the field was drained out at the reproductive phase to allow them dry and to facilitate for development of a drought situation. Withdrawal of monsoon in the Terai Zone of Cooch Behar usually takes place during the first fortnight of October, whereas local genotypes of rice flower during the second fortnight of October to the first fortnight of November. Thus, if there is no supplementary irrigation after the withdrawal of monsoon, the crop fetch terminal drought.

Drought Tolerant Indices

Considering the importance of terminal drought in traditional cultivars of rice in this region, 59 cultivars were screened using different drought tolerance indices. These indices were computed based on the mathematical relationship between yield under stressed and non-stressed (irrigated) environments using the following equations-

1. Stress tolerance index [7]
$STI = [(Y_S) \times (Y_P)] / (Y_P)^2$

2. Geometric mean of productivity [19]
$GMP = \sqrt{(Ys) * (Yp)}$

3. Stress tolerance [20]
TOL = (Grain yield under stress) − (Grain yield under non-stress)

4. Stress susceptibility index [9]
$SSI = (1- Y_S/Y_P) / (1- \bar{Y}_S/\bar{Y}_P)$

5. Stress tolerance efficiency [8]
$STE = [(Y_S) / (Y_P)] \times 100$

6. Mean relative performance [12]
$MRP = (Y_S / \bar{Y}_S) + (Y_P / \bar{Y}_P)$

7. Relative efficiency index [12]
$REI = (Y_S / \bar{Y}_S) * (Y_P / \bar{Y}_P)$

8. Yield index[11]
$YI= Y_S / \bar{Y}_S$

9. Mean productivity index [12]
$MPI =[(Y_P) + (Y_S)]/2$

Where, Y_S and Y_P are yield under stress and non-stress yield of a given genotype, respectively.

$\bar{Y}_S$ and $\bar{Y}_P$ are average yields of all genotypes under stress and non-stress conditions, respectively

RESULTS

The relative yield performance of rice genotypes under drought stress and non-stress conditions can be used as an indicator for the identification of drought-tolerant genotype(s) for drought-prone areas. Several indices are being used to identify suitable drought-tolerant genotypes. In this present endeavor, nine indices were used to evaluate the drought-tolerant ability of 59 traditional cultivars of rice.

Analysis of Variance

Analysis of the variance of grain yield per plant indicated a significant difference among the rice varieties, different drought environments (irrigated, the stress created by the application of potassium iodide at the reproductive stage and normal drought conditions), and genotype × stress-level interaction.

Yield Performance under Non-Stressed and Stressed Environments

The mean performance of traditional cultivars in respect of grain yield per plant varied from16.06 to 58.77 g/plant, 9.17 to 62.99 g/plant and9.60 to 59.73 g/plant under non-stressed, stress conditions created by spraying KI and terminal drought stress environments, respectively (Table 2).

Ten best-performing cultivars under a non-stress environment were Jhagrikartik, Ghee Bora, Hatidat Komal, Panikuthi Shyamlal, Sial Bhomra, Garu Chakua, Silathia Bora, Tulsimukul, Tarapakri, Dudhekalam (Table 1). The 10 top-ranking cultivars which perform better under drought conditions created by spraying KI were Jhagrikartik, Panikuthi Shyamlal, Tulsimukul, Kataribhog, Baigon Machua, Sitalkuchi, Malshira, Ladu, Ghee Bora, and Lagidhan. Another set of 10 cultivars that performed better under normal drought situations were Hatidat Komal, Dubari Komal, Bonnidhan, Garu Chakua, Silathia Bora, Dhyapa, Laldhyapa, Kagey, Kalodhyapa, and Kabra (Table 4). The cultivars Jhagrikartik, Ghee Bora, Panikuthi Shyamlal, Garu Chakua, Silathia Bora andTulsimukul were found to be performed better in drought-free condition and either one of the drought conditions. Thus, these cultivars may be considered as drought-tolerant.

The overall mean yield in the drought-free environment was the highest (33.90 g/plant) followed by normal terminal drought (31.59 g/plant) and the lowest was obtained when drought was created by spraying KI (26.64 g/plant).

Stress Tolerance Index (STI) and Geometric Mean Productivity (GMP)

STI of the traditional cultivars under stress created by spraying KI varied from 0.33 to 2.16% with a mean of 0.96% (Table 1). Twenty-nine traditional cultivars showed relatively high yield under water stress (STI > mean STI). STI under normal terminal stressed conditions varied from 0.273 to 1.31 with a mean of 0.79 (Table 1). Thirty cultivars showed higher yield as compared to the mean under terminal drought stress.Kashiyabinni, Bora, Muni, Dhyapa, Kagey, Radunipagal, Dubari Komal, Kaltury, Kabra, and Bonnidhan were found to have high STI values under stress created by spraying KI (Table 4). Based on STI, Tulsimukul, Beto, Seshaphal, Jhagrikartik, Sitalkuchi, Kaltury, Kalojeera, Baigon Machua, Kalo Nunia, and Kataribhog showed high values for STI under normal terminal drought condition. Kalturey showed higher values under both environments.

Under normal terminal drought, GMP varied from 13.80 to 60.84 with a mean of 29.70. Twenty-five cultivars showed higher GMP as compared to the mean, such as Dudhekalam, Ladu, Malshira, Sitalkuchi, Baigon Machua, Kataribhog, Ghee Bora, Tulsimukul, Panikuthi Shyamlal, and Jhagrikartik etc. The remaining 34 cultivars had lower values than the mean. The rice cultivars Ladu, Dhyapa, Laldhyapa, Panikuthi Shyamlal, Ghee Bora, Dubari Komal, Silathia Bora, Jhagrikartik, Garu Chakua, and Hatidat Komal were reported to have high GMP under stress created by spraying KI. GMP varied from 13.27 to 56.87 with a mean of 32.24 under stress created by spraying KI during the emergence of rice panicles (Table 1). The cultivars Ladu, Panikuthi Shyamlal, Ghee Bora, and Jhagrikartik showed high values of GMP under both stress environments (Table 4).

Stress Tolerance (TOL) and Stress Susceptibility Index (SSI)

TOLunder stress created by spraying KI of traditional cultivars varied from -11.31 to 27.80 with an average of 7.26 (Table 1). Thirty-two cultivars were recorded with the lower value of TOL than the mean(TOL < mean TOL) indicating the high-stress tolerance ability of a given cultivar (Table 2), such as Dubari Komal, Bitti, Dhyapa, Bonnidhan, Dudheswar Mota Jaswa, Kalshipa, Tulaipanji, Khasa, and Dudhekalam. Under normal terminal drought stress conditions TOL ranged from -29.61 to 29.46 with a mean of 2.31 (Table 1). Thirty-two cultivars showed lower value than the mean for TOL indicating its tolerant ability under normal terminal drought situations, such as Garu Chakua, Kalo Nunia, Boichi, Khasa, Satia, Kalojeera, Seshaphal, Ladu, Jhapaka and Kataribhog. However, none of the cultivars exhibited low values simultaneously under both the drought environments (Table 4).

SSI assesses the reduction in yield caused by drought as compared to drought-free situations. The SSI showed high variability among the cultivars. The SSI varied from -1.47 to 3.39 under stress created by spraying KI with a mean of 0.54. The cultivars showed low values for SSI were Dubari Komal, Radunipagal, Dhyapa, Tulaipanji, Dudhekalam, Kalshipa, Dudheswar Mota Jaswa, Khasa, and Rampha. The SSI under normal drought conditions varied from -17.05 to 9.81 with a mean of 0.96 (Table 2). Binni, Garu Chakua, Boichi, Khasa, Satia, Kalojeera, Ladu, Seshaphal, Kataribhog, and Jhapaka performed well under normal drought conditions which was reflected by their low values of SSI. But, none of the cultivars performed better equally in both the drought environments (Table 4).

Stress Tolerance Efficiency (STE)

STE is a measure of drought resistance mechanisms and determines the consistency of selected genotypes in response to drought having different severity, timing, and duration and thus may be useful in identifying drought-tolerant rice cultivars. The values of STE ranged from 33.17 to 216.21% with an average 96.34% (Table 3) under stress created by spraying KI. Twenty-nine traditional cultivars were found to have a higher value than the mean. The values of STE under normal terminal drought stress ranged from 27.32 to 131.48% with an average 79.35% (Table 3). Thirty cultivars showed a higher value than the mean(STE < mean STE) under the stress created by spraying KI. Best 10 cultivars that showed high STE value under artificially created terminal drought conditions using KI were Kashiya Binni, Bora, Muni, Dhyapa, Kagey, Radunipagal, Dubari Komal, Kaltury, Kabra and Bonnidhan (Table 4). Thirty-one cultivars showed higher vale than the mean under normal terminal stress conditions. The 10 top-ranking cultivars that showed high STE value under normal terminal drought were Kaltury,

Table 1 Drought tolerance indices in response to drought stress and irrigated condition

Genotypes	YN	YS1	YS2	STI		GMP		TOL		SSI	
				S1	S2	S1	S2	S1	S2	S1	S2
Beto	34.22	36.36	40.49	1.18	1.06	37.22	35.27	-2.14	-6.27	-2.69	-0.29
Binni	33.97	18.16	36.59	1.08	0.53	35.26	24.84	15.81	-2.62	-1.13	2.17
Bitti	16.06	11.85	10.97	0.68	0.74	13.27	13.80	4.21	5.09	4.65	1.22
Boichi	30.11	18.62	30.98	1.03	0.62	30.54	23.68	11.49	-0.87	-0.42	1.78
Bonnidhan	25.48	19.97	55.09	2.16	0.78	37.47	22.56	5.51	-29.61	-17.05	1.01
Dhyapa	34.88	29.46	45.97	1.32	0.84	40.04	32.06	5.42	-11.09	-4.67	0.73
Dudhekalam	43.01	35.87	30.66	0.71	0.83	36.31	39.28	7.14	12.35	4.21	0.78
Dudheswar MotaJaswa	32.39	26.69	39.06	1.21	0.82	35.57	29.40	5.7	-6.67	-3.02	0.82
Jashyopa	39.57	20.82	36.8	0.93	0.53	38.16	28.70	18.75	2.77	1.03	2.21
Jhagrikartik	58.77	62.99	40.36	0.69	1.07	48.70	60.84	-4.22	18.41	4.60	-0.34
Kalakali	23.55	14.87	17.34	0.74	0.63	20.21	18.71	8.68	6.21	3.87	1.72
Kalodhyapa	33.92	24.01	42.09	1.24	0.71	37.78	28.54	9.91	-8.17	-3.53	1.36
Kalshipa	32.62	26.88	38.15	1.17	0.82	35.28	29.61	5.74	-5.53	-2.49	0.82
Kashiya Binni	27.89	19.64	35.22	1.26	0.70	31.34	23.40	8.25	-7.33	-3.86	1.38
Kauka	30.17	14.32	33.51	1.11	0.47	31.80	20.79	15.85	-3.34	-1.62	2.45
Kharadhan	39.54	36.35	18.07	0.46	0.92	26.73	37.91	3.19	21.47	7.97	0.38
Ladu	40.02	40.50	38.9	0.97	1.01	39.46	40.26	-0.48	1.12	0.41	-0.06
Laldhyapa	40.49	28.66	44.42	1.10	0.71	42.41	34.07	11.83	-3.93	-1.42	1.36
Malshira	39.98	40.66	26.74	0.67	1.02	32.70	40.32	-0.68	13.24	4.86	-0.08
Panikuthi Shyamlal	52.67	54.02	34.65	0.66	1.03	42.72	53.34	-1.35	18.02	5.02	-0.12
PhoolPakri	31.85	21.12	35.93	1.13	0.66	33.83	25.94	10.73	-4.08	-1.88	1.57
Sadamala	33.39	34.03	36.03	1.08	1.02	34.68	33.71	-0.64	-2.64	-1.16	-0.09
Satia	25.31	25.48	25.43	1.00	1.01	25.37	25.39	-0.17	-0.12	-0.07	-0.03
Seshaphal	19.26	20.57	18.38	0.95	1.07	18.81	19.90	-1.31	0.88	0.67	-0.32
Sial Bhomra	48.32	26.62	31.17	0.65	0.55	38.81	35.86	21.7	17.15	5.21	2.10
Sitalkuchi	39.2	42.88	32.3	0.82	1.09	35.58	41.00	-3.68	6.9	2.58	-0.44
Tarapakri	43.71	24.45	14.5	0.33	0.56	25.18	32.69	19.26	29.21	9.81	2.06
Thuri	28.87	20.5	19.03	0.66	0.71	23.44	24.33	8.37	9.84	5.00	1.35
Tulsimukul	44.85	47.45	15.39	0.34	1.06	26.27	46.13	-2.6	29.46	9.64	-0.27
Badshabhog	30.2	20.44	26.66	0.88	0.68	28.37	24.85	9.76	3.54	1.72	1.51
Baigon Machua	38.76	43.95	35.29	0.91	1.13	36.98	41.27	-5.19	3.47	1.31	-0.63
Bora	31.41	19.97	40.12	1.28	0.64	35.50	25.05	11.44	-8.71	-4.07	1.70
Dubari Komal	40.37	36.21	56.01	1.39	0.90	47.55	38.23	4.16	-15.64	-5.69	0.48
Dudheswar	33.94	13.39	23.84	0.70	0.39	28.45	21.32	20.55	10.1	4.37	2.83
Fudugey	30.37	18.72	23.06	0.76	0.62	26.46	23.84	11.65	7.31	3.53	1.79
Garu Chakua	49.56	28.41	51.82	1.05	0.57	50.68	37.52	21.15	-2.26	-0.67	1.99
Ghee Bora	56.15	38.55	39.78	0.71	0.69	47.26	46.53	17.6	16.37	4.28	1.46
Gobindabhog	31.09	16.98	28.03	0.90	0.55	29.52	22.98	14.11	3.06	1.44	2.12
Hatidat Komal	54.15	26.35	59.73	1.10	0.49	56.87	37.77	27.8	-5.58	-1.51	2.40
Jhapaka	25.25	25.4	23.79	0.94	1.01	24.51	25.32	-0.15	1.46	0.85	-0.03
Kabra	24.88	22.71	41.67	1.67	0.91	32.20	23.77	2.17	-16.79	-9.90	0.41
Kagey	33.57	9.17	44.39	1.32	0.27	38.60	17.55	24.4	-10.82	-4.73	3.39
Kalojeera	17.66	19.64	17.66	1.00	1.11	17.66	18.62	-1.98	0	0.00	-0.52
Kolajoha	31.62	20.05	21.93	0.69	0.63	26.33	25.18	11.57	9.69	4.50	1.71
Kalokhasa	25.32	25.69	9.6	0.38	1.01	15.59	25.50	-0.37	15.72	9.11	-0.07
Kalo Nunia	20.04	23.01	21.72	1.08	1.15	20.86	21.47	-2.97	-1.68	-1.23	-0.69
Kaltury	17.71	19.49	27.27	1.54	1.10	21.98	18.58	-1.78	-9.56	-7.92	-0.47

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Kataribhog	35.93	47.24	33.95	0.94	1.31	34.93	41.20	-11.31	1.98	0.81	-1.47
Khasa	34.89	28.54	35.6	1.02	0.82	35.24	31.56	6.35	-0.71	-0.30	0.85
Konkonijoha	30.15	21.67	25.56	0.85	0.72	27.76	25.56	8.48	4.59	2.23	1.31
Lagidhan	35.06	36.92	24.4	0.70	1.05	29.25	35.98	-1.86	10.66	4.46	-0.25
Mohanbhog	37.38	16.74	23.55	0.63	0.45	29.67	25.01	20.64	13.83	5.43	2.58
Muni	24.77	11.12	32.63	1.32	0.45	28.43	16.60	13.65	-7.86	-4.66	2.57
Radhatilak	33.88	15.39	28.26	0.83	0.45	30.94	22.83	18.49	5.62	2.43	2.55
Radunipagal	20.14	17.97	26.7	1.33	0.89	23.19	19.02	2.17	-6.56	-4.78	0.50
Rampha	20.08	15.98	23.04	1.15	0.80	21.51	17.91	4.1	-2.96	-2.16	0.95
Silathia Bora	45.83	28.75	50.73	1.11	0.63	48.22	36.30	17.08	-4.9	-1.57	1.74
Tulaipanji	35.69	29.81	17.48	0.49	0.84	24.98	32.62	5.88	18.21	7.49	0.77
Tulsibhog	30.13	29.69	25.14	0.83	0.99	27.52	29.91	0.44	4.99	2.43	0.07
Range	16.06-58.77	9.17-62.99	9.60-59.73	0.33-2.16	0.27-1.31	13.27-56.87	13.80-60.84	-11.31-27.80	-29.61-29.46	-1.47-3.39	-17.05-9.81
Mean	33.90	26.64	31.59	0.96	0.79	32.24	29.70	7.26	2.31	0.54	0.96
Reduction in yield	-	21.42%	6.81%	-	-	-	-	-	-	-	-

YN = Grain yield under non-stress (g/plant), YS1 = Grain yield (g/plant) under stressed condition created by spray chemical desiccant Potassium Iodide (KI), YS2 = Grain yield (g/plant) normal terminal stress at un-irrigated condition, STI = Stress tolerance index,GMP =Geometric mean of productivity, TOL = Stress tolerance,GMP = Stress susceptibility index; S1 =stressed condition created by spray chemical desiccant KI; S2 = normal terminal stress at un-irrigated condition.

Table 2 Classification of rice cultivars based on SSI

Classes	Stress created by spraying KI	Normal terminal stress
Highly tolerant (SSI < 0.50)	Kataribhog, Kalo Nunia, Baigon Machua, Kalojeera, Kaltury, Sitalkuchi, Jhagrikartik, Seshaphal, Beto, Tulsimukul, Lagidhan, Panikuthi Shyamlal, Sadamala , Malshira, Kalokhasa, Ladu, Satia, Jhapaka, Tulsibhog, Kharadhan, Kabra and Dubari Komal	Bonnidhan, Kabra, Kaltury, Dubari Komal, Radunipagal, Kagey, Dhyapa, Muni, Bora, Kashiya Binni, Kalodhyapa, Dudheswar MotaJaswa, Beto, Kalshipa, Rampha, PhoolPakri, Kauka, Silathia Bora, Hatidat Komal, Laldhyapa, Kalo Nunia, Sadamala, Binni, Garu Chakua, Boichi, Khasa, Satia, Kalojeera and Ladu
Tolerant (SSI ≥ 0.51 &≤ 0.75)	Radunipagal and Dhyapa	Seshaphal
Moderately tolerant (SSI ≥ 0.76 &≤ 1.00)	Tulaipanji, Dudhekalam, Kalshipa, Dudheswar MotaJaswa, Khasa and Rampha	Kataribhog and Jhapaka
Susceptible (SSI > 1.00)	Bonnidhan, Bitti, Konkonijoha, Thuri, Kalodhyapa, Laldhyapa, Kashiya Binni, Ghee Bora, Badshabhog, PhoolPakri, Bora, Kolajoha, Kalakali, Silathia Bora, Boichi, Fudugey, Garu Chakua, Tarapakri, Sial Bhomra, Gobindabhog, Binni, Jashyopa, Hatidat Komal, Kauka, Radhatilak, Muni, Mohanbhog, Dudheswar and Kagey	Kataribhog, Jhapaka, Jashyopa, Baigon Machua, Gobindabhog, Badshabhog, Konkonijoha, Tulsibhog, Radhatilak, Sitalkuchi, Fudugey, Kalakali, Dudhekalam, Ghee Bora, Dudheswar, Lagidhan, Kolajoha, Jhagrikartik, Bitti, Malshira, Thuri, Panikuthi Shyamlal, Sial Bhomra, Mohanbhog, Tulaipanji, Kharadhan, Kalokhasa, Tulsimukul and Tarapakri

Kalokhasa, Badshabhog, Kagey, Kalo Nunia, Sial Bhomra, Jashyopa, Satia, Beto, and Tulsibhog. Only Kaltury recorded better performance under both drought conditions (Table 4).

Mean Relative Performance (MRP) and Relative Efficiency Index (REI)

MRP of rice cultivars under stress created by spraying KI varied from 0.82 to 3.49with a mean of 2.00 (Table 3). High value for MRP was observed for 30 rice cultivars. Cultivarsthatexhibited high values for MRP may be considered as drought tolerant. MRP of rice cultivars under normal terminal drought differed from 0.92 to 4.10 with a mean of 2.00. Twenty-four cultivars exhibited high value for MRP under normal terminal drought. The best 10 cultivars which showed higher values

Table 3 Drought tolerance indices in response to drought stress and irrigated condition

Genotypes	STE		MRP		REI		YI		MPI	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Beto	118.32	106.25	2.29	2.37	1.29	1.38	1.28	1.36	37.36	35.29
Binni	107.71	53.45	2.16	1.68	1.16	0.68	1.16	0.68	35.28	26.07
Bitti	68.31	73.78	0.82	0.92	0.16	0.21	0.35	0.44	13.52	13.96
Boichi	102.89	61.84	1.87	1.59	0.87	0.62	0.98	0.70	30.55	24.37
Bonnidhan	216.21	78.37	2.50	1.50	1.31	0.56	1.74	0.75	40.29	22.73
Dhyapa	131.79	84.46	2.48	2.13	1.50	1.14	1.46	1.11	40.43	32.17
Dudhekalam	71.29	83.39	2.24	2.62	1.23	1.71	0.97	1.35	36.84	39.44
Dudheswar MotaJaswa	120.59	52.61	2.19	1.96	1.18	0.96	1.24	1.00	35.73	29.54
Jashyopa	93.00	107.18	2.33	1.95	1.36	0.91	1.16	0.78	38.19	30.20
Jhagrikartik	68.67	63.14	3.01	4.10	2.21	4.10	1.28	2.36	49.57	60.88
Kalakali	73.63	70.78	1.24	1.25	0.38	0.39	0.55	0.56	20.45	19.21
Kalodhyapa	124.09	82.40	2.33	1.90	1.33	0.90	1.33	0.90	38.01	28.97
Kalshipa	116.95	70.42	2.17	1.97	1.16	0.97	1.21	1.01	35.39	29.75
Kashiya Binni	126.28	47.46	1.94	1.56	0.92	0.61	1.11	0.74	31.56	23.77
Kauka	111.07	91.93	1.95	1.43	0.94	0.48	1.06	0.54	31.84	22.25
Kharadhan	45.70	101.19	1.74	2.53	0.67	1.59	0.57	1.36	28.81	37.95
Ladu	97.20	70.78	2.41	2.70	1.45	1.79	1.23	1.52	39.46	40.26
Laldhyapa	109.71	101.70	2.60	2.27	1.68	1.28	1.41	1.08	42.46	34.58
Malshira	66.88	102.56	2.03	2.71	1.00	1.80	0.85	1.53	33.36	40.32
Panikuthi Shyamlal	65.79	66.31	2.65	3.58	1.70	3.15	1.10	2.03	43.66	53.35
PhoolPakri	112.81	101.91	2.08	1.73	1.07	0.74	1.14	0.79	33.89	26.49
Sadamala	107.91	100.67	2.13	2.26	1.12	1.26	1.14	1.28	34.71	33.71
Satia	100.47	106.80	1.55	1.70	0.60	0.71	0.81	0.96	25.37	25.40
Seshaphal	95.43	55.09	1.15	1.34	0.33	0.44	0.58	0.77	18.82	19.92
Sial Bhomra	64.51	109.38	2.41	2.42	1.41	1.42	0.99	1.00	39.75	37.47
Sitalkuchi	82.40	55.93	2.18	2.77	1.18	1.86	1.02	1.61	35.75	41.04
Tarapakri	33.17	71.00	1.75	2.21	0.59	1.18	0.46	0.92	29.11	34.08
Thuri	65.92	105.79	1.45	1.62	0.51	0.66	0.60	0.77	23.95	24.69
Tulsimukul	34.31	67.68	1.81	3.10	0.64	2.36	0.49	1.78	30.12	46.15
Badshabhog	88.28	113.39	1.73	1.66	0.75	0.68	0.84	0.77	28.43	25.32
Baigon Machua	91.05	63.57	2.26	2.79	1.28	1.89	1.12	1.65	37.03	41.36
Bora	127.73	89.69	2.20	1.68	1.18	0.69	1.27	0.75	35.77	25.69
Dubari Komal	138.74	39.45	2.96	2.55	2.11	1.62	1.77	1.36	48.19	38.29
Dudheswar	70.24	61.64	1.76	1.50	0.76	0.50	0.75	0.50	28.89	23.67
Fudugey	75.93	57.32	1.63	1.60	0.65	0.63	0.73	0.70	26.72	24.55
Garu Chakua	104.56	68.65	3.10	2.53	2.40	1.56	1.64	1.07	50.69	38.99
Ghee Bora	70.85	54.61	2.92	3.10	2.09	2.40	1.26	1.45	47.97	47.35
Gobindabhog	90.16	48.66	1.80	1.55	0.81	0.58	0.89	0.64	29.56	24.04
Hatidat Komal	110.30	100.59	3.49	2.59	3.02	1.58	1.89	0.99	56.94	40.25
Jhapaka	94.22	91.278	1.50	1.70	0.56	0.71	0.75	0.95	24.52	25.33
Kabra	167.48	27.31	2.05	1.59	0.97	0.63	1.32	0.85	33.28	23.80
Kagey	132.23	111.21	2.40	1.33	1.39	0.34	1.41	0.34	38.98	21.37
Kalojeera	100.00	63.40	1.08	1.26	0.29	0.38	0.56	0.74	17.66	18.65
Kolajoha	69.35	101.46	1.63	1.69	0.65	0.70	0.69	0.75	26.78	25.84
Kalokhasa	37.91	114.82	1.05	1.71	0.23	0.72	0.30	0.96	17.46	25.51
Kalo Nunia	108.38	110.05	1.28	1.45	0.41	0.51	0.69	0.86	20.88	21.53
Kaltury	153.98	131.47	1.39	1.25	0.45	0.38	0.86	0.73	22.49	18.60

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Kataribhog	94.49	81.80	2.13	2.83	1.14	1.88	1.07	1.77	34.94	41.59
Khasa	102.03	71.87	2.16	2.10	1.16	1.10	1.13	1.07	35.25	31.72
Konkonijoha	84.78	105.30	1.70	1.70	0.72	0.72	0.81	0.81	27.86	25.91
Lagidhan	69.59	44.78	1.81	2.42	0.80	1.43	0.77	1.39	29.73	35.99
Mohanbhog	63.00	44.89	1.85	1.73	0.82	0.69	0.75	0.63	30.47	27.06
Muni	131.73	45.42	1.76	1.15	0.75	0.30	1.03	0.42	28.70	17.95
Radhatilak	83.41	89.22	1.89	1.58	0.89	0.58	0.89	0.58	31.07	24.64
Radunipagal	132.57	79.58	1.44	1.27	0.50	0.40	0.85	0.67	23.42	19.06
Rampha	114.74	62.73	1.32	1.19	0.43	0.36	0.73	0.60	21.56	18.03
Silathia Bora	110.69	83.52	2.96	2.43	2.17	1.46	1.61	1.08	48.28	37.29
Tulaipanji	48.98	98.54	1.61	2.17	0.58	1.18	0.55	1.12	26.59	32.75
Tulsibhog	83.44	106.25	1.68	2.00	0.71	0.99	0.80	1.11	27.64	29.91
Range	33.17-216.21	27.32-131.48	0.82-3.49	0.92-4.10	0.16-3.02	0.21-4.10	0.30-1.89	0.34-2.36	13.52-56.94	13.96-60.88
Mean	96.34	79.35	2.00	2.00	1.05	1.08	1.00	1.00	32.74	30.27

STE =Stress tolerance efficiency,MRP = Mean relative performance, REI: Relative efficiency index,YI = Yield index, MPI = Mean productivity index.

Table 4 Best ten performing cultivars under different stress environments based drought tolerance indices

Drought tolerance indices	Farmers' varieties		
	Stress created by spraying KI (S1)	Normal terminal stress (S2)	Common in S1 and S2
Grain yield	Jhagrikartik, Panikuthi Shyamlal,Tulsimukul, Kataribhog, Baigon Machua, Sitalkuchi, Malshira, Ladu, Ghee Bora, Lagidhan	Hatidat Komal, Dubari Komal, Bonnidhan, Garu Chakua, Silathia Bora, Dhyapa, Laldhyapa, Kagey, Kalodhyapa and Kabra	-
Stress tolerance index (STI)	Kashiya Binni, Bora, Muni, Dhyapa, Kagey, Radunipagal, Dubari Komal, Kaltury, Kabra and Bonnidhan	Tulsimukul, Beto, Seshaphal, Jhagrikartik, Sitalkuchi, Kaltury, Kalojeera, Baigon Machua, Kalo Nunia and Kataribhog	Kaltury
Geometric mean of productivity (GMP)	Ladu, Dhyapa, Laldhyapa, Panikuthi Shyamlal, Ghee Bora, Dubari Komal, Silathia Bora, Jhagrikartik, Garu Chakua and Hatidat Komal	Dudhekalam, Ladu, Malshira, Sitalkuchi, Baigon Machua, Kataribhog, Ghee Bora, Tulsimukul, Panikuthi Shyamlal and Jhagrikartik	Ladu, Panikuthi Shyamlal, , Ghee Bora and Jhagrikartik
Stress tolerance (TOL)	Dubari Komal, Bitti, Dhyapa, Bonnidhan, Dudheswar MotaJaswa, Kalshipa, Tulaipanji, Khasa and Dudhekalam	Garu Chakua, Kalo Nunia, Boichi, Khasa, Satia, Kalojeera, Seshaphal, Ladu, Jhapaka and Kataribhog	-
Stress susceptibility index (SSI)	Dubari Komal, Radunipagal, Dhyapa, Tulaipanji, Dudhekalam, Kalshipa, Dudheswar MotaJaswa, Khasa and Rampha	Binni, Garu Chakua, Boichi, Khasa, Satia, Kalojeera, Ladu, Seshaphal, Kataribhog and Jhapaka	-
Stress tolerance efficiency (STE)	Kashiya Binni, Bora, Muni, Dhyapa, Kagey, Radunipagal, Dubari Komal, Kaltury, Kabra and Bonnidhan	Kaltury, Kalokhasa, Badshabhog, Kagey, Kalo Nunia, Sial Bhomra, Jashyopa, Satia, Beto and Tulsibhog	Kaltury
Mean relative performance (MRP)	Dhyapa, Bonnidhan, Laldhyapa, Panikuthi Shyamlal, Ghee Bora, Silathia Bora, Dubari Komal, Jhagrikartik, Garu Chakua and Hatidat Komal	Dudhekalam, Ladu, Malshira, Sitalkuchi, Baigon Machua, Kataribhog, Ghee Bora, Tulsimukul, Panikuthi Shyamlal and Jhagrikartik	Panikuthi Shyamlal, Ghee Bora and Jhagrikartik
Relative Efficiency Index (REI)	Ladu, Dhyapa, Laldhyapa, Panikuthi Shyamlal, Ghee Bora, Dubari Komal, Silathia Bora, Jhagrikartik, Garu Chakua and Hatidat Komal	Dudhekalam, Ladu, Malshira, Sitalkuchi, Kataribhog, Baigon Machua, Tulsimukul, Ghee Bora, Panikuthi Shyamlal and Jhagrikartik	Ladu, Panikuthi Shyamlal, Ghee Bora and Jhagrikartik

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Yield index (YI)	Kashiya Binni, Bora, Muni, Dhyapa, Kagey, Radunipagal, Dubari Komal, Kaltury, Kabra and Bonnidhan	Tulsimukul, Beto, Seshaphal, Jhagrikartik, Sitalkuchi, Kaltury, Kalojeera, Baigon Machua, Kalo Nunia and Kataribhog	Kaltury
Mean productivity index (MPI)	Bonnidhan, Dhyapa, Laldhyapa, Panikuthi Shyamlal, Ghee Bora, Dubari Komal, Silathia Bora, Jhagrikartik, Garu Chakua and Hatidat Komal	Hatidat Komal, Ladu, Malshira, Sitalkuchi, Baigon Machua, Kataribhog, Tulsimukul, Ghee Bora, Panikuthi Shyamlal and Jhagrikartik	Panikuthi Shyamlal, Ghee Bora, Jhagrikartik, Hatidat Komal

of MRP were Dhyapa, Bonnidhan, Laldhyapa, Panikuthi Shyamlal, Ghee Bora, Silathia Bora, Dubari Komal, Jhagrikartik, Garu Chakua, and Hatidat Komal were reported with high MRP under stress created by spraying KI (Table 4). Under normal terminal drought conditions Dudhekalam, Ladu, Malshira, Sitalkuchi, Baigon Machua, Kataribhog, Ghee Bora, Tulsimukul, Panikuthi Shyamlal, and Jhagrikartik were found to have high MPR. The cultivars Panikuthi Shyamlal, Ghee Bora and Jhagrikartik showed high value of MRP under both the stress environments confirming their ability to perform better under drought conditions.

REI varied from 0.16 to 3.02 with a mean of 1.05 under stress created by spraying KI (Table 3). Twenty-three cultivars were found to have higher REI values as compared to the mean value. The high value of REI was observed for Ladu, Dhyapa, Laldhyapa, Panikuthi shyamlal, Ghee Bora, Dubari Komal, Silathia Bora, Jhagrikartik, Garu Chakua and Hatidat Komal under stress created by spraying KI (Table 4). Under normal terminal drought stress conditions the REI values varied from 0.21 to 4.10 with a mean of 1.08 (Table 4). The cultivars Dudhekalam, Ladu, Malshira, Sitalkuchi, Kataribhog, Baigon Machua, Tulsimukul, Ghee Bora, Panikuthi Shyamlal, and Jhagrikartik exhibited high value for REI. The cultivars that performed well under both stress conditions were Ladu, Panikuthi Shyamlal, Ghee Bora, and Jhagrikartik.

Yield Index (YI)

YI varied from 0.30 to 1.89 with a mean of 1.00 under stress created by spraying KI (Table 4). Twenty-eight cultivars had YI values of more than 1.00. Top ten cultivars having high YI were Kashiya Binni, Bora, Muni, Dhyapa, Kagey, Radunipagal, Dubari Komal, Kaltury, Kabra and Bonnidhan under stress created by spraying KI (Table 4).YI varied from 0.34 to 2.36 with a mean of 1.00 under normal terminal drought. Tulsimukul, Beto, Seshaphal, Jhagrikartik, Sitalkuchi, Kaltury, Kalojeera, Baigon Machua, Kalo Nunia, and Kataribhog showed high YI value under terminal drought. Kaltury performed well in stressed conditions in respect of YI (Table 4).

Mean Productivity Index (MPI)

MPI varied from 13.52 to 56.94 with a mean of 32.74 under terminal drought created by spraying KI and 13.96 to 60.88 with a mean of 30.69 under normal terminal drought stress conditions (Table 3). Thirty cultivars had MPI more than the mean under the drought created by spraying KI as well as under normal terminal drought stress. The top 10 cultivars that had high MPI values under drought created by spraying KI were Bonnidhan, Dhyapa, Laldhyapa, Panikuthi Shyamlal, Ghee Bora, Dubari Komal, Silathia Bora, Jhagrikartik, Garu Chakua and Hatidat Komal (Table 4). The top 10 cultivars that had higher MPI values under normal terminal drought were Hatidat Komal, Ladu, Malshira, Sitalkuchi, Baigon Machua, Kataribhog, Tulsimukul, Ghee Bora, Panikuthi Shyamlal and Jhagrikartik. Among those cultivars, Panikuthi Shyamlal, Ghee Bora, Jhagrikartik, and Hatidat Komal were common in both environments (Table 4).

Common Cultivars under Both the Drought Conditions

Ten best performing genotypes under different stress environments of each drought index were listed in Table 4. The genotype(s) listed under both environment may be considered drought tolerant. Based on indices, namely GMP, MRP, REI, and MPI three rice cultivars, viz. Panikuthi Shyamlal, Ghee Bora and Jhagrikartik were listed under drought conditions and those cultivars may be considered as drought tolerant. Kaltury performed well under both the stressed environments based on STI, STE, and YI. Ladu also showed higher values in the desirable direction in respect of GMP and REI. Those drought-tolerant cultivars may be used for further improvement of rice as donors against drought conditions.

DISCUSSION

Our study showed a decrease in mean grain yield in both drought conditions by 21.42% and 6.81%, respectively. Reduction in grain yield under drought environments had been observed by many researchers [6, 15]. Jhagrikartik, Ghee Bora, Panikuthi shyamlal and Tulsimukul performed well under stress conditions created by spraying KI, however, the cultivars Hatidat Komal, Garu Chakua and Silathia Bora performed well under terminal drought stress environment. These three cultivars were reported to be highly lodging susceptible under non-stress condition [5]. The lodging susceptibility of those cultivars were be due to luxurious growth under stress-free environment leading to reduction of grain yield. But, Hatidat Komal and Garu Chakua were reported to be highly lodging tolerant and Silathia Bora was found to have moderately lodging susceptible under a normal terminal drought stress environment by Debbarma and Roy [5]. None of that cultivar performed well in both the stressed environments.

The overall mean yield in the drought-free environment was the highest followed by normal terminal drought and the lowest was obtained when drought was created by spraying KI (Table 2). The reasons in the reduction in yield in the KI sprayed drought situation may be that KI acts as a desiccant and inhibits photosynthesis and reduce chlorophyll content without a detrimental effect on the translocation of assimilates to developing grains. It resembles the terminal drought stress on physiological and biochemical parameters leading in leaf senescence (Sawhney and Singh 2002). Moreover, KI sprayed plots were irrigated as and when required. The growth of the plant I those plots was normal and luxurious which made the plant's lodging susceptible leading to a reduction in plant yield [5]. This technique has been extensively employed for large-scale field evaluation of genotypes for tolerance to terminal drought in rice [2, 26].

The traditional cultivars that showed higher SIT values under terminal drought conditions may be considered tolerant. Khan and Dhruve [13] also suggested that the rice genotypes with high SIT values indicate tolerance to drought. Kalturey showed higher SIT values under both terminal drought environments. High GMP values are considered to be suitable when the breeding objective is set for testing the performance of the cultivars under normal and drought conditions [13]. The cultivars Ladu, Panikuthi Shyamlal, Ghee Bora and Jhagrikartik showed high value of GMP under both the stress environments (Table 5). STI and GMP was used to identify cultivars that yield practically well under both drought and normal conditions. GMP is suitable when the breeding objective is directed toward testing the performance under normal and drought conditions [19]. Based on STI and GMP the rice cultivars Kalturey, Ladu, Panikuthi Shyamlal, Ghee Bora, and Jhagrikartik were considered as potential performers under terminal drought conditions. A high STI indicates a high tolerance [10, 13, 16, 27], thus Kalturey may be considered a terminal drought cultivar. As per the opinion of Fernandez [7], STI and GMP may be used for screening rice cultivars for moisture stress.

TOL and SSI are useful for the identification of stress-tolerant cultivars that performing well in drought environments [27]. Higher values of TOL indicated the drought susceptibility of the cultivars and they are non-suitable for drought conditions [10]. Low values of TOL may be useful for selecting more stable cultivars under drought and non-drought situations [13]. The best 10 cultivars that showed the low value of TOL were Dubari Komal, Bitti, Dhyapa, Bonnidhan, Dudheswar Mota Jaswa, Kalshipa, Tulaipanji, Khasa and Dudhekalam under created by spraying KI. The rice cultivars Garu Chakua, Kalo Nunia, Boichi, Khasa, Satia, Kalojeera, Seshaphal, Ladu, Jhapaka, and Kataribhog were found to be tolerant under terminal drought stress. None of the rice cultivars performed well in both the stressed environments. Similar research also has been conducted by many researchers [10, 17, 28]. As outlined by Kumar et al. [14]and based upon the value and direction of desirability, the ranking was done for different cultivars. Lower values of SSI are also an indication of tolerance of cultivars under drought conditions [10, 13]. Twenty-two rice cultivars were categorized as highly drought tolerant (SSI<0.50), two drought tolerant (SSI between 0.51 and 0.75), six cultivars were moderately drought tolerant (SSI between 0.76 and 1.00), and the remaining 29 cultivars were drought susceptible (SSI>1.00) under stress created by spraying KI (Table 3). Under normal terminal drought stress conditions 29 cultivars were highly drought tolerant, one was drought tolerant, two cultivars were moderately drought tolerant and the remaining 27 cultivars were drought susceptible (Table 3).Chauhan et al. [3] also suggested that the rice cultivars having SSI<1.0 can be considered drought tolerant because they exhibited smaller yield reductions or no yield reduction. The results of this study are in agreement with the earlier findings [1, 10, 13, 14].

Best 10 cultivars that showed high STE value under artificially created terminal drought conditions using KI were Kashiya Binni, Bora, Muni, Dhyapa, Kagey, Radunipagal, Dubari Komal, Kaltury, Kabra, and Bonnidhan. Thirty-one cultivars showed higher vale than the mean under normal terminal stress conditions. Best 10 cultivars that showed high STE value under normal terminal drought were Tulsimukul, Beto, Seshaphal, Jhagrikartik, Sitalkuchi, Kaltury, Kalojeera, Baigon Machua, Kalonunia, and Kataribhog. Only Kaltury was recorded as tolerant in both drought situations.

Cultivars with high MRP and REI were considered to be tolerant. MRP is the mean yield for a genotype in drought and drought-free conditions. The cultivars Panikuthi Shyamlal, Ghee Bora, and Jhagrikartik showed a high value of MRP under both the drought environments confirming their ability to perform better under drought conditions. However, as per the suggestion by Anitha et al. [1], both MRP and REI are not very effective in distinctively discriminating cultivars that perform well under both normal and drought. MRP can select genotypes with high Y_P but with relatively low Y_S [16]. The cultivars that performed well under drought conditions based on REI value were Ladu, Panikuthi Shyamlal, Ghee Bora, and Jhagrikartik. Based on MRP and REI values, the cultivars Panikuthjrugui Shyamlal, Ghee Bora, and Jhagrikartik were found to have a high tolerance ability to perform better under terminal drought conditions.

The cultivars that exhibited YI values >1.00 may be suitable for a terminal drought environment (Garg and Bhattacharya 2017). A Higher YI value was observed for 23 rice cultivars. Kalturey was found to have high YI under both drought environments indicating its tolerant ability to augment the yield. Anitha et al. [1] and Khan and Dhruve [13] also suggested that the cultivars exhibiting high under drought conditions may be identified as tolerant. For severe and recurrent drought-prone regions, cultivars with high YI may be selected for cultivation.

MPI is relevant for selecting cultivars for the reproductive drought in rice [1, 13]. Among those cultivars, Panikuthi shyamlal, Ghee Bora, Jhagrikartik, and Hatidat Komal were the common cultivars that performed well in both environments indicating their tolerance ability under terminal drought conditions.

Finally considering GMP, MRP, REI, and MPI, three rice cultivars, namely Panikuthi Shyamlal, Ghee Bora, and Jhagrikartik were listed under both the drought conditions and those cultivars may be considered as drought tolerant. Kaltury accomplished well under both the stressed environments based on STI, STE, and YI. Ladu also showed higher values in the desirable direction in respect of GMP and REI. So, Panikuthi Shyamlal, Ghee Bora, Jhagrikartik, Kaltury, and Ladu may be considered drought tolerant. Previously many researchers used drought tolerant indices for screening of tolerant genotypes of rice [1, 10, 13, 15, 27]. The above-mentioned traditional rice cultivars were drought tolerant and also exhibited high yield in both the terminal drought conditions and non-stress conditions. These five cultivars belong to different districts of West Bengal state and they are popular in the respective district for their eating quality and pup rice. Further, those drought-tolerant cultivars may be used for the improvement of rice as donor against drought conditions.

The use of KI for the creation of artificial drought has proven to be a novel technology for screening tolerant rice cultivars. The application of KI to create drought conditions by enhancement of the senescence of plants is supported by the earlier finding of many researchers [5, 25, 26, 29].

CONCLUSIONS

Water stress at the reproductive phase is important in many long-duration rice-growing areas. Nine drought tolerant indices, viz. STI, GMP, TOL, SSI, STE, MRP, REI, YI, and MPI were used to find out the better-performing rice cultivars. Jhagrikartik, Ghee Bora, Panikuthi Shyamlal, Kaltury, and Ladu were screened as drought tolerant using different indices. None of the index provided matching results with any other of the indices. Another novel finding of this endeavour is the use of potassium iodide to create artificial drought situations for screening tolerant genotypes in addition to the normal drought environment. It can be concluded that the tolerant indices used in this endeavour may be used for screening of rice genotypes to identify the drought-tolerant genotypes.

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