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Yield Benefit of Selected Rice Landraces under Drought Stress at Germination

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Abstract: In this era of continuous industrialization and deforestation, where climate change is inevitable, adequate cereal crop production to meet global hunger is extremely difficult. Drought is one of the most alarming constraints to rice production. The purpose of this study was to assess the drought tolerance ability of six rice landraces grown in the western lateritic area of West Bengal along with an already established drought-tolerant variety. Drought stress was induced on the seeds during germination using Poly-Ethylene-Glycol (PEG) at three different concentrations (5, 10, and 20%). Morphological and biochemical parameters like germination percentage, root length, root-shoot ratio, proline accumulation, survivability was estimated after 10 days of treatment. Under stress, land races accumulated more amount of proline indicating better tolerance. The stress induction at the germination stage reduced the yield of 3 landraces by 8-10% whereas production of the check variety was reduced by 20%.These landraces were collected from rural areas where farmers do not cultivate them commercially but maintain them each year traditionally. These landraces if involved in breeding programs can be modified to develop high-yielding, true-drought-tolerant, climate-resilient variety that can ultimately benefit the farmers in coming days.

Keywords: Rice landrace, Drought stress, Poly-ethylene-glycol, Proline content, Yield

Rice (*Oryza sativa* L.) is one of the most important staple foods in the world, specifically in South and Southeast Asia that alone contributes to more than 20% of the global dietary energy supply (Panda et al 2021, De et al 2022). After China, India ranks second in the world in rice production, and West Bengal is known as the "bowl of rice" because it has the most agricultural land dedicated to rice cultivation (Mishra and Sinha 2012). The western part of West Bengal, comprises of red lateritic plateau area, is no exception when it comes to rice cultivation and faces physiological drought condition due to the low water holding capacity of the soil. Not only that, due to climate change and other pollution related reasons, the erratic rainfall pattern also causes a massive decline in *kharif* rice production in the upland areas where farming is totally rainfall dependent. Around 60% rainfall occurs within the first 14 rainy days, so the rainfall during the germination and seedling growth (July-September) is not enough for the optimum yield of Kharif rice (Ministry of Agriculture and Farmers Welfare, GOI, 2011). Rahman and Zhang (2016) observed that no true drought tolerant variety has been identified till date that can withstand drought at varying degrees (mild to severe) and at any growth stage. So, there is an urgent need to develop climate-resilient, high-yielding, true-drought-tolerant variety. Landraces are the most unexploited section and can be used as the donor of drought tolerance capacity. They are the store-hub of various biotic and abiotic stress-tolerant factors. The main aim of this study was to assess the drought tolerance capacity of six landraces collected from Purulia, Bankura (Western part of West Bengal) and subject them to drought stress at different degrees at germination stage and study their physiological, biochemical and agro-morphological parameters to analyze their productivity and stress tolerance.

MATERIAL AND METHODS

Plant materials: Seven germplasms were collected for this study, of which six are landraces namely, Vutmuri, Langalmathi, Bhuri, Lohasal, Aswinsal, Tulsikamal and an already established drought tolerant variety, Sahabhagidhan; collected from various farmers of Purulia and Bankura districts in West Bengal (Fig. 1).

Stress induction at germination stage: PEG (Poly-ethylene-glycol) was used to mimic the drought condition. Stress effect was imposed at three levels including a control set (Table 1).

Physiological, biochemical, and agronomic parameters: Previous reports showed that germination percentage (GP), root length (RL), root-shoot ratio (R:S) had direct correlation with drought tolerance (Pandey and Shukla 2015). Similarly, over accumulation of an amino acid, proline provides resistance against water scarcity (Mishra et al 2018). Decrease in total chlorophyll (Chl) content of a plant under stress is also reported (Pandey and Shukla 2015). These characters were estimated for the germplasms after 10 days of treatment at each stress level as well as for the control set. After treating them they were shifted to polyhouse in plastic pots and normal watering was done. Their survivability percentage (SP) were recorded after 7 days of normal watering. Yield has been considered as a definitive character to identify drought tolerant germplasm, so the treated plants were grown till harvesting and various agro-morphological characters like number of tillers, panicle length and seed yield/plant were recorded.

Statistical analysis: The treatments were designed based on a complete randomized design of two factors. One factor used the germplasms and the second factor was dry stress at different levels with three replications. Association within the characters and with drought stress was studied by using Pearson's correlation matrix. SPSS software, Ver. 18 was used for statistical analysis.

RESULTS AND DISCUSSION

Variability study: Synergistic effect of both stress and germplasms significantly varied for each of characters at 0.01% level of significance.

Germination percentage: Rate of germination reduced as drought severity increased. Germination percentage was 100% for all the germplasms in control. At mild stress the established variety, Sahabhagidhan and three landraces Vutmuri, Aswinsal, and Tulsikamal showed 100% GP. But at 10% and 20% PEG treatment GP of Sahabhagidhan reduced to 80% and 60% respectively. Under severe stress highest GP was observed in Tulsikamal (90%) followed by Vutmuri, Aswinsal. Lohasal (80%). Only 1 landrace Bhuri did not survive this condition and died with no germination. This result corroborated with Purbajanti et al (2019).

Root length: Root length decreased as stress increased. At 5% stress RL was highest in Vutmuri, a landrace followed by the established variety. In moderate and severe condition highest RL was observed in landraces like Vutmuri, Aswinsal and Tulsikamal. Similar observations were also observed earlier scientist (Panja et al 2017, Saha et al 2019, Nasrin et al 2020).

Root: shoot: This ratio increased as stress increased. Under severe stress the R:S ratio was highest in Vutmuri which indicated RL was 6.15 times higher than the SL. Increase in root: shoot ratio indicates that food reserves are mostly invested in elongation of root as compared to shoot by altering carbohydrate partitioning (Xu et al 2015).

Proline content: Over accumulation of this amino acid provides stress tolerance by maintaining turgor pressure and acts as an excellent osmolyte. Highest amount of proline accumulation was in Vutmuri in all stress condition. The established variety showed higher proline content under mild stress, but in moderate and severe stress other landraces like Tulsikamal and Aswinsal showed higher values. Similar findings are also supported by Dien et al (2019).

Total chlorophyll: Total chlorophyll decreased as stress increased for all the germplasms. Though the landraces had higher amount of chlorophyll as compared to the established variety under stress condition. Stability of chlorophyll has direct effect on grain yield (Nahakpam et al 2015).

Survivability percentage: After normal watering SP was highest in landraces as compared to the established varieties.

Table 1. Osmotic potential and severity of stress at different concentrations of PEG

PEG concentration	Osmotic potential (bar)	Severity of stress
0%	0	Control or no stress
5%	-0.49	Mild stress
10%	-1.48	Moderate stress
20%	-4.91	Severe stress

Table 2. Character with synergistic effect of germplasms and PEG concentration

Source	Dependent variable	F-value	Significance
Intercept (PEG and Germplasms)	Germination percentage	935.112	.000*
	Root length	547.632	.000*
	Root:Shoot	113.179	.000*
	Proline under stress	479.287	.000*
	Total Chl	1118.090	.000*
	Survivability percentage	1289.826	.000*
	No of tillers	1018.677	.000*
	Panicle length	561.634	.000*
	Seed yield/plant	1220.290	.000*

*significantly different at 0.01 % level (P < 0.001)

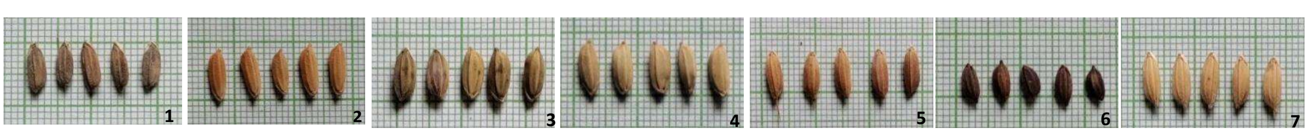

Fig. 1. Seven germplasms: 1-Vutmuri; 2- Langalmathi; 3- Bhuri; 4- Lohasal; 5- Aswinsal; 6- Tulsikamal; 7- Sahabhagidhan

Other agro-morphological characters: No of tillers, Panicle length and seed yield/plant decreased with stress. Under severe stress seed yield of Sahabhagidhan reduced by 20% whereas reduction in Tulsikamal, Aswinsal, Vutmuri was 8, 9, 10% respectively.

Correlation study: Pearson's Correlation study provides a complete knowledge on inter-relationship of characters. Negative significant correlation between PEG concentration and GP, RL, Total Chl, SP, no of tillers, PL, and seed yield/plant was found. Positive significant correlation was observed between PEG stress and R:S, Proline content. Association between seed yield and other characters under

Table 3. Agro-morphological and biochemical parameters for each germplasm under no stress or control condition

Germplasm	Germination (%)	RL	R:S	Proline (ug/ml)	Total Chl	Survivability (%)	No. of tillers	Panicle length (cm)	Seed yield/ plant (g)
Sahabhagidhan	100	6.3	1.30	101.57	4.3	100	10	22.4	22.59
Vutmuri	100	6.5	1.62	96.91	4.7	100	12	23.1	20.91
Langalmathi	100	6.9	1.16	88.88	5.4	100	12	28.2	22.44
Bhuri	100	7.4	1.33	80.50	5.5	95.99	12	29.1	18.82
Lohasal	100	6.5	1.31	88.56	4.5	98.89	12	25.5	18.02
Aswinsal	100	7.1	1.18	90.49	4.8	100	14	24.0	19.44
Tulsikamal	100	5.6	0.99	97.65	5.1	100	10	19.2	20.09

Table 4. Agro-morphological and biochemical parameters for each germplasm under mild stress condition (5% PEG mild stress)

Germplasm	Germination (%)	RL	R:S	Proline (ug/ml)	Total Chl	Survivability (%)	No. of tillers	Panicle length (cm)	Seed yield/ plant (g)
Sahabhagidhan	100	6.0	1.65	205.12	4.0	77.50	10	21.9	21.90
Vutmuri	100	6.1	2.10	211.23	4.0	90.50	9	24.5	19.98
Langalmathi	80	4.1	0.94	131.08	3.9	82.15	8	25.5	20.21
Bhuri	70	3.5	0.81	101.01	3.0	71.01	7	23.1	14.09
Lohasal	90	4.5	1.10	166.49	3.9	85.11	10	22.1	16.10
Aswinsal	100	5.9	1.81	172.84	4.0	90.00	12	22.1	18.99
Tulsikamal	100	5.1	1.51	197.25	4.4	90.50	10	19.2	19.85

Table 5. Agro-morphological and biochemical parameters for each germplasm under moderate stress condition (10% PEG moderate stress)

Germplasm	Germination (%)	RL	R:S	Proline (ug/ml)	Total Chl	Survivability (%)	No. of tillers	Panicle length (cm)	Seed yield/ plant (g)
Sahabhagidhan	80	2.9	2.00	216.87	3.2	85.13	8	18.3	18.22
Vutmuri	100	3.6	2.55	230.11	3.9	88.50	9	20.4	19.00
Langalmathi	50	2.4	1.29	179.98	3.1	75.25	6	15.5	17.09
Bhuri	50	0.5	0.6	129.10	2.1	45.25	4	21.8	11.12
Lohasal	90	3.3	2.10	172.67	2.8	65.81	8	22.1	14.71
Aswinsal	100	3.6	1.84	222.98	3.1	85.90	10	22.0	18.10
Tulsikamal	100	3.5	2.11	228.12	3.2	85.22	8	19.0	19.00

Table 6. Agro-morphological and biochemical parameters for each germplasm under severe stress condition (20% PEG severe stress)

Germplasm	Germination (%)	RL	R:S	Proline (ug/ml)	Total Chl	Survivability (%)	No. of tillers	Panicle length (cm)	Seed yield/ plant (g)
Sahabhagidhan	60	1.2	2.75	249.35	2.3	67.01	5	16.8	18.07
Vutmuri	80	1.5	6.15	288.50	2.8	77.50	9	21.6	18.81
Langalmathi	40	0.2	1.05	225.78	2.1	55.70	5	16.3	14.36
Bhuri	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Lohasal	80	0.9	3.43	200.90	2.1	45.35	6	19.3	14.05
Aswinsal	80	3.4	2.41	256.11	2.5	75.91	8	20.6	17.50
Tulsikamal	90	3.2	1.61	270.35	2.8	78.21	8	17.9	18.48

Table 7. Pearson's correlation matrix

Parameters	PEG	Germination (%)	RL	R:S	Proline	Total Chl	Survivabilty (%)	No. of tillers	Panicle length	Seed yield/plant
PEG	1									
Germination (%)	-.591**	1								
RL	-.892**	.790**	1							
R:S	.409*	.221	-.208	1						
Proline	.624**	.156	-.348	.673**	1					
TotalChl	-.870**	.817**	.914**	-.095	-.228	1				
Survivabilty (%)	-.704**	.884**	.838**	.089	.073	.917**	1			
No. of tillers	-.763**	.888**	.901**	.080	-.102	.901	.915**	1		
Panicle length	-.611**	.766**	.673**	.129	.010	.771	.758**	.764**	1	
Seed yield/plant	-.511**	-.840**	.684**	.260	.292	.804**	.925**	.796**	.732**	1

*significant at 5%, **significant at 1% level

stress is of paramount importance as yield is the definitive character for selection to the breeder in drought condition. Seed yield/plant showed a high positive significant correlation with RL, Total Chl, No of Tillers, PL. So direct selection for these characters will be beneficial for choosing under stress.

CONCLUSION

Landraces like Vutmuri, Tulsikamal and Aswinsal showed better performance for almost all the parameters under moderate and severe stress as compared to Sahabhagidhan, the established drought-tolerant variety. Though in mild stress Sahabhagidhan showed higher yield, but as water scarcity increased the landraces were found to have more grain production. These three landraces can be used as donor parents in different breeding programs for developing high-yielding, drought-tolerant, climate-resilient lines. These can also be studied further for presence of any major QTL (Quantitative trait loci) directly associated to drought tolerance.

AUTHORS CONTRIBUTION

ADe conducted experiments and collected the data from the field, worked out data curation and formal analysis, and wrote the manuscript. A Dey devised and designed the research, supervised the research, and reviewed the manuscript. AK Sinha provided the experimental materials. S Raha and D Kar provided facilities and edited the manuscript.

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