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Agronomic evaluation of rice (*Oryza sativa*) landraces for sustainable crop resilience in a changing climate

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Global warming has emanated a seasonal shift giving rise to erratic rainfall, and temperature fluctuations in several parts of the world leading to crop loss (Panda *et al.* 2021). Rice (*Oryza sativa* L.) varieties grown in rainy (*kharif*) season face scattered rainfall (hydrological drought), as well as physiological drought due to low water holding capacity of the lateritic soil of Purulia (eastern part of Chota-Nagpur plateau), West Bengal, India. The existing high-yielding drought-resistant established rice varieties are not true-drought-tolerant (Rahman and Zhang 2016). On the other hand, landraces are less productive but are highly tolerant to biotic and abiotic stresses (Mishra *et al.* 2018). This study aims to explore the agronomic performance of selected landraces, to better understand the drought resistance mechanism in rice and selection of some landraces for breeding programs to develop true-drought tolerant lines.

A study was carried out at Zonal Drought Resistance Paddy Research Station, Hathwara, Purulia, West Bengal during rainy (*kharif)* seasons of 2021 and 2022 to evaluate the agronomic performance of selected rice landraces, known for their tolerance to stress. The landraces were collected from the farmers of different villages in Purulia and Bankura. Seven released varieties and 22 landraces were used for the present research (Supplementary Table 1). Data on rainfall and temperature patterns from 2014–22 as well month wise rain fall patterns during 2021 and 2022 in Purulia were collected from the Bureau of Applied Economics and Statistics, Govt. of West Bengal (Supplementary Fig 1 and Supplementary Table 2) which supports erratic rainfall pattern in this district. Data shows that precipitation was way less in 2021 but sufficient in 2022. Total 29 germplasms were direct-seeded at two different locations in Zonal Drought Resistance Paddy Research Station, Hathowara, Purulia, Govt. of West Bengal in 3 replications following a Randomised Block Design. Agronomic parameters like Plant height (PH), No of tillers (NT), No of panicles (NP), Panicle length (PL), Days to 50% flowering (DF), Days to maturity (DM), Root length (RL), Leaf rolling (LR), Leaf drying (LD), No. of total grains, filled grains and unfilled grains per panicle (TG/P, FG/P and UG/P respectively), Spikelet fertility (SF), 1000-seed weight (1000SW) and Seed yield/plant (SY/P) were recorded. Proline and chlorophyll content were estimated from germplasms showing higher yield following the protocol by Bates *et al.* (1973) and Arnon (1949) respectively. Pooled data were used for Analysis of Variance (ANOVA), correlation and cluster analysis using PASW ver. 2018. Mean, coefficient of variation (CV), phenotypic and genotypic coefficient of variation (PCV and GCV), heritability (h^2), genetic advance (GA), and critical difference (CD) for seed yield were worked out.

Variability in characters: Observable differences for all the traits within germplasms were significant at 1% and 5% levels of significance (Supplementary Table 3). PCV was higher than GCV for all the characters indicating the presence of environmental influence (Table 1). Out of them, PCV was much higher in leaf rolling and Leaf drying showing high involvement of environmental effects. The heritability was very low for LR but high in LD, though their genetic advance was too low. These two characters were governed by non-additive gene action and selection would not be fruitful. Similar result was also demonstrated by Garg *et al.* (2017). PCV was slightly higher than GCV in NT, NP, RL, and UG/P indicating little environmental interference. High heritability coupled with low GA indicated non-additive gene action. Except for UG/P where the GA was moderate proved that additive gene action was present. For the rest of the characters; PH, PL, DF, DM, TG/P, FG/P, SF, 1000SW, and SY/P there was no such difference between PCV and GCV. High heritability and low GA of PL, 1000SW, and SY/P indicated non-additive gene action. But PH, DF, DM, TG/P, FG/P, and SF showing high heritability and moderate to high GA are governed by

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Table 1 Various genetic parameters in different traits of rice germplasms

Characters	Mean	Range		CV		h^2	GA	GA as a per cent of mean
		Max	Min	PCV	GCV			
PH	123.70	170.33	84.33	17.27	17.01	97.03	42.06	11.33
NT	9.57	14.33	4.67	26.40	23.09	76.53	3.49	12.13
NP	8.21	12.00	4.33	27.19	23.04	71.83	2.80	11.36
PL	24.01	28.33	16.33	13.36	12.26	84.28	5.11	7.10
DF	89.57	122.67	56.33	18.77	18.71	99.41	34.33	12.78
DM	116.53	141.33	88.00	13.25	13.18	99.05	31.35	8.97
RL	22.85	29.00	14.67	18.75	15.77	70.76	5.25	7.66
LR	5.75	8.33	2.33	39.56	19.78	25.00	0.59	3.40
LD	4.86	8.33	1.00	51.86	46.56	80.60	3.76	25.77
TG/P	137.05	200.33	84.67	19.63	17.34	78.03	38.20	9.29
FG/P	106.17	151.67	62.67	22.34	20.18	81.57	36.00	11.30
UG/P	30.87	59.67	13.67	46.35	40.61	76.77	19.83	21.41
SF	77.53	88.63	52.76	12.33	11.06	80.42	14.20	6.11
1000-SW	24.27	36.98	14.73	22.52	20.73	84.70	8.78	12.06
SY/P	22.75	26.55	16.93	14.00	12.01	73.59	4.14	6.07

Refer to the Methadology for characters detail.

Table 2 Correlation coefficient matrix for the parameters of rice landraces

Trait	PH	NT	NP	PL	DF	DM	RL	LR	LD	TG/P	FG/P	UG/P	SF	1000SW	SY/P
PH	1														
NT	.213	1													
NP	.266	.947**	1												
PL	.778**	.245	.227	1											
DF	.310	-.206	-.210	.095	1										
DM	.339	-.185	-.197	.162	.977**	1									
RL	.265	.583**	.656**	.263	-.262	-.247	1								
LR	-.246	-.267	-.320	-.118	.190	.247	-.445*	1							
LD	-.036	-.176	-.304	-.013	.263	.245	-.477**	.124	1						
TG/P	-.020	-.205	-.149	-.020	.206	.191	-.209	.152	-.159	1					
FG/P	.141	-.063	.013	.090	.077	.075	.042	-.193	-.314	.850**	1				
UG/P	-.276	-.281	-.304	-.191	.259	.234	-.466*	.613**	.230	.454*	-.084	1			
SF	.358	.281	.335	.258	-.180	-.156	.486**	-.639**	-.391	-.021	.504**	-.891**	1		
1000SW	.309	.252	.275	.327	.001	.016	.260	-.372*	-.034	-.142	.045	-.345	.321	1	
SY/P	.255	.279	.341	.156	-.063	-.069	.561**	-.755**	-.327	.030	.479**	-.752**	.880**	.326	1

*Significant at 5% level; **significant at 1% level. Refer to the methodology for trait details.

additive gene action and can be selected for improvement. These findings are broadly in agreement with the findings of Kumar *et al.* (2018) and Aravind *et al.* (2022).

Correlation studies: Pearson's correlation matrix (Table 2) showed positive and significant correlations between PH and PL and between NP and RL. Saha *et al.* (2019) and Aravind *et al.* (2022) found similar results. NT was also significantly correlated with NP and RL. According to Zhao *et al.* (2022) higher root length, root width, and root area contribute to higher no of tillers in rice. A positive correlation between RL and SF; LR and UG/P, TG/P and FG/P; FG/P and SF implies that better root system along with other tolerance traits improves spikelet fertility and number of filled grains (Lekshmy *et al.* 2022). Higher RL with lower LR and LD scores produced lower UG/P and showed better drought tolerance. LR was negatively correlated with SF and 1000SW. SY/P was positively correlated with RL (Liao *et al.* 2022), FG/P (Chinaworn *et al.* 2023), 1000SW (Shivani *et al.* 2021), and negatively correlated with LR (Kumar *et al.* 2014) and UG/P (Ratna *et al.* 2015).

Cluster analysis: Based on all the agronomic parameters germplasms were grouped into two main clusters (Fig 1). Cluster I comprised five established varieties and four landraces. Whereas in Cluster II there were two sub-clusters;

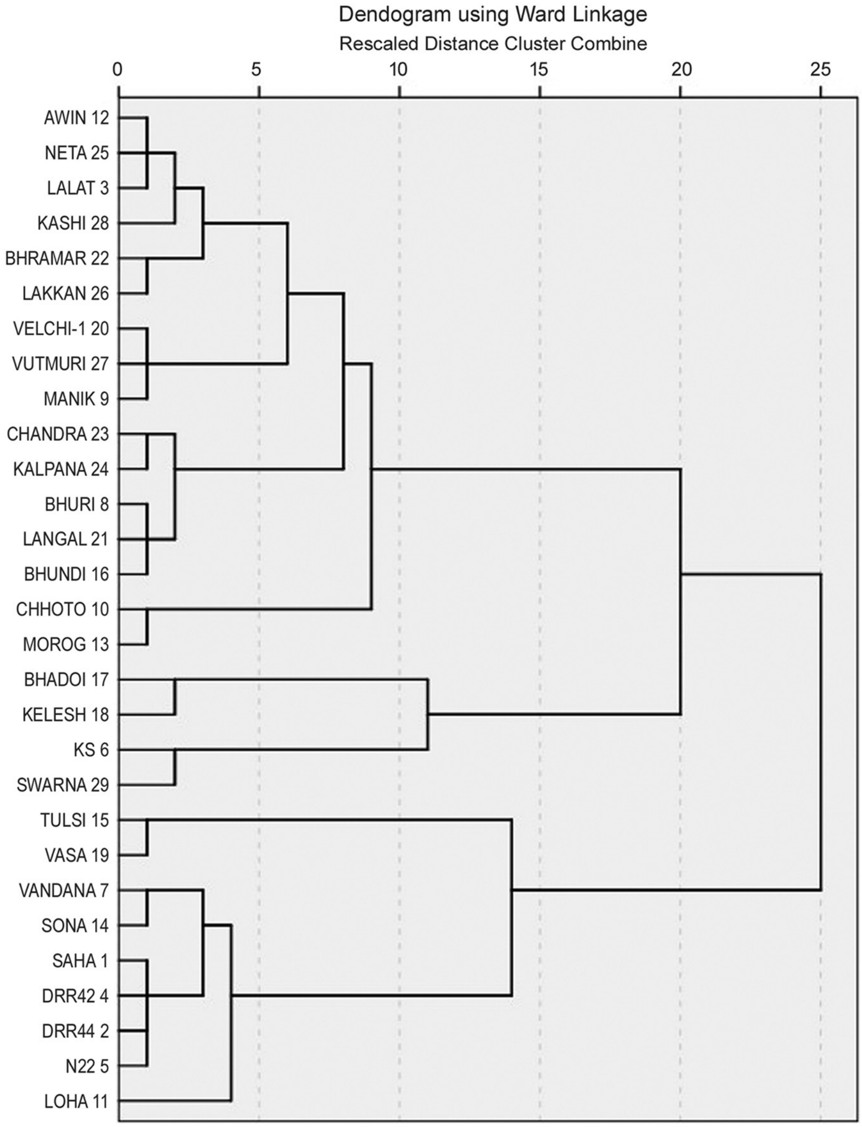

Fig 1 Dendrogram of the germplasms based on the agro-morphological characters using PASW statistics version 2018.

the least yielders and lowest performing germplasms like Bhadoi, Kelesh, Kerala Sundari, and Swarna were in subcluster-I and the rest of the germplasms were grouped in subcluster-II.

Selection of plants based on CD value of yield: Yield being the most crucial factor under water stress, selection of the highest yielding germplasms was done based on the CD value (Supplementary Table 4). Eleven germplasms were found which could be categorized within a single highest-yielding group, i.e. Kalpana, Chhotodidi, Nagina22, Morogjhota, Langalmathi, Sonagori, Maniksal, DRR44, Kelesh, Chandrakanti and Sahabhagidhan.

Biochemical analysis: Proline content was highest in Chhotodidi, followed by Kalpana, N22 and DRR44 (Fig 2). In this set of germplasms, DM ranged between 88–141.33 days. Based on their maturity, there are early (<100), medium (100–120), and late (>120) varieties. It was observed that the medium and late-maturing varieties had higher proline content as compared to the early maturing varieties. Proline content is higher under water stress to provide the plant with tolerance against adverse situations (Abdula *et al.* 2016, Dien *et al.* 2019). The germplasms maturing late, possess tolerance mechanism whereas the early varieties follow escape mechanism.

Total chlorophyll varied from 3.57–6.34. Kalpana had the highest amount of chlorophyll followed by N22, Chhotodidi, Morogjhota, Maniksal, and DRR44 (Fig 2). Higher chlorophyll content leads to higher production.

Selection of germplasms based on characters like plant height, days to 50% flowering, days to maturity, no. of total grain/panicle, no of filled grain/panicle and spikelet fertility, having higher variability, heritability, and genetic advance can be opted in the field of plant breeding. Selection for root length, no. of filled grains/panicle and 1000-seed weight having positive and significant correlation with seed yield/plant will also be helpful. Landraces like Kalpana, Chhotodidi, Morogjhota, Langalmathi, Sonagori, Maniksal, Kelesh, and Chandrakanti along with established varieties like DRR44 and Sahabhagidhan produced high seed yield/plant under rainfed upland situation where abundance of physiological drought always affects plant growth. Crossing within only the improved varieties will eventually result in a situation where yield parameters reach a plateau. Incorporation of new genetic variation can be

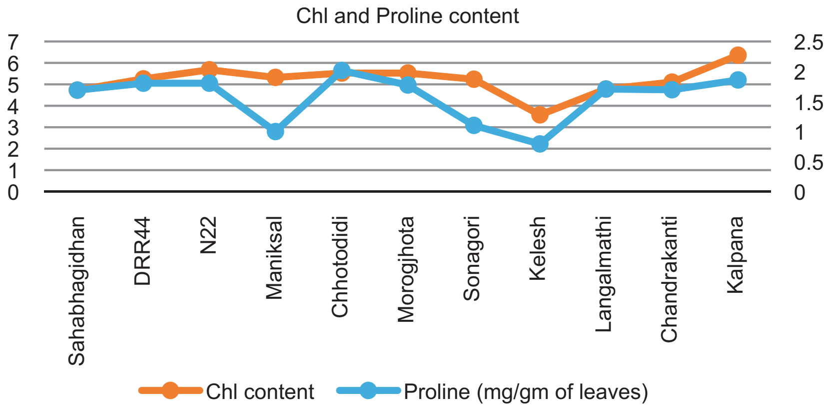

Fig 2 Total chlorophyll content and proline content in the germplasms.

done if landraces and wild varieties are used in breeding programs as they possess various biotic and abiotic stress tolerance genes. In this study, these landraces showing better performance under water stress can be selected for varietal development to produce high-yielding drought-tolerant lines. Conservation of such germplasms is also needed to check the biodiversity loss. Further research on landraces at molecular level might lead to discovery of major and minor genes associated to drought stress.

SUMMARY

Water scarcity and the adverse effects of climate change have significant impact on rice cultivation, leading to declining yields worldwide. The study focuses on red lateritic zone of West Bengal, where irregular rainfall and low water retention pose formidable challenges for farmers. The study was carried out at Zonal Drought Resistance Paddy Research Station, Hathwara, Purulia, West Bengal during 2021 and 2022 to evaluate the agronomic performance of selected landraces, known for their tolerance to stress. Characters like plant height, days to maturity, total grain/plant, filled grains/plant, and spikelet fertility showed positive correlations with seed yield. Proline content and chlorophyll levels were higher in landraces as compared to the existing varieties. Findings suggest that late-maturing varieties exhibit tolerance mechanism while early varieties demonstrate an escape mechanism in response to water stress. The research underscores that by harnessing the genetic diversity of landraces rice breeding can be enriched to enhance resilience against changing climatic conditions. Overall, this study provides valuable insights into mitigating the impact of climate change on rice cultivation by utilizing landraces in breeding programs, ensuring food security, and supporting the livelihoods of vulnerable farming communities.

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