Research Article

Genetic Variability, Heritability, Correlation Coefficient and Path Analysis of Morphophysiological and Yield Related Traits of Rice under Drought Stress

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Abstract

An experiment was conducted to detect the variability, heritability and genetic advance for morphophysiologcal and yield related traits in rice under drought stress. For this study 81 genotypes were phenotyped for drought tolerance under field condition in 9×9 lattice square design with two replicates at Regional Agricultural Research Station, Pattambi during the month of *Sept to Dec* 2017. Drought stress was induced from panicle initiation stage for a period of 25 consecutive days by withdrawing irrigation. The result obtained from the current study showed that adequate variability was present among the genotypes for morphophysiological and yield parameters. For all ten traits tested, the phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV). High GCV and PCV were observed for yield plant-^{1}(22.71, 23.05). Broad sense heritability varied from 57.23 for tiller number to 96.33 for grain yield. Path analysis revealed that the relative water content had maximum positive direct effect on yield. The present study revealed that for rice yield under drought stress a genotype should possess high relative water content, chlorophyll stability index and high spikelet fertility percentage.

Keywords: drought, rice, GCV, PCV, heritability, path coefficient analysis

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Introduction

Rice growth and development is sensitive to water limited conditions due to reduced resource consumption compared to other crops [1]. In response to drought stress, rice plant displays many morphological changes at different stages of growth. Water stress results in reduced plant height, leaf rolling, and senescence of the leaf, stomatal closure, reduced leaf elongation and lower production of dry matter [2]. Other changes were also observed in response to water stress, such as chlorophyll content, canopy-to-air temperature differences, transpiration and photosynthesis [3]. Drought stress occurs during the vegetative stage in rice impedes leaf and tiller formation which subsequently affects the production of panicles per crop resulting in yield loss [4].The intensity of drought on rice yield depends upon the duration of drought, stages of growth in which stress is experienced, and the extent of severity [5]. However the effect of drought stress on specific morpho physiological changes in rice cultivars will differ significantly [2]. From an application perspective, understanding the physiological and molecular effects of drought stress in rice and its expression in plant morphology is important [6].

Water is part of several important biochemical reactions in plants and is very important for maintaining healthy metabolism in them, and its lack contributes to a range of morphological and physiological complications [7]. In a country such as India, where many regions lack basic irrigation facilities, severe drought can lead to the loss of yields of important crops like rice. Under rainfed conditions in marginal areas, the drought is often exacerbated by erratic and unpredictable rainfall, high temperatures, high solar radiation and poor soil characteristics. The combined effect of temperature stresses along with drought frequently leads to a complex response in the metabolism of the plants, highly altered from those of the individual stresses that function alone[8]. Therefore it is very important to understand the mechanisms that regulate the manifestation of drought stress in rice plants [6]. To overcome drought stress that leads to crop loss access to efficient protocols for development of drought tolerant varieties is necessary. A better understanding of the morphological and physiological basis of changes in drought stress tolerance could be used in plants to develop new crop varieties in order to achieve better productivity under conditions of drought stress.

Breeding for drought tolerance is usually performed by selecting genotypes for high yield under water limited conditions. In view of this the present study was conducted to assess the genetic variability, heritability, path analysis, correlation study and genetic advance of morpho physiological traits in 81 rice genotypes to assist the future breeding programmes for yield improvement under drought stress condition. Genetic variation is the fundamental factor to be considered during selection. Heritability suggests a character's transmissibility in future generations [9]. The level of contribution to direct and indirect effects of each yield component trait to final grain yield is determined by path analysis [10].

Materials and Methods

Experimental design and treatments

In this study 81 genotypes were phenotyped under field condition in 9×9 lattice square design with two replicates at Regional Agricultural Research Station, Pattambi during the month of Sept –Dec 2017. Each genotype was raised in four rows of 2m length. **Figure 1** represents over all view of the plot. At the time of panicle initiation, irrigation was withdrawn for 25 consecutive days and observations were taken on morphological and physiological parameters after 10-12 days induction of stress. After 25th day, re-watering was given and plants were kept up to maturity. At the time of harvest, plant production traits were taken from each genotype under drought condition. Plant height was measured from the base of the plant to the tip of the primary panicle at the time of maturity and expressed in centimetres. Tiller number was counted from each replication and days to 50% flowering were recorded by the number of days taken from sowing to exertion of 50% of panicles in each replication. Cell membrane stability index was calculated as suggested by Blum [11]. Relative water content of leaves was estimated using the formula suggested by Turner [12] and chlorophyll stability index was calculated as suggested by Arnon [13]. The grain yield per plant was derived by taking the weight of filled grains in each panicle and expressed in grams. Spikelet fertility percentage was calculated by counting the total numbers of filled and unfilled spikelets of three randomly selected primary tillers of the target plants in each treatment. Thousand grain weight was counted by one thousand seeds were taken randomly from each replication, weighed and expressed in grams. Statistical analysis was done using SAS program [14]. Genotypic and phenotypic correlation coefficients were then determined to study the relationship between measured traits with yield. Phenotypic correlation coefficients between paddy yield and other characteristics are divided to direct (path coefficient) and indirect effects using the Dewey and Lu method [15] to demonstrate the importance of each characteristics. The phenotypic and genotypic coefficient of variability was computed by as per Burton [16]. Heritability in broad sense was done using the formula suggested by Lush [17]. Genetic advance was worked out as per the formula given by Jhonson [18].

Figure 1 Over all view of the experimental plot

Result and Discussion

One of the most important environmental stresses affecting plant growth and development is the drought stress [19]. It has been confirmed that drought stress affects various physiological processes in plants and leads to morphological and physiological responses in plants. That helps the plants to adapt to various environmental conditions. A wide range of variation was observed among 81 genotypes for ten observed traits.

Coefficients of variation

The measurements of the phenotypic coefficient of variation (PCV) for all the traits are higher than those of the genotypic coefficient. The extent of the environmental impacts on the traits was explained by the magnitude of the GCV-PCV difference (**Table 1**). The large difference between the values of GCV and PCV reflects a high environmental impact on trait expression. In this study all the parameters except the tiller numbers (15.254, 20.912) the minor difference between the GCV and PCV value indicating minimum environmental influences and consequently greater role of genetic factors on the expression of traits. Similar to our study, a lower GCV and PCV values were reported for rice [20-23]. The GCV ranged from 2.070 for leaf temperature to 22.721 for grain yield, whereas PCV ranged from 2.116 for leaf temperature to 23.05 for grain yield. Among all the characters studied the grain yield per plant showed higher estimate of PCV and GCV value (23.05-22.721). A higher GCV for grain yield may help in selecting better genotypes through breeding programmes for higher grain productivity under drought. The estimate of GCV and PCV were moderate for plant height (11.74, 12.07), tiller number (15.25.20.91), days to 50% flowering (11.85, 12.00) and relative water content (10.00, 10.15).The estimate of GCV and PCV value low for leaf temperature (2.07, 2.11), cell membrane stability index (4.31, 4.53), chlorophyll stability index (4.24, 4.41),thousand grain weight (6.49, 6.67) and spikelet fertility percentage (7.20, 7.46).

Table 1 Genetic parameters of morphophysiological traits and yield component traits in rice

Characters	GCV	PCV	Heritability (%)	Genetic advance (as % of mean)
Plant height	11.74	12.03	95.19	23.59
Tiller no	15.25	20.91	53.20	22.92
.	11.85	12.00	97.46	24.10
Leaf temp	2.07	2.11	95.69	4.17
Relative Water Content (%)	10.00	10.15	97.07	20.30
Cell membrane stability index (%)	4.31	4.53	90.59	8.45
Chlorophyll stability index (%)	4.24	4.41	92.71	8.42
Grain yield /plant	22.72	23.15	96.33	45.93
1000 gwt	6.49	6.67	94.87	13.03
Spikelet fertility Percentage (%)	7.20	7.46	93.04	14.31

Heritability

While GCV is a measure of genetic variation, the heritable component can only be calculated using heritability estimates and genetic advance estimates. The result from broad sense heritability estimate demonstrated that all the traits were affected by drought stress. Under drought stress the heritability of rice is lower than irrigated condition [24]. Broad sense heritability varied from 53.207 to 96.332 (Table 1) under drought stress condition. In this study all the traits exhibited high heritability except the tiller numbers. High heritability suggests a high component of the heritable portion of variation that breeders can exploit in the selection of superior genotypes based on phenotypical performance [25].

Similar to the coefficient of variance, if the variability in the sampled population is high, an effective selection of most of the breeding traits would be possible, so that high amount of genetic advance would be confirmed [26]. Genetic advance is a useful indicator of the improvement that can be expected from the selection of the appropriate trait. In conjunction with genetic advance, heritability would provide a more accurate index of selection value. The estimate of genetic advance as percent of mean were high for grain yield per plant, plant height, days to 50% flowering and relative water content respectively. Moderate for thousand grain weight and spikelet fertility percentage and very low for leaf temperature. High heritability does not always indicate high genetic gain; heritability with genetic advance should be used in predicting selection of superior genotypes [27]. In this study high to medium estimates of heritability and high genetic advance were obtained for plant height, days to 50% flowering, grain yield, and relative water content of leaves which suggests that these traits can be used for upland rice improvement through selection. Apart from this high heritability combined with high genetic advance indicates additive gene action and a good scope of selection using their phenotypic performance. These results are in confirmatory with the report of [28, 29] for yield and yield related components. High heritability with moderate genetic advance observed for thousand grain weight and spikelet fertility percentage indicates the role of both additive and non-additive gene action in its inheritance [21]. Cell membrane stability index, chlorophyll stability index and leaf temperature showed high heritability with low genetic advance indicates the non-additive type of gene action and genotype and environmental interaction played a significant role in gene expression. These findings are in agreement with earlier works on rice [22, 30]. Relatively high GCV, PCV, heritability and genetic advance obtained for plant height, days to 50 % flowering, relative water content and grain yield. Such characters could be transmitted through hybridization to the progeny and phenotypic selection would be effective.

Correlation coefficients

Genotypic and phenotypic correlation coefficients of traits under drought stress are presented in **Tables 2** and **3**. Significant and positive correlation between yield and other characteristics has shown that variable can change the correlation coefficients in these characteristics. A perusal of these findings showed common direction and significance in phenotypic and genotypic comparisons. Genotypic correlations, however, had a higher magnitude than phenotypic correlations suggesting the environmental masking impact. These findings are in agreement with earlier work on rice [20, 31]. Phenotypic and genotypic correlation under drought stress condition showed that, grain yield was found to be positively and significantly correlated with 1000 grain weight, spikelet fertility percentage, relative water content, Cell membrane stability index and chlorophyll stability index indicating that grain yield was increasing with increase in these parameters. Priority should therefore give to these characteristics, while selecting to boost yield. Under water stress conditions there was a positive correlation between the spikelet fertility percentage and paddy yield. Abarshahr *et al*. [26] also reported that plant height, 1000 grain weight and spikelet fertility percentage positively and significantly associated with grain yield under drought stress condition. Whereas grain yield had negative and significant correlation with days to 50 % flowering both at phenotypic and genotypic level and it showed positive and non-significant association with tiller per plant both at phenotypic and genotypic level. Similar results were reported in days to 50% flowering [31] and tillers/plant [33].

Table 2 Genotypic correlation coefficients among the plant traits of rice under drought stress

	Plant height	**Tiller no**	**Days to 50 %**	**Leaf temp**	**RWC**	**CMS**	**CSI**	**Yield/ plant**	**1000 gwt**
Tiller no	0.04^{NS}								
Days to 50%	0.04^{NS}	0.30^{**}							
Leaf temp	0.33^{**}	0.10^{N}	-0.21^{**}						
RWC	0.23^{**}	0.13^{NS}	-0.17^{*}	0.60^{**}					
CMS	0.23^{**}	0.21^{**}	-0.30^{**}	0.67^{**}	0.72^{**}				
CSI	0.36^{**}	0.19^{*}	-0.25^{**}	0.69^{**}	0.71^{**}	0.84^{*}			
Yield/plant	0.22^{**}	0.02^{NS}	-0.26^{**}	0.59^{**}	0.93^{**}	0.71^{**}	0.71^{**}		
1000 gwt	0.24^{**}	0.06^{NS}	-0.21^{**}	0.56^{**}	0.63^{**}	0.76^{*}	0.79^{**}	0.62^{**}	
Spikelet fertility %	0.09^{NS}	0.16^{*}	-0.25^{**}	0.57^{**}	0.66^{**}	0.75^{**}	0.68^{**}	0.70^{**}	0.64^{**}

Table 3 Phenotypic correlation coefficients among the characters of rice under drought stress

	Plant height	**Tiller no**	**Days to 50 %**	**Leaf temp**	**RWC**	**CMS**	**CSI**	**Yield/ plant**	**1000 gwt**
Tiller no	0.04^{NS}								
Days to 50%	-0.03^{NS}	-0.22^{**}							
Leaf temp	0.31^{**}	0.07^{NS}	-0.20^{**}						
RWC	0.22^{**}	0.09^{NS}	-0.16^{*}	0.58^{**}					
CMS	0.22^{**}	0.12^{NS}	-0.29^{**}	0.60^{**}	0.68^{**}				
CSI	0.34^{**}	0.08^{NS}	-0.25^{**}	0.65^{**}	0.67^{**}	0.79^{**}			
Yield /plant	0.21^{**}	0.02^{NS}	-0.25^{**}	0.56^{**}	0.91^{**}	0.67^{**}	0.67^{**}		
1000 gwt	0.23^{**}	0.01^{NS}	-0.21^{**}	0.53^{**}	0.61^{**}	0.72^{**}	0.76^{**}	0.59^{**}	
Spikelet fertility %	0.08^{NS}	0.09^{NS}	-0.24^{**}	0.53^{**}	0.64^{**}	0.70^{**}	0.66^{**}	0.67^{**}	0.61^{**}

RWC- Relative water content, CMS- Cell membrane stability index, CSI- Chlorophyll stability index

Path coefficient analysis

Path coefficient analysis offers an important means of identifying the direct and indirect causes of interaction and presents a critical examination of the particular forces acting to create a correlation and also measures the relative importance of each causal factor. Therefore, in the present investigation the yield related traits which are directly and indirectly effecting grain yield per plant was carried out and the results obtained are presented in **Table 4**. It was showed that under drought stress condition RWC (0.844) showed maximum positive direct effect on grain yield followed by spikelet fertility percentage (0.151), chlorophyll stability index (0.138) days to 50 % flowering (0.136) plant height (0.017), and thousand grain weight [29]. The direct effect of tiller number/plant on yield was negative (-0.166**).** A positive indirect effect was observed through plant height, days to 50% flowering, CSI and spikelet fertility percentage and indirect negative effect through leaf temperature, CMS and thousand grain weight. Days to 50% flowering showed a direct positive effect on grain yield. The result is in confirmatory with the earlier findings in rice [20]. The indirect positive effect through tiller number, leaf temperature, CMS and thousand grain weights. The direct effect of leaf temperature on yield was negative (-0.050).The indirect positive effect was observed through plant height, days to 50% flowering, RWC, CSI and thousand grain weight. Relative water content showed high positive and direct effect on yield (0.844) and indirect positive effect was observed through plant height, days to 50 % flowering, CSI and spikelet fertility percentage. Cell membrane stability index (-0.021) showed negative direct effect on yield and chlorophyll stability index (0.0980) showed positive direct effect on yield. The indirect positive effect was observed through plant height, days to 50% flowering, RWC and spikelet fertility percentage. Spikelet fertility percentage (0.151) showed positive direct effect on yield and indirect positive effect was observed through plant height, days to 50 % flowering, RWC and CSI. The results are similar to the earlier findings in rice [34]. Among the traits largest direct effect was observed in relative water content. In addition, plant height, days to 50% flowering; CSI and spikelet fertility percentage had significant and indirect effect on rice yield through the relative water content. Many research works revealed similar results for the positive direct effect of days to 50% flowering [35], chlorophyll content [23] and spikelet fertility percentage in rice [36]. So it seems that, these traits were the most important influencing traits on paddy yield under drought stress and it was studied as good selection criteria in breeding programs.

Table 4 Direct and indirect effects of highly correlated characters of rice on yield plant^{-1}

	Direct effect	**Plant height**	**Tiller no**	**Days to 50 %**	**Leaf temp**	**RWC**	**CMS**	**CSI**	**1000 gwt**	**Spikelet fertility%**
Plant height	0.01	0.01	-0.007	0.05	-0.01	0.19	-0.006	0.05	-0.02	0.01
Tiller no	-0.16	0.00	-0.16	0.04	-0.005	0.11	-0.006	0.26	-0.005	0.02
Days to50%	0.13	-0.06	0.05	0.13	0.01	-0.14	0.008	-0.03	0.01	-0.03
Leaf temp	-0.05	0.05	-0.01	0.02	-0.05	0.51	-0.019	0.09	-0.05	0.08
RWC	0.84	0.03	-0.02	0.02	-0.03	0.84	-0.021	0.09	-0.05	0.10
CMS	-0.02	0.03	-0.02	0.02	-0.03	0.84	-0.021	0.09	-0.05	0.10
C**SI**	0.13	0.038	-0.02	0.02	-0.03	0.84	-0.021	0.09	-0.05	0.10
1000 gwt	0.09	0.06	-0.03	0.02	-0.02	0.53	-0.022	0.11	0.09	0.09
Spikelet fertility %	0.15	0.001	-0.02	0.03	-0.02	0.56	-0.022	0.09	-0.05	0.15

RWC- Relative water content, CMS- Cell membrane stability index, CSI- Chlorophyll stability index

Conclusion

The characters which we have studied in this experiments like plant height, days to 50% flowering, relative water content and final grain yield exhibited relatively high GCV, PCV, heritability and genetic advance. Such characters could be transmitted through hybridization to the progeny and phenotypic selection would be effective. Phenotypic and genotypic correlation under drought stress showed that grain yield was positively correlated with 1000 grain weight, spikelet fertility percentage, chlorophyll stability index, cell membrane stability index and relative water content. Path coefficient analysis showed that the relative water content have maximum positive direct effect on grain yield followed by spikelet fertility percentage, chlorophyll stability index, days to 50 % flowering, plant height, and thousand grain weight. So it can be concluded, these traits were the most important influencing traits on paddy yield under drought stress and it was studied as good selection criteria in breeding programs.

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