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Research Article

STUDIES ON GENETIC VARIABILITY & INTERRELATIONSHIP AMONG MORPHOLOGICAL TRAITS OF RICE (*Oryza sativa* L.) GENOTYPES UNDER DROUGHT STRESS CONDITION AT REPRODUCTIVE STAGE

PANJA S.*, GARG H.S. AND BHATTACHARYA C.
Department of Agricultural Extension and Communication, Sam Higginbottom University of Agriculture Technology and Sciences, Allahabad, 211007, India
*Corresponding Author: Email - sudeshnapanja.panja@gmail.com

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Abstract: The present investigation was carried out at Jaguli Instructional Farm, Bidhan Chandra Krishi Viswavidyalaya, Moganpur, Nadia, West Bengal in Kharif-2015 to asses genetic variability and association among 12 different morphological traits of rice under two hydrological regimes irrigated and water stress condition at reproductive stage. The study revealed that the maximum phenotypic and genotypic co-efficient of variation was exhibited by the characters root to shoot ratio, number of effective tillers per plant and flag leaf area under both the environments. Highest heritability was recorded for plant height followed by days to maturity, root length and test weight across the environments. High heritability coupled with high genetic advance was evaluated for the character root to shoot ratio and high heritability with moderate genetic advance was observed for the characters number of effective tillers, flag leaf area and days to maturity in both the environments suggesting that direct selection of these characters maybe useful for future improvement of these genotypes for drought tolerance and grain yield. High heritability with low genetic advance was showed by the character fertility percentage under both hydrological regimes indicating that direct selection of this trait would not be useful but further improvement of this trait could be done by population improvement method. The character association study revealed that the characters root to shoot ratio, number of effective tillers per plant, root length and panicle length had positive significant correlation in water stress condition at both genotypic and phenotypic level whereas root length and root to shoot ratio had positive correlation with yield per plant in irrigated condition. Plant height and flag leaf area had positive correlation with yield per plant in both the environments. Results from the study highlighted that the characters root to shoot ratio, root length, flag leaf area and number of effective tillers per plant were correlated with yield and had either high direct or indirect effect and could be considered for selection of desirable lines. So, further improvement of these traits through selection may provide a high response to selection.

Keywords: *Association, Drought, Genetic-variability, Rice, Tolerance*

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Introduction

Drought is a common feature of climate change which in the current time period is a great threat to society for intensifying natural calamities around the globe. Drought occurs mainly due to increased global temperature, frequent changes in monsoon and uneven distribution of rainfall and has become the single largest yield reducing factors in many rice growing areas in South and Southeast Asia affecting more than 23 million ha area [1]. Drought stress not only occurs in arid or semi-arid regions but it also occurs in irrigated regions due to irregular and un-uniform rainfall causing reduction in plant growth and development which results in yield loss [2]. Among the cereal crops rice which is the staple food crop of more than two-third of the world's population and globally ranked third after wheat and maize production [3] is highly sensitive to soil moisture stress and more susceptible to drought than other crops. In Asia around 45% of the world's rice area falls under rain-fed ecosystem accounting for around 40 million ha of rain-fed area in South and South-east Asia [4]. In India the highly drought prone area lies in Eastern India where the estimated area of 16.2 million ha [5] comprises of 6.3 million ha of upland and 7.3 million ha of lowland [6] resulting in huge losses. Eastern India states like Chhattisgarh, Orrisa, Jharkhand, Bihar and eastern Uttar Pradesh are affected severely due to moisture deficit as most of the high yielding and traditional varieties are being cultivated in these areas which are highly susceptible to reproductive stage drought. Most of the high yielding varieties which were evolved in the green revolution period gave a boost to the world rice production were fertilizer responsive and were adapted to cultivation under intensive irrigation facilities [7, 8]. These varieties were never tested for drought tolerance and resulted in severe yield loss suffering from drought stress [7].

It has been reported that by 2025, around 15-20 million ha of irrigated rice will face scarcity of water [9] and by 2050 amount of crop water consumption will increase by 70-90%. To ensure food security development of drought tolerant rice varieties with increased yield has become important so that the farmers can produce rice with limited water to meet the food demand. Drought tolerance is a complex trait and plant adaptation to drought is the result of expression of many traits in a specific environment. Plant type traits such as tiller number per plant and plant height modify the expression of secondary traits. The yield component traits viz., days to flowering, plant height, number of productive tillers per plant, panicle length, grains per panicle, 1000 grains weight, biomass yield and harvest index are also important for selecting drought resistant varieties if the traits are highly heritable and genetically independent or positively correlated with grain yield. Heritability is an important criteria for selection of characters as it indicates the transmissibility of the characters to next generations and improvement of the selected traits further helps in development of improved breeding lines. So, keeping in my mind the above points the present study was undertaken to analyse and asses direct selection of morphological parameters, their genotypic and phenotypic interrelationship with grain yield under irrigated as well as drought stress condition exposed at reproductive period.

Materials and Methods

Experimental sites, genotypes and screening environment

The present investigation was carried out in WS in 2015 under irrigated (E1) as well as water stress (E2) condition at flowering stage at the Jaguli Instructional Farm, Jaguli, Mohanpur, Department of Genetics & Plant Breeding, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal. The morphological characters were studied for twenty genotypes which were collected from different institutions [Table-1].

Experimental design

The experiment was carried out in Randomized Block Design with 3 replications under both control (irrigated) and water stress condition. The genotypes were planted in a spacing of 20 x 20 cm. All recommended agronomic practices were followed.

Table-1 Experimental design

SN	Genotypes	Source
1	ANNADA	Seed Certification Office, Bankura, Purulia, Paschim Medinipur Zone, Govt. of West Bengal
2	BULLET	
3	GB-1	
4	IR-36	
5	LALAT	
6	MINICATE	
7	MTU 1010	
8	PARIJAT	
9	SARAYU-52	
10	DULAR	Chinsurah Rice Research Centre, Chinsurah, Hooghly, West Bengal
11	HEERA	
12	IR-50	
13	IR-64	
14	JALDI-13	
15	DHANALAXMI	Rajendra Agricultural University, Pusa, Samastipur, Bihar
16	GAUTAM	
17	RASHI	
18	SAHBAGIDHAN	
19	TURANTA BOLD	
20	VANDANA	

Water management

The experiment was conducted with well-defined protocol for water management under two environmental conditions (E1 and E2). Under E1 the field was well irrigated as well as received rain water to maintain enough moisture in the field. Under E2 condition the genotypes were planted under rain out shelter made of polythene sheet with good drainage system to exclude occasional rain water. The drought stress was created at heading stage and continued till 15 days. Soil moisture content during stress period was monitored at 5 days, 10 days and 15 days of interval.

Observations recorded

Observations were recorded on five randomly chosen plants of each plot of three replications under both control and water stress condition. Twelve morphological traits such as days to maturity, plant height (cm), flag leaf area (cm^2), number of tillers per plant, root length (cm), root o shoot ratio, panicle length (cm), panicle weight (g), fertility percentage, test weight (g), straw weight (g) and grain yield per plant (g) were studied. The data were subjected to Genotypic and Phenotypic Co-efficient of Variation [10], Genetic Advance [11, 12], broad sense Heritability [13], Correlation Co-efficient and Path Co-efficient analysis [14].

Results & Discussion

The magnitude of genetic variability effects the selection of characters as the greater the variability among the characters of the genotypes better is the chance of further improvement in the crop. In this study the genetic variability parameters were studied where the total variation of 12 traits was partitioned into genotypic variation and variation through other sources. The estimates of different genetic parameters of variation under both hydrological regimes are presented in [Table-2]. The values of phenotypic co-efficient of variation (PCV) was higher than the genotypic co-efficient of variation (GCV) which corresponded with the findings reported by [15, 16] though the differences between PCV and GCV was quite low for all the characters indicating less influence of environment in expression of these characters. The influence of environment on the characters which increases the value of PCV than GCV was also reported [17]. However, the differences were comparatively greater in case of straw weight (15.59 & 10.61 in E1; 21.27 & 14.47 in E2) in both the environments and yield per plant (20.53 & 17.79 in E2) only in stress condition. PCV and GCV was highest for root to shoot ratio (29.63 & 27.57 in E1; 39.15 & 38.39 in E2) followed by number of effective tillers/plant (18.71 & 17.80 in E1; 17.82 & 16.85 in E2) and flag leaf area (15.60 & 14.16 in E1; 16.99 & 16.54 in E2) under both environments. Similar result for trait root to shoot ratio and number of effective tillers per plant was reported [18. 19]. The high variation in root to shoot ratio, number of effective tillers per plant and flag leaf area could be considered in selection of desirable lines in both the environments especially in development of drought resistant lines. Straw weight (21.27) and yield per plant (20.53) had higher PCV under water stress condition than other characters but they exhibited moderate magnitude of GCV. PCV and GCV was lowest for fertility percentage (5.88 & 5.69 in E1; 5.90 & 5.33 in E2) in both control and stress environments followed by panicle length (8.78 & 8.13 in E1; 8.80 & 8.01 in E2).

The genetic variability of the parameters can be utilized better if the traits are heritable. The insufficiency of variation to set the selection criteria itself unless the heritable fraction of the variation is known was explained [10] as variation is unable to provide clean picture of the extent of genetic gain to be expected from selection of phenotypic traits. Again, heritability estimation alone is insufficient for selection of the traits as it indicates both additive and non-additive gene action. Thus, heritability coupled with genetic advance is more helpful in predicting the gain under procedure as it indicates that the heritability is most likely due to the additive gene action. The heritable portion of the overall observed variation can be ascertained by studying heritability and predicted genetic advance which serve as the reliable estimate to conclude about selection and the similar was also reported [20]. In the present investigation high heritability coupled with high genetic advance as percent mean was observed for the character root to shoot ratio. Hence selection would be effective for improvement of this character as the character is controlled by additive gene action. High heritability was recorded for most of the traits except straw weight (46.33 in E1; 46.29 in E2), panicle weight (75.64 in E1, 74.76 in E2) and yield per plant (77.97 in E1; 75.12 in E2) in both the environments. Plant height (98.40 in E1; 98.33 in E2) and days to maturity (97.98 in E1; 97.53 in E2) exhibited highest heritability in both stress and irrigated condition followed by root length (92.83 in E1; 90.27 in E2) and test weight (94.69 in E1; 87.28 in E2). Similar results were also reported [21, 22]. High heritability with moderate genetic advance as percent mean was recorded for the characters number of effective tillers per plant, flag leaf area and days to maturity which is similar to earlier reports [23, 24]. Hence selection of these traits would be more effective as compared to others. Fertility percentage showed high heritability with low genetic advance as percent mean indicating non-additive gene action. So, direct selection of this trait would not be effective. These characters showing high heritability with moderate and low genetic advance as percent mean can be improved by crossing with the elite parental lines in the population through recombination breeding. [25]. Moderate heritability with moderate genetic advance was exhibited by the trait yield per plant under water stress condition whereas in irrigated condition the trait showed high heritability with low genetic advance, so direct selection of this trait would not be useful but further improvement of this trait could be done by population improvement method.

The objective of this investigation is to study the relationship of different traits on grain yield in both stress and irrigated condition as yield being a complex trait is contributed by several other yield attributing traits. In this aspect the correlation coefficient of component traits with grain yield provides the nature and magnitude of relationship between the component traits of yield and grain yield itself [26]. It is an index of degree of relationship between two continuous variables. Correlating traits under drought situation is helpful in development of rice varieties tolerant to drought stress. Apart from yield attributing traits several other traits like root traits and morphological traits like plant height, flag leaf area contributing to drought could serve as a reliable criterion for improving yield in water stress condition. Therefore, phenotypic and genotypic correlations were studied for all the 12 characters to understand the nature of association among morphological characters like plant height, flag leaf area, root traits, yield attributing traits and grain yield which are presented in [Table-3] for irrigated condition and [Table-4] for drought stress condition.

Table-2 Estimation of genetic parameters of variability for 12 characters of rice under irrigated and drought condition

Characters	Env	General Mean	S.E.	Variance			CV		H^2 (%)	GA as % Mean
				PV	GV	EV	PCV (%)	GCV (%)		
DM	E1	116.00	0.98	141.51	138.65	2.85	10.27	10.17	97.98	20.74
	E2	112.00	1.11	150.71	146.99	3.72	10.96	10.83	97.53	22.03
PH	E1	114.17	0.82	126.76	124.73	2.03	9.86	9.78	98.40	19.99
	E2	104.33	0.83	123.37	121.31	2.06	10.65	10.56	98.33	21.56
FLA	E1	31.28	1.18	23.83	19.64	4.19	15.60	14.16	82.41	26.49
	E2	31.67	0.71	28.93	27.43	1.50	16.99	16.54	94.81	33.17
ET	E1	13.00	0.44	6.16	5.58	0.59	18.71	17.80	90.51	34.89
	E2	11.00	0.46	3.52	2.89	0.63	17.82	16.15	82.11	30.15
RL	E1	22.22	0.36	5.53	5.13	0.40	10.59	10.20	92.83	20.24
	E2	24.85	0.44	5.92	5.35	0.58	9.79	9.30	90.27	18.21
R/S	E1	0.56	0.04	0.03	0.02	0.00	29.63	27.57	86.59	52.85
	E2	0.57	0.03	0.05	0.05	0.00	39.15	38.39	96.15	77.54
PL	E1	24.67	0.47	4.69	4.02	0.67	8.78	8.13	85.80	15.52
	E2	23.20	0.49	4.17	3.45	0.72	8.80	8.01	82.80	15.01
PW	E1	3.03	0.07	0.07	0.05	0.02	8.62	7.50	75.64	13.44
	E2	2.77	0.12	0.18	0.14	0.05	15.51	13.41	74.76	23.89
F%	E1	84.98	0.72	25.00	23.42	1.58	5.88	5.69	93.70	11.36
	E2	78.68	1.16	21.58	17.57	4.01	5.90	5.33	81.43	9.90
TW	E1	23.82	0.31	5.30	5.02	0.28	9.67	9.41	94.69	18.86
	E2	22.85	0.46	5.04	4.40	0.64	9.83	9.18	87.28	17.67
SW	E1	18.50	1.22	8.31	3.85	4.46	15.59	10.61	46.33	14.87
	E2	17.18	1.55	13.36	6.19	7.18	21.27	14.47	46.29	20.29
Y/P	E1	19.32	0.48	3.12	2.43	0.69	9.14	8.07	77.97	14.68
	E2	15.25	0.90	9.80	7.36	2.44	20.53	17.79	75.12	31.77

Table-3 Estimation of genotypic and phenotypic correlation for 12 characters of rice under irrigated condition

Characters	G/P	DM	PH	FLA	ET	RL	R/S	PL	PW	F%	TW	SW
DM	G											
	P											
PH	G	0.825**										
	P	0.811**										
FLA	G	-0.024	-0.132									
	P	-0.026	-0.11									
ET	G	-0.01	0.167	0.304*								
	P	-0.003	0.149	0.218								
RL	G	-0.091	0.227	-0.035	0.074							
	P	-0.087	0.211	-0.026	0.083							
R/S	G	-0.320*	-0.500**	0.08	0.015	-0.176						
	P	-0.293*	-0.470**	0.039	-0.016	-0.165						
PL	G	0.576**	0.416**	0.148	0.048	-0.043	0.252					
	P	0.531**	0.379**	0.083	0.024	-0.04	0.225					
PW	G	0.261*	0.244	-0.338**	-0.048	0.24	-0.127	-0.07				
	P	0.234	0.216	-0.204	-0.072	0.217	-0.08	-0.104				
F%	G	0.311*	0.051	0.275*	-0.159	-0.127	-0.337**	0.261*	-0.066			
	P	0.303*	0.052	0.24	-0.153	-0.114	-0.302*	0.241	-0.075			
TW	G	0.087	-0.146	-0.325*	-0.345**	0.200	0.399**	0.203	0.409**	-0.04		
	P	0.088	-0.14	-0.271*	-0.325*	0.185	0.372**	0.163	0.389**	-0.045		
SW	G	-0.242	-0.185	0.193	0.577**	0.013	0.221	-0.039	-0.335**	-0.426**	-0.059	
	P	-0.15	-0.109	0.143	0.421**	0.041	0.163	-0.089	-0.115	-0.298*	-0.016	
Y/P	G	0.199	0.162	0.138	-0.109	0.118	0.159	0.018	-0.11	0.001	0.011	-0.026
	P	0.170	0.132	0.049	-0.070	0.090	0.125	-0.011	-0.131	-0.014	0.000	-0.023

Yield per plant showed significant positive genotypic and phenotypic correlation with number of effective tillers per plant (0.538** & 0.504**), root length (0.618** & 0.515**), root to shoot ratio (0.811** & 0.666**) and panicle length (0.477** & 0.362**) under water stress condition, whereas in irrigated condition root to shoot ratio (0.159 & 0.125) and root length (0.118 & 0.090) showed non-significant positive and number of effective tillers per plant (-0.190 & -0.070) showed non-significant negative genotypic and phenotypic correlation with yield per plant. Presence of positive significant correlation between yield and panicle length was also reported [27-29]. Significant positive correlation of yield with root length, root to shoot ratio, dry root weight, number of effective tillers per plant, plant height and days to maturity was reported [30]. The presence of positive significant correlation between yield and panicle length was also found earlier [29]. Hence, direct selection of these traits showing positive significant association with grain yield would improve grain yield. Plant height (0.162 & 0.132 in E1; 0.197 & 0.178 in E2) and flag leaf area (0.138 & 0.049 in E1; 0.279* & 0.226 in E2) exhibited positive genotypic and phenotypic correlation with grain yield per plant in both irrigated and water stress condition whereas test weight was significantly positively (0.303* & 0.252) correlated with yield per plant only in stress condition at genotypic level non-significantly at phenotypic level. It was also mentioned that there was presence of positive correlation between grain yield and plant height, filled grains per panicle, spikelet fertility percentage, test weight, biomass yield and harvest index [31-33]. In the present study, under stress condition panicle length among the yield contributing traits was significantly correlated with plant height. Plant height is a manifestation of inter node elongation which might have also an impact on the panicle length which was reported in earlier studies [34]. Under water stress condition plant height showed significant positive correlation with root length, root length was significantly positively correlated with root to shoot ratio which was like earlier findings [30]. Panicle weight showed non-significant positive correlation with test weight under water stress condition. Days to maturity (-0.199 & -0.165) showed negative genotypic and phenotypic correlation with yield per plant under stress condition whereas number of effective tillers per plant (-0.109 & -0.070), panicle weight (-0.110 & -0.131) and straw weight (-0.026 & -0.023)

Table-4 Estimation of genotypic and phenotypic correlation for 12 characters of rice under water stress condition

Characters	G/P	DM	PH	FLA	ET	RL	R/S	PL	PW	F%	TW	SW
DM	G											
	P											
PH	G	0.462**										
	P	0.447**										
FLA	G	-0.115	0.178									
	P	-0.107	0.171									
ET	G	-0.337**	0.065	0.195								
	P	-0.300*	0.065	0.168								
RL	G	-0.290*	0.422**	0.046	0.416**							
	P	-0.262*	0.396**	0.06	0.337**							
R/S	G	-0.360**	-0.096	0.248	0.433**	0.294*						
	P	-0.360**	-0.099	0.234	0.377**	0.267*						
PL	G	0.303*	0.291*	0.104	0.345**	0.256*	0.531**					
	P	0.269*	0.258*	0.088	0.277*	0.201	0.477**					
PW	G	0.171	0.227	-0.619**	0.139	0.232	0.331**	0.391**				
	P	0.139	0.196	-0.523**	0.118	0.186	0.306*	0.294*				
F%	G	0.033	0.004	0.119	0.081	-0.049	0.109	0.249	-0.154			
	P	0.01	0.01	0.107	0.045	-0.03	0.097	0.193	-0.07			
TW	G	-0.016	-0.129	-0.384**	-0.06	0.284*	0.433**	0.193	0.677**	0.073		
	P	-0.023	-0.116	-0.346**	-0.051	0.269*	0.394**	0.175	0.576**	0.079		
SW	G	0.471**	0.215	0.188	0.165	-0.251	-0.015	0.222	0.183	0.126	0.127	
	P	0.317*	0.142	0.136	0.081	-0.147	-0.062	0.103	0.094	0.133	0.072	
Y/P	G	-0.199	0.197	0.279*	0.538**	0.618**	0.811**	0.477**	0.256*	0.201	0.303*	0.175
	P	-0.165	0.178	0.226	0.504**	0.515**	0.666**	0.362**	0.198	0.132	0.252	0.094

Table-5 Estimation of direct and indirect effect of 12 characters of rice on yield per plant across the environments

Characters	DM		PH		FLA		ET		RL		R/S		PL		PW		F%		TW		SW	
Env	E1	E2	E1	E2	E1	E2	E1	E2	E1	E2	E1	E2	E1	E2	E1	E2	E1	E2	E1	E2	E1	E2
DM	0.36	1.77	0.84	-1.11	0.00	-0.12	0.01	0.32	-0.03	-0.81	-0.43	-0.58	-0.58	-0.48	-0.02	0.45	0.20	0.03	-0.03	0.04	-0.11	0.30
PH	0.30	0.82	1.02	-2.40	-0.01	0.19	-0.10	-0.06	0.07	1.19	-0.67	-0.15	-0.42	-0.47	-0.02	0.59	0.03	0.00	0.05	0.35	-0.08	0.14
FLA	-0.01	-0.20	-0.13	-0.43	0.10	1.06	-0.18	-0.18	-0.01	0.13	0.11	0.40	-0.15	-0.17	0.03	-1.62	0.18	0.12	0.11	1.05	0.09	0.12
ET	0.00	-0.60	0.17	-0.16	0.03	0.21	-0.59	-0.95	0.02	1.17	0.02	0.70	-0.05	-0.55	0.00	0.36	-0.10	0.08	0.12	0.16	0.26	0.11
RL	-0.03	-0.51	0.23	-1.01	0.00	0.05	-0.04	-0.39	0.33	2.81	-0.24	0.47	0.04	-0.41	-0.02	0.61	-0.08	-0.05	-0.07	-0.78	0.01	-0.16
R/S	-0.12	-0.64	-0.51	0.23	0.01	0.26	-0.01	-0.41	-0.06	0.83	1.35	1.61	-0.26	-0.85	0.01	0.87	-0.22	0.11	-0.14	-1.19	0.10	-0.01
PL	0.21	0.54	0.42	-0.70	0.02	0.11	-0.03	-0.33	-0.01	0.72	0.34	0.85	-1.01	-1.60	0.01	1.02	0.17	0.25	-0.07	-0.53	-0.02	0.14
PW	0.09	0.30	0.25	-0.54	-0.03	-0.66	0.03	-0.13	0.08	0.65	-0.17	0.53	0.07	-0.63	-0.09	2.62	-0.04	-0.15	-0.14	-1.85	-0.15	0.12
F%	0.11	0.06	0.05	-0.01	0.03	0.13	0.09	-0.08	-0.04	-0.14	-0.45	0.17	-0.26	-0.40	0.01	-0.40	0.65	0.99	0.01	-0.20	-0.20	0.08
TW	0.03	-0.03	-0.15	0.31	-0.03	-0.41	0.20	0.06	0.07	0.80	0.54	0.70	-0.21	-0.31	-0.03	1.77	-0.03	0.07	-0.35	-2.74	-0.03	0.08
SW	-0.09	0.83	-0.19	-0.52	0.02	0.20	-0.34	-0.16	0.00	-0.70	0.30	-0.02	0.04	-0.35	0.03	0.48	-0.28	0.12	0.02	-0.35	0.46	0.64

exhibited negative correlation under irrigated condition. This undesirable negative association between important traits contributing to yield can be broken by recombination breeding.

Correlation co-efficient alone could not provide a comprehensive picture on direct and indirect influences of each character to the yield per plant for which path coefficient analysis was done. To get an understanding on direct and indirect influence of the traits on yield per plant and results were presented in [Table-5]. Path coefficient analysis permits the separation of the correlation coefficient into components of direct and indirect effect on grain yield. In the present investigations yield per plant was taken as a dependent or resultant variable and all the others characters, under study as independent or causal variables. Highest positive direct effect on grain yield was exhibited by root length (2.81) followed by panicle weight (2.62), root to shoot ratio (1.61), days to maturity (1.77), flag leaf area (1.06) and lowest positive direct effect was showed by straw weight (0.64) under drought stress condition whereas plant height (-2.40), number of effective tillers per plant (-0.95), panicle length (-1.60) and test weight (-2.74) showed negative direct effect on yield per plant. Under irrigated condition the character root to shoot ratio (1.35) had highest positive direct effect on yield per plant followed by plant height (1.02), fertility percentage (0.65), straw weight (0.46), days to maturity (0.36) and root length (0.33) whereas flag leaf area (0.10) had lowest positive direct effect. The characters number of effective tillers per plant (-0.59), panicle length (-1.01), panicle weight (-0.09) and test weight (-0.35) exhibited negative direct effect on yield per plant under irrigated condition. Root to shoot ratio had high positive direct effect (1.35 in E1; 1.61 in E2) on yield per plant in both water stress and irrigated condition followed by fertility percentage (0.65 in E1; 0.99 in E2), straw weight (0.46 in E1; 0.64 in E2), flag leaf area (0.10 in E1; 1.06 in E2), root length (0.33 in E1; 2.81 in E2) and days to maturity (0.36 in E1; 1.77 in E2) whereas number of effective tillers per plant (-0.59 in E1; -0.95 in E2), panicle length (-1.01 in E1; -1.60 in E2) and test weight (-0.35 in E1; -2.74 in E2) had negative direct effect. Root to shoot ratio had positive indirect effect on yield per plant via flag leaf area and panicle weight. It can be concluded that, root to shoot ratio, fertility percentage, straw weight, flag leaf area, root length and days to maturity could be considered for selection of lines adaptable to both rainfed and irrigated condition. Past workers identified the traits for selection in different ecosystem as: harvest index, plant height and panicle length [35] under low land stress, filled grains per panicle, spikelet fertility [36] in upland condition and spikelet fertility, biomass and harvest index [37] under irrigated condition. Thus, practical applicability of yield and yield attributing traits, such as root to shoot ratio, root length, straw weight, days to maturity and spikelet fertility could be considered, as selection criteria for development of lines suitable for rainfed cultivation and the characters were enlightened with either high direct or indirect effect on grain yield.

Conclusion

Results from the study highlighted that the characters root to shoot ratio, root length, flag leaf area and number of effective tillers per plant were correlated with yield and had either high direct or indirect effect and could be considered for selection of desirable lines. The study also indicated that direct selection of the characters root to shoot ratio, number of effective tillers per plant, flag leaf area and days to maturity would be effective and genotypes that are capable of maintaining high values of these characters could be considered suitable for improving the grain yield in rice breeding programs targeting development of lines adaptable to rainfed area maintaining high economic yield.

Application of research: The genetic variability and interrelationship among morphological characters under water stress condition helps in selecting the traits for improvement of grain yield under drought condition in rice breeding program for development of high yielding drought tolerant lines.

Research Category: Genetic variability

Abbreviations: DM: Days to Maturity; Env: Environment; ET: Number of Effective Tillers; EV: Environmental Variance; E1: Control; E2: Stress; FLA: Flag Leaf Area; F%: Fertility Percentage; G: Genotypic Correlation Coefficient; GA: Genetic Advance; GCV: Genotypic Coefficient of Variation; GV: Genotypic Variance; H_2: Heritability broad sense; P: Phenotypic Correlation Coefficient; PCV: Phenotypic Coefficient of Variation; PH: Plant Height; PL: Panicle Length; PV: Phenotypic Variance; PW: Panicle Weight; RL: Root Length; R/S: Root to Shoot Ratio; SE: Standard Error; SW: Straw Weight; TW: Test Weight; Y/P: Yield per Plant

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****Research Guide or Chairperson of research: Prof Dr Chandan Bhattacharya**
University: Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, 741252, West Bengal, India
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Study area / Sample Collection: Jaguli Instructional Farm, Jaguli, Mohanpur

Cultivar / Variety / Breed name: Rice (*Oryza sativa* L.)

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