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SCREENING FOR DROUGHT TOLERANCE IN RICE GENOTYPES FOR IMPROVING RICE PRODUCTIVITY OF WATER SCARCE AREAS

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ABSTRACT

Screening studies of twenty four rice genotypes under water stress and irrigated non stress conditions were conducted during three consecutive years in kharif season under hydroponically controlled as well as under the field conditions. The objective of these studies was to identify potential water stress tolerant genotypes of rice on the basis of morphological traits. All morphological and yield traits were decreased with varying intensities under water stress conditions as compared to non stress conditions. Results of these combined studies revealed that among 24 tested genotypes, the IR83140-B-28-B followed by IR83141-B-18-B, GML- 499 and GML-500 were observed comparatively better in most of traits studied along with less relative reduction in yield under water stress. Correlation studies among different yield and yield component have revealed that the trait of grain yield was positively related with all yield components. These genotypes may be used in breeding program for developing drought tolerant rice genotypes as well as for adoption in water scarce areas.

Key words: Rice screening, Water stress, Yield and yield components

INTRODUCTION

Water is an indispensible, precious resource for sustaining life on the earth and its limited availability affect whole biological system and worldwide economy. Shortage of water is prevailing and is expected to increase at faster rate in near future due to climate change increase in temperature. This shortage of water is a worldwide threat for crop productivity and food security especially in arid and semi arid areas. Rice is a main staple crop provides food for more than half of world population and fulfill 80% of calories requirements of Asian countries (Rasheed *et al*., 2020).This crop needs more water to grow (3000 L/kg rice production) is mostly cultivated under submerged water conditions, consumes 24-30% of total fresh water available for agriculture (Ahmad *et al*., 2020). In Asia, where 92% of the world rice is grown, more than half of the rice area is affected by drought reducing its productivity every year by varying intensity (Dar *et al.*, 2020). Rice crop exhibits higher sensitivity towards water stress due to its aquatic origin and shallow root system. Most improve rice varieties developed for general cultivation were originally bred for irrigated condition and were not selected /developed for drought, when grown in drought areas suffer substantial yield losses (Kumar *et al.*, 2015). Water stress affects multiple aspects of plant growth and developmental processes in rice with resulting decrease in productivity (Rasheed *et al*., 2020).In addition to these, various other factors such as duration and severity of water stress at certain specific sensitive stages of plant also variably affect yield (Ahmadikhah *et al.*, 2016). Stress at seedling and flowering stages results in more poor plant growth and yield with infertile grains (Tsujimoto *et al.*, 2021). The identification of low water requiring rice genotypes that could produce economic yield under drought stress is imperative in order to alleviate the future food crises. Sustaining rice productivity under water scarce environments requires both management of agronomic practices and improvement with genetics aspects. Many studies have been conducted on water saving management practices and several approaches and possible techniques have been suggested so far, e.g. direct-seeding, aerobic rice and alternate wetting and drying (AWD) rice-production systems (Santos *et al.*, 2018; Salleh *et al.*, 2020). Little is known about how these techniques affect rice grain yield under water stress open field conditions. However, any of these techniques can potentially decrease yield due to other factors associated with less availability of water (rise in canopy temperature and stomatal closure) at critical stages of growth and no single technique alone covers all aspects effectively without improving crop potential for stress tolerance. To date breeding efforts for developing water stress tolerant cultivars are limited and may not be used as an immediate measure for sustaining rice yield under stress due to incomplete knowledge about complex nature of involved traits and lack of effective screening techniques. The improvement of crop under stress environment is mostly based on existing genetic variability, inheritability of the traits and relationship of environmental influence on the expression of different yield contributing traits. It is reported that more than 75% of genetic variability has been unexplored. Therefore screening of genetically diverse material might be good option for the improvement of rice yield under stress (Nuruzzaman *et al*., 2017). The major bottlenecks in the process are lack of suitable screening technique. Experiments conducted under controlled laboratory conditions play an important role in understanding plant responses to their environment. Laboratories screens under controlled conditions at seedling stage artificially create stress condition avoids interaction of genotype with environment and maximize the possibilities of exploring genetic component of observed variations. Whereas on the other side the responses of plants in field are not often exactly similar, as observed under laboratory conditions therefore does not correlate with field results (Poorter *et al*., 2016). Many factors such as experimental design, stress level, method of stress induction, growth stage and field vagaries may make the task complex. However there is a need to established effective protocol for quantifying tolerance potential for drought. Some of the approaches such as application of water stress under hydroponically controlled conditions in open green-house environment can create more similar conditions as plants faces in field, thus could make the task more successful. Considering these problems combination of technique (controlled & field stress conditions) were utilized simultaneously in the present study to screen out genetic potential of some rice genotypes under water stress environment.

MATERIAL AND METHODS

Two sets of long terms experiments were conducted simultaneously one in controlled hydroponic conditions and second under field conditions for the period of consecutive three years (2017-2019) during kharif season. Each experiment comprised of non-stressed (control) and stressed (water stress) conditions.

Hydroponically controlled conditions

Rice nursery comprised of twenty four genotypes (IRRI origin) obtained from National Institute of Biotechnology and Genetic Engineering (NIBGE), Faisalabad was grown in normal soil of Nuclear Institute of Agriculture (NIA) for four weeks thereafter was transplanted in controlled hydroponics system's cemented beds (size LxB: 9m x1.2m) filled with coarse river sand equipped with water recycling system at NIA. The twenty seedlings were transplanted in four rows at the distance of 20 cm between plants and rows. The plants were irrigated with ¼ th strength Hoagland solution (Hoagland and Arnon 1950). Stress conditions were applied one week after establishing plants by draining and withholding water for 15 days. Soil samples were taken from treatment beds at the depth of 20 cm and moisture contents were measured gravimetrically twice a week from the start of treatment till next irrigation (Fig.1). The treatments were maintained upto maturity by irrigating thin film of water (up to saturation point at field capacity) at an interval of fifteen days. The control beds were receiving normal irrigation (Flood). Flowering time was recorded through visual observation throughout the flowering period and calculated on the basis of days after transplantation. The agronomical traits (i.e. plant height, number of total and productive tillers, straw weights and net grains weight per plant, harvest index and yield contributing traits) were taken at the time of maturity.

Field conditions

Experiments were conducted at two sites (plot size: 35 x35 m each) adjacent to each other in RCBD with three replicates and twenty four genotypes. Transplanting of rice nursery was done at the age of four weeks. There were total 150 plants /entry/replicate (6.0 m^2) at a distance of 20 cm and 60 cm between the hill and entries, respectively. Normal cultural practices and recommended fertilizers dose of Nitrogen, Phosphorous and Potassium, (120, 60 & 60 kg/ha N, P and K, respectively) from urea, DAP and potassium nitrate were followed after one week of establishing plants. Afterward two water regimes were developed: Controlled plot was normally irrigated under continuous flooding. The treatment plots were flood irrigated (2cm) followed by dry period of 15 days, afterward re-irrigated following alternate wetting and drying method (AWD). The stress was imposed from vegetative stage till maturity. Observations for different growth and yield parameters were recorded at maturity. The genotypes for these parameters were analyzed on the basis of three years pooled data.

Statistical analysis

Analysis of variance was done for analyzing genotypes, treatments and their interactions followed by Tukey HSD test (at α 0.05). To assess the extent of interrelationships between the traits correlation studies (Pearson's) for different growth and yield parameters were done by statistix 8.1.Cluster analysis using complete linkage method Euclidean distance coefficients was used to study phenogram based on using 8 quantitative traits of these genotypes.

RESULTS AND DISCUSSION

Responses of rice genotypes under hydroponically controlled water stress conditions

The analysis of variance (ANOVA) for growth and yield parameters revealed significant ($p > 0.001$) differences among the rice genotypes, drought treatments, and genotype treatment interaction (Table 1). All growth and yield parameters reduced variably among genotypes under water stress conditions (Table 2 and 3 and Fig.2).

Plant height

The data of plant height has shown overall range from 82.7 cm to 116 cm under water stress with variable reduction in comparison to their respective controls (Table 2). Drought tolerant check (IR04L191) and irrigated check (PSBRC-82) exhibited reduction of 11 and 23% in plant height under water stress conditions. Among the tested genotypes IR83105-B-B-5, Zaoxion- 14 and IR84677-34-1-B exhibited no or little reduction in plant height.

Total and productive tillers

Tiller bearing capacity of these genotypes under irrigated conditions was in range of 8 to 14 which was reduced to some extent under water stress conditions. Maximum number of tillers was observed in GML-502 followed by, IR83140-B-28-B, and OM-7938. These genotypes were equally good in their productive tiller numbers (Table 2) with comparatively less reduction under water stress.

Straw weight

These genotypes exhibited varying degree of relative reduction (0-57%) in straw weight under water stress. The drought tolerant check exhibited 12% reduction. Among tested genotypes IR833142-B-60-B produced highest straw weight followed by OMCS-2009, IR83141-B-18-B and GML-502 with reduction of 3, 13, 22 and 9 %, respectively under water stress (Table2).

Flowering responses

These genotypes under water stress conditions have shown delayed flowering (Table 3 b). The delay in flowering was in the range of 1-11 days. Irrigated check genotypes (PSBRC-82) have shown a delay of 11 days in flowering whereas; drought tolerant check (IR04L191) exhibited no delay in their flowering time under stress conditions. Among the tested genotypes GML-499, 515, IR83141-B-18-B, IR-83142-B-21-B &GML - 498 have shown no delay in their flowering time. Whereas, GML: - 505, 514, IR-84677-34-1-B and Sal-10- DT_2-DT_1 have shown earlier response of 1 and 6 days respectively (Table 3 b).

Table 1. Analysis of variance (ANOVA) across the genotypes, treatments, and their interaction for the morphological parameters, yield and yield components of rice genotypes under water stress.

HP data						
	SoV	Genotypes (G)	Treatment (T)	G x T	Error	CV %
	d.f.	23	1	23	94	
	Plant height	425.38**	9817.51**	87.26**	8.5	2.7
	Tillers number	20.74**	294.69**	15.46**	2.0	10.8
	Panicles number	24.48**	377**	12.73**	1.5	10.5
	Panicles length	14.98**	273.08**	9.28**	3.2	7.3
	Spikelet number	4.58**	54.14**	2.38**	1.2	12.7
	Grain weight	155.4 **	3864.69**	56.07**	6.1	14.2
	100 grain weight	0.283**	14.47**	0.08**	0.0	3.0
	straw weight	253.11**	1482.9**	46.03**	10.7	13.1
	Harvest Index	0.023**	0.2417**	0.014**	0.003	13.1
	Flowering days	166.95 **	144 **	17.79 **	2.8	3.0

Table 2. Growth performance of rice genotypes under hydroponically controlled water stress conditions.

Genotypes	**Plant height (cm)**			**Tillers/Plant (no)**			**Straw weight (g/plant)**		
	control	**W.Stress**	**Red %**	**control**	**W.Stress**	**Red %**	**control**	**W.Stress**	**Red %**
BINDESHWARI	115.7	100.7	13	11.7	11.3	3	28.8	21.6	25
GML 498	123.7	103.7	16	22.7	8.3	63	38.7	19.7	49
GML 499	110.7	92.0	17	13.0	8.7	33	15.4	12.2	21
GML 500	111.7	96.0	14	14.0	9.7	31	24.9	25.2	-1
GML 502	121.3	100.0	18	15.0	16.0	-7	30.1	27.4	9
GML 505	123.3	95.0	23	14.0	12.3	12	24.8	20.1	19
GML 506	125.0	101.7	19	10.7	8.7	19	33.9	14.7	57
GML 512	109.3	94.3	14	16.0	13.0	19	25.5	23.5	8
GML 514	107.3	82.7	23	13.7	13.0	5	25.7	19.5	24
GML 515	114.3	100.0	13	16.0	12.3	23	36.9	25.0	32
HHZ11-Y11-Y3-DT1	105.3	86.7	18	11.7	9.0	23	19.5	16.1	18
HHZ5-SAL10-DT2-DT1	102.0	86.3	15	12.7	9.0	29	13.3	10.4	22
IR 04L191	129.7	116.0	11	13.7	11.3	17	32.7	28.6	12
IR 83105-B-B-5	107.0	107.0	0	8.3	10.3	-24	17.7	14.5	18
IR 83140-B-28-B	120.3	104.3	13	14.3	14.0	2	34.5	23.8	31
IR 83141-B-18-B	112.7	111.0	1	16.0	13.0	19	40.0	31.2	22
IR 83142-B-20-B	110.3	92.7	16	19.0	12.0	37	27.2	24.9	8
IR 83142-B-21-B	113.0	97.7	14	13.7	11.7	15	28.3	24.8	12
IR 83142-B-60-B	131.7	106.3	19	13.7	11.7	15	35.7	34.5	3
IR 84677-34-1-B	103.3	95.7	7	13.7	13.3	2	26.9	22.2	17
IRRI 123 (PSBRc 82)	134.0	102.0	24	14.0	13.3	5	37.3	22.9	39
OM 7938	105.0	90.7	14	17.0	13.7	20	18.0	16.9	6
OMCS 2009	122.3	105.7	14	17.3	12.3	29	36.0	31.3	13
ZAOXIAN 14	94.0	88.7	6	16.7	12.0	28	25.5	12.2	52
HSD Value (at Alpha 0.05) for Genotypes (G)	6.2967			3.0802			7.0763		
HSD Value (at Alpha 0.05) for Treatment (T)	0.9635			0.4713			1.0828		
HSD Value (at Alpha 0.05) for G X T	9.7658			4.7772			10.975		

Table 3 a. Effect of water stress on yield components of rice genotypes.

Genotypes	Panicle/Plant (no)			Panicle length (cm)		Spikelets/Panicle (no)	
	control	W.Stress	Red %	control	W.Stress	control	W.Stress
BINDESHWARI	12	11	11	22.4	22.1	8	7
GML 498	22	8	62	26.2	23.6	9	7
GML 499	13	8	38	27.0	23.4	10	9
GML 500	11	9	18	26.3	23.0	10	9
GML 502	14	14	5	25.8	23.7	9	8
GML 505	14	12	12	25.9	19.0	8	8
GML 506	9	8	14	26.4	25.2	9	7
GML 512	15	10	31	27.2	21.0	11	7
GML 514	10	10	6	27.2	23.7	10	10
GML 515	13	10	26	25.6	20.6	10	7
HHZ11-Y11-Y3-DT1	11	8	26	23.7	22.2	8	7
HHZ5-SAL10-DT2-DT1	13	9	26	24.5	23.7	8	7
IR 04L191	12	8	35	24.2	22.8	10	9
IR 83105-B-B-5	9	7	22	24.5	22.1	8	7
IR 83140-B-28-B	14	14	2	25.8	23.4	8	9
IR 83141-B-18-B	16	13	21	26.1	24.4	9	9
IR 83142-B-20-B	12	5	61	25.2	26.6	9	8
IR 83142-B-21-B	14	12	19	26.7	21.1	8	8
IR 83142-B-60-B	13	10	23	27.8	23.8	9	9
IR 84677-34-1-B	14	12	15	22.8	22.1	8	7
IRRI 123 (PSBRc 82)	12	8	38	27.2	24.6	10	7
OM 7938	16	14	9	22.1	20.0	8	7
OMCS 2009	15	10	36	32.4	22.0	12	7
ZAOXIAN 14	13	12	8	26.5	23.9	10	9
HSD Value (at Alpha 0.05) for Genotypes (G)	2.6377			3.8504		2.3496	
HSD Value (at Alpha 0.05) for Treatment (T)	0.4036			0.5892		0.3595	
HSD Value (at Alpha 0.05) for G X T	4.091			5.9717		3.6441	

Table 3 b. Effect of water stress on yield components of rice genotypes.

Genotypes	**100 Grain weight (g)**		**Harvest Index (%)**		**Flowering DAT (no.)**	
	control	**W.Stress**	**control**	**W.Stress**	**control**	**W.Stress**
BINDESHWARI	2.34	1.76	39	36	52	57
GML 498	2.68	1.83	52	40	62	62
GML 499	2.39	1.97	41	39	62	62
GML 500	2.54	1.81	51	40	57	59
GML 502	2.62	2.14	52	41	55	56
GML 505	2.12	1.52	44	35	56	55
GML 506	2.33	1.60	39	16	57	63
GML 512	2.31	1.43	51	35	52	55
GML 514	2.12	1.52	51	43	51	50
GML 515	2.38	1.57	44	38	54	54
HHZ11-Y11-Y3-DT1	2.25	1.34	45	36	55	62
HHZ5-SAL10-DT2-DT1	2.40	1.66	53	35	48	42
IR 04L191	2.19	1.79	44	30	62	63
IR 83105-B-B-5	2.37	1.60	45	29	56	58
IR 83140-B-28-B	2.72	2.10	42	49	56	62
IR 83141-B-18-B	2.67	2.00	37	40	62	62
IR 83142-B-20-B	2.71	2.03	44	20	57	62
IR 83142-B-21-B	2.95	2.20	46	38	55	55
IR 83142-B-60-B	2.76	1.98	41	23	59	62
IR 84677-34-1-B	2.45	2.18	29	27	56	55
IRRI 123 (PSBRc 82)	2.36	1.78	42	33	54	65
OM 7938	2.33	2.10	54	50	48	51
OMCS 2009	2.87	1.78	39	28	55	58
ZAOXIAN 14	2.27	2.21	37	50	41	42
HSD Value (at Alpha 0.05) for Genotypes (G)	0.1373		0.1131		3.6315	
HSD Value (at Alpha 0.05) for Treatment (T)	0.021		0.0173		0.5557	
HSD Value (at Alpha 0.05) for G X T	`0.2129		0.1754		5.6323	

Grain weight/Plant

Overall grain weight productions of these genotypes were in range of 11- 41 g/p under irrigated and 3-23g /p under water stress conditions. The genotypes GML- 498, GML- 502, GML- 515 and IR83140-B-28-B were significantly different in their overall grain weight production under irrigated conditions. The drought tolerant check genotype IR 04L191produced 12 g /p and exhibited relative reduction of 52.8% under stress. Whereas, the genotype IR83140-B-28-B was best followed by IR83141-B-18-B, GML-502 and OM 7938 produced comparatively higher grain weights with less relative reduction of 9, 13, 43 &23% respectively under water stress (Fig. 2).

Yield components

The data of yield components i.e. panicle length, number of spikelet and 100 grain weight have also indicated varying responses under stress (Table 3a). However, overall genotypes comparison has shown that the largest panicle length was attained by GML -512, IR83142-B-60-B and GML-514. Under water stress conditions significant treatment effects were observed on panicle length. Among all genotypes GML-512 exhibited largest panicle length (27.2 cm) with no reduction under stress was followed by IR83142-B-60-B, IR83142- B-20-B, GML-14, IR83141-B-18-B and GML-500. The data of spikelet's number / panicle has shown that GML-514, IR83142-B-60-B, GML-500, D.T check, Zaoxian-14, IR83140-B-28, IR83141-B-18-B and GML-502 were comparatively better in spikelet's number. Under well irrigated conditions the 100 grain weights were varied from 2.1-3.0 g, these weights were reduced under stress conditions in the range of 1.3-2.2 g. The maximum weight (2.2 g) under water stress was observed in genotypes Zaoxian-14, IR-83142- B-21-B and IR-84677-34-1-B. These genotypes have also exhibited comparatively higher values for 100 grain weights under well irrigated conditions (Table 3 b). The values of harvest index (%) of these genotypes under well irrigated conditions were in the range of 29- 54. These values were reduced under water stress conditions in the range of 16- 50. The interactions of genotypes with treatment have shown that ZAOXIAN 14, OM-7938 and IR84140-B-28-B with high harvest index of 50, 50 and 49, respectively (Table 3 b). Correlations coefficient studies for all growth and yield traits have indicated that all traits were positively correlated ($p < 0.001$) with grain weight except flowering days (Table 4).

Table 4. Pearson˝s Correlation coefficient among growth and yield traits of rice genotypes under water stress.

	Grain weight	Tillers	Flowering days	Panicleno.	Panicle length	Spikelets	100gwt
Tillers	0.7113						
	***						
Flowering days	-0.0134	-0.1145					
	ns	ns					
Panicle no.	0.7063	0.808	-0.1723				
	***	***	ns				
Panicle length	0.4505	0.3664	0.0417	0.2271			
	**	*	ns	ns			
Spikelets	0.5477	0.455	-0.0728	0.3432	0.6734		
	***	**	ns	*	***		
100gwt	0.6683	0.5925	-0.0802	0.6416	0.6227	0.4946	
	***	***	ns	***	***	**	
Harvest index	0.703	0.4266	-0.3608	0.5647	0.1586	0.383	0.4658
	***	**	**	***	ns	**	**

** = Significant @1% prob., * = Significant @ 5% probability, ns = Non-significant

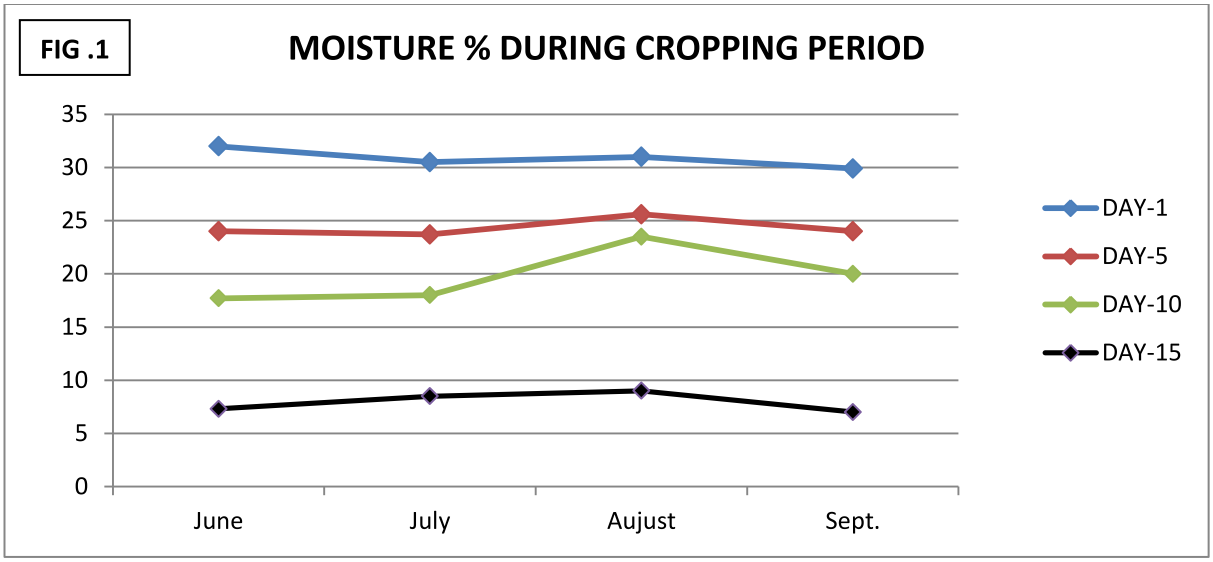

Fig.1. Moisture % during cropping period from June to September.

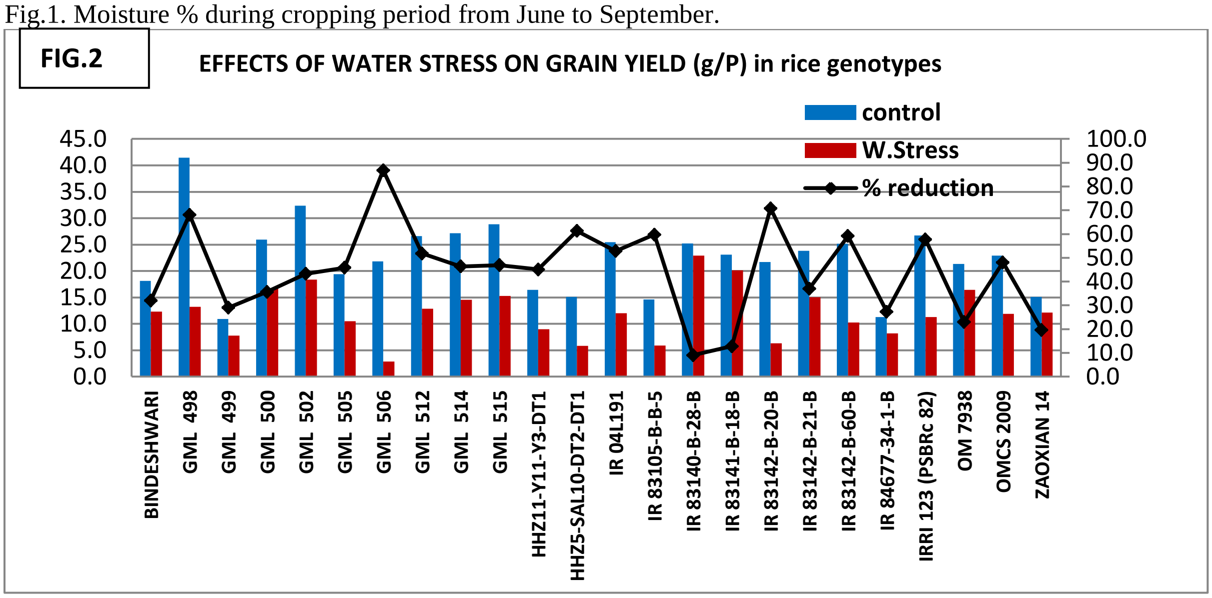

Fig. 2. Effects of water stress on grain yield (g/p) in rice genotypes.

Responses of rice genotypes under field conditions

The results 3 years data for growth and yield components were pooled for analysis of variance. The data showed that all rice genotypes and yield traits were significantly affected under water stress (Table 5). There were seven genotypes (GML-500, GML-499, IR 83140-B-28-B, GML-498, IR83142-B-60-B, IR83142-B-20-B and OMCS-2009) produced higher grain weight (24-18g in descending order) than drought tolerant check genotype which produced 17g grain weight per plant under controlled water stress condition. These studies have indicated that these rice genotypes were showing variable responses in different yield contributing traits therefore, grouping of genotypes was done to identify best genotypes possess better yields contributing traits under water stress conditions. The cluster analysis of twenty four genotypes using complete linkage method Euclidean distance formulated six clusters (Fig.3) on the basis of eight yield and yields contributing quantitative traits and their similarity. This cluster analysis revealed that most of the potential genotypes were in cluster 5 and in cluster 4. In cluster 5; there were 7 genotypes exhibited plant height ≤ 100cm, productive tillers ≤17, biomass production ≤ 39g, grain weight 17-24g per plant with good harvest index and 100 grain weights. Among these seven genotypes, 3 genotypes (GML -500, GML- 499 and IR 83140-B-28-B) have produced comparatively higher grain weights (24-20g/plant) under water stress. These genotypes were also observed as high yielder under non stress conditions (Table 5). Whereas in cluster 4; four genotypes (IR 83140-B-20-B, IR83142-B-60-B and GML- 498) along with drought tolerant check produced

18-19g grain weight per plant. In cluster 6; genotype OMCS-2009 was entirely different from rest of the genotypes and formed a separate group with yield of 48 and18 g/p under non stress and stress condition, respectively.

Table 5. Growth and yield performance of rice genotypes under water stress conditions in field

Genotypes	Plant height (cm/plant)		ProductiveTillers (no/plant)		Straw weight (g/plant)		Grain weight (g/plant)		Harvest Index (%)		100 GWt (g)	
	control	W.Stress	control	W.Stress	control	W.Stress	control	W.Stress	control	W.Stress	control	W.Stress
IR 84677-34-1-B	78.8	75.9	22	16	36.8	28.5	22.8	17.1	40	34	2.1	2.0
IR 83105-B-B-5	93.2	84.6	23	15	53.5	36.0	30.8	17.8	38	28	2.3	1.7
IR 83142-B-60-B	103.3	97.1	17	13	38.7	33.0	22.5	19.1	35	32	2.7	2.2
IR 83142-B-21-B	94.3	88.0	16	15	38.3	34.5	23.5	15.1	35	27	2.7	2.4
IR 83142-D-20-D	99.1	95.0	17	13	41.4	33.3	31.8	18.4	43	34	2.6	2.0
IR 83141 B 18 B	102.1	82.8	19	15	45.4	36.6	28.1	13.5	36	25	2.3	2.1
IR 83140 B 28 B	114.2	91.5	17	15	39.3	32.1	25.6	20.2	39	34	2.5	2.4
IR 04L191	109.1	98.2	18	13	39.1	35.6	23.3	17.3	34	30	2.1	2.1
IRRI 123 (PSBRc 82)	104.9	92.4	22	15	49.2	33.9	43.8	16.7	46	33	2.2	2.0
HHZ11-Y11-Y3-DTI	89.7	81.0	18	12	37.3	33.5	33.3	16.2	46	31	2.0	1.9
HHZ5-SAL10-DT2-DT1	92.1	82.6	22	14	47.8	35.8	30.0	17.2	38	31	2.4	1.9
GML 498	101.2	95.8	20	16	41.6	37.3	29.8	19.5	39	31	2.5	2.0
GML 499	93.6	89.1	18	16	39.8	38.8	37.7	23.3	46	36	2.4	2.0
GML 500	99.2	85.2	18	16	41.9	28.4	33.5	24.2	44	41	2.5	2.0
GML 502	99.2	88.4	20	12	48.0	37.5	33.6	13.2	39	24	2.5	2.2
GML 505	94.8	83.0	21	14	48.0	38.8	33.0	10.2	40	20	2.0	1.7
GML 506	89.1	84.4	20	17	35.5	31.4	29.8	17.2	43	33	2.3	1.7
GML 512	98.7	81.6	22	14	47.1	36.5	33.4	15.7	40	31	2.1	2.0
GML 514	93.4	80.8	17	15	43.4	39.3	35.9	14.3	44	26	1.8	1.8
GML 515	96.1	77.6	19	14	45.7	24.8	34.4	12.9	41	30	2.2	2.1
BINDESHWARI	97.3	87.8	24	14	41.3	37.2	29.9	10.8	40	20	2.1	1.7
OM 7938	98.7	85.8	21	15	50.9	35.1	27.6	16.7	35	31	2.2	1.9
OMCS 2009	117.3	90.5	23	15	70.9	56.2	45.8	18.0	38	20	2.8	2.1
ZAOXIAN 14	103.8	85.8	22	13	37.3	32.4	45.9	17.6	53	33	2.0	1.9
HSD Value (at Alpha 0.05) for Genotypes (G)	6.204		3.4421		7.5787		2.7245		4.2602		0.1343	
HSD Value (at Alpha 0.05) for Treatment (T)	0.9494		0.5267		1.1596		0.4169		0.6519		0.0205	
HSD Value (at Alpha 0.05) for G X T	9.6233		5.3385		11.754		4.2256		6.6074		0.2082	

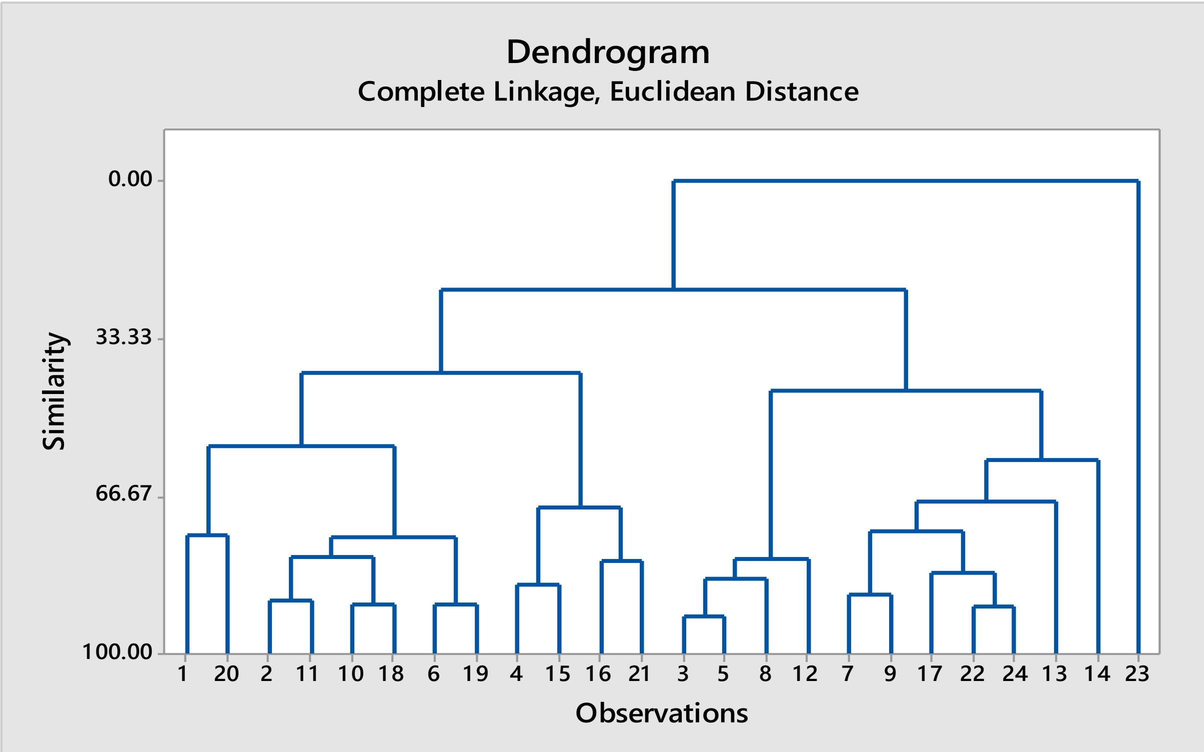

Fig.3.Dendrograms using complete linkage Eucladean distance represents the groups formed by clustering of genotypes and their similarity levels.

Description of Genotypes:

1. IR 84677-34-1-B, 2. IR 83105-B-B-5, 3. IR 83142-B-60-B, 4. IR 83142-B-21-B, 5. IR 83142-B-20-B, 6. IR 83141-B-18-B, 7. IR 83140-B-28-B, 8. IR 04L191, 9. IRRI 123 (PSBRc 82), 10. HHZ11-Y11-Y3-DT1, 11. HHZ5-SAL10-DT2-DT1, 12. GML 498, 13. GML 499, 14. GML 500, 15. GML 502, 16. GML 505, 17. GML 506, 18. GML 512, 19. GML 514, 20. GML 515, 21. BINDESHWARI, 22. OM 7938, 23. OMCS 2009, 24. ZAOXIAN 14

DISCUSSION

Numbers of short term studies on water stress have been done so far in rice, using multiple methodologies and growth parameters included germination, visual screening on the basis of dead leaves, recovering ability from stress and achieving vigor in growth (Kumar *et al.*, 2015; Swapna *et al*. 2017; Susanto*et al.*, 2019; Salleh *et al.*, 2020; Umego *et al*. 2020). Very little information of screening of rice genotypes on the basis of multiple agronomic traits under continuous water stress conditions up to maturity is available. In the present study we have assessed variability among genotypes potential for drought tolerance in rice using a technique of alternate wetting and drying (AWD) method for different morphological and yield traits up to maturity stage simultaneously under hydroponically controlled and field conditions. Significant differences were observed for most of the traits studied among rice genotypes (Table 1-3) which reflect the potential of exploitable genetic variability. However, these genotypes have shown a general reduction with variable intensity in all growth and yield parameters i.e., plant height, productive tillers, and biomass production. Among 24 tested genotypes the IR83140-B-28-B followed by IR83141-B-18-B, , GML- 499 and GML-500 were observed comparatively better in most of the traits studied along with less relative reduction in yield under water stress (Fig.3 & Fig.2). There may be many causes of reduction in growth under water stress conditions. Water stress exerts multidimensional effects on rice growth depends on stages of growth, flowering, panicle formation and grain filling stage (Kim *et al*., 2020; Iqbal *et al*., 2020) through alterations in man yphysio-biochemical process, including water stress induced deficiency in mineral nutrition and reduced metabolic activity (Singh *et al*., 2018; Dien *et al*., 2019), reduce canopy photosynthesis, gas exchange rate, enzyme activities (Swapna *et al*., 2017; Fahad *et al*., 2017; Hassan *et al*.. 2020), conversion of assimilates to biomass and assimilates partitioning to grains (Lone *et al*., 2019; Rasheed *et al*., 2020; Sahoo *et al*., 2020; Ahmad *et al*., 2020).This ultimately results in reduction in number of productive tillers, leaf growth, biomass and yield (Pervin *et al.*, 2017; Sahebi *et al.*, 2018).

In the present study correlation of different yield components with yield indicated direct significant relationship. Tiller ingability and high value of harvest index determine grain yield as these two traits were highly correlated in this study (Table 4),which indicates higher mobilization of assimilates to the grains from vegetative part of the plant under drought (Sahoo *et al.*, 2020). Lone *et al*. (2019) and Salleh *et al*. (2020) are of the view that these component traits are useful for plant breeders if they are easily measured and having greater genetic variability and high heritability.

Delay in flowering under drought stress is considered another important trait to predict genotypic potential. Drought stress enhances the transformation from vegetative to reproductive phase. It is reported that susceptible plant flowers early while tolerant plants maintains their time of flowering near to normal (Singh *et al*., 2018). In the present study some genotypes exhibited early flowering under stress earlier than control showing their early completion of life cycle by opting escape mechanism whereas, other maintaining their period by adaptation as was observed in drought tolerant check, IR 83141-B-18-B andGML-499 (Table 3b). There are reports indicate the non-flooded and saturated conditions increased flowering-time, canopy temperature, heat-induced sterility and low yield. (Ahmad *et al*., 2020; Tsujimoto *et al*., 202). However, in our study no significant correlation was observed for this trait (Table 4). Zou *et al*. (2007) have reported negative relationship of flowering days with yield.

Conclusions

Three genotypes (GML -500, GML- 499 and IR 83140-B-28-B) have produced higher grain weight (24-20g/plant) along with less relative reduction under water stress. These genotypes were also observed as high yielder under non stress conditions. These genotypes may be used in breeding program for developing drought tolerant rice genotypes as well as for adoption in water scarce areas.

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