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Effects of Different Combination of Drought QTLs and their Physiological Response Under Controlled Moisture Stress Condition

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Abstract

Rice (*Oryza sativa* L.) being a water loving cereal crop, the water scaricity during the crop period is detrimental to the productivity. The present investiagation was undertaken to study the effect of different yield QTLs under drought and their physiological response to drought. Near-Isogenic Lines (NILs) of IR64 (CB-193 and CB-229) along with IR64, APO and the traditional rice variety Norungan were raised under both water stress and control condition. Infrared Gas Analyser (LICOR-Model LI 6400 version. 5) was used to observe the gas exchange parameters in each genotype both under control and stress condition in different intervals (52, 58, 66, 72 and 77 days after sowing) of stress induction with diverse moisture content. The reduction in moisture level in pot culture under stress condition minimizes the trait value of all gas exchange parameters *viz.*, photosynthetic rate, stomatal conductance, transpiration rate, ratio between internal and atmospheric CO_2 concentration (Ci/Ca) and relative water content in the leaf tissues. Among the genotypes studied, CB-229 ($DTY_{2.2}$, $DTY_{3.1}$ and $DTY_{8.1}$) had recorded higher photosynthetic rate and relative water content than the NIL CB-193 ($DTY_{3.1}$ and $DTY_{8.1}$) under stress condition. This NIL also maintained the photosynthetic rate (reduction is minimum when stress increased) and relative water content as APO (72 and 77 DAS) when moisture stress is increased upto the lower level in pot culture. Relative water content was estimated by Weatherley (1950) method and expressed in percentage. Several biometrical traits were also observed in both under control and moisture stress condition. The overall study clearly visualized that the combination of three drought QTL line exhibited better performances with higher gas exchange parameter values than two QTL combination line which shown lesser response towards moisture stress.

Keywords

Rice; QTL; Near-Isogenic Lines; Drought and Relative Water Content.

Introduction

Rice is particularly susceptible to water deficit compared to other crop species, and this sensitivity is severe around flowering. Drought resistance is a complex trait, expression of which depends on action and interaction of different morphological, physiological and biochemical characters. But, the progress in genetic improvement of rice for water-limiting environments has been slow and limited (Evenson and Gollin, 2003) due to poor understanding of the inheritance of tolerance and lack of efficient techniques for screening breeding materials for drought tolerance (Khush, 2001). Alternatively, selection for the drought resistance traits with molecular marker technology has been recommended. Several putative traits contributing to drought resistance in rice have been

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proposed (Nguyen *et al.,* 1997; Bernier *et al.,* 2009; Kamoshita *et al.,* 2008). On a more realistic note an interdisciplinary and comprehensive breeding strategy is what required for successful exploitation of genomics to drought prone environments.

Materials and Methods

The material used in this study is two Near isogenic lines (NILs) of IR64 developed from the cross combination of IR64 X APO. Apo, drought tolerant upland variety, developed at IRRI, recommended for cultivation under aerobic conditions. Owing to its drought tolerance nature and good performance under aerobic conditions, they serve as important source for mining drought tolerant QTLs. IR64 is a medium duration and high yielding variety but highly prone to drought. NILs from the cross between IR64 X APO were generated which carried three mega QTL classes namely *DTY 2.2, DTY 3.1* and *DTY 8.1*. The two NIL lines of CB-193 ($DTY_{3.1}$ and $DTY_{8.1}$), CB-229 ($DTY_{2.2}$, $DTY_{3.1}$ and $DTY_{8.1}$) were raised under control and water stress condition (pot culture experimentation). Infrared Gas Analyzer (IRGA) is a portable photosynthetic system (LICOR- Model LI 6400 version.5) and major component used for the measurement of different parameters *viz*., photosynthetic rate, stomatal conductance, transpiration rate and Ci/Ca ratio. The basic principle (Barrs and Weatherley, 1962) of this technique consists essentially in comparing the water content of leaf tissue when fresh leaf sampled with the fully turgid water content and expressing the results on percentage basis. Relative water content was estimated by Weatherley (1950) method and expressed in percentage. Several biometrical traits were also observed in both under control and moisture stress condition.

Results and Discussion

Photosynthesis and its associated traits are fundamental to biomass production, but sensitive to abiotic stress especially drought. Various physiological parmeters viz., photosynthetic rate, stomatal conductance, transpiration rate, Ci/Ca ratio and relative water content were measured in NILs of CB-193 ($DTY_{3.1}$ and $DTY_{8.1}$), CB-229 ($DTY_{2.2}$, $DTY_{3.1}$ and $DTY_{8.1}$), their parents (IR64 and APO) and check (Norungan) at different intervals (52, 58, 66,72 and 78 days after sowing (Fig. 1) and the results were presented in Table 1. During initial stage of moisture reduction in pot culture at 52 DAS (days after sowing), the NIL CB-193 recorded higher photosynthetic rate

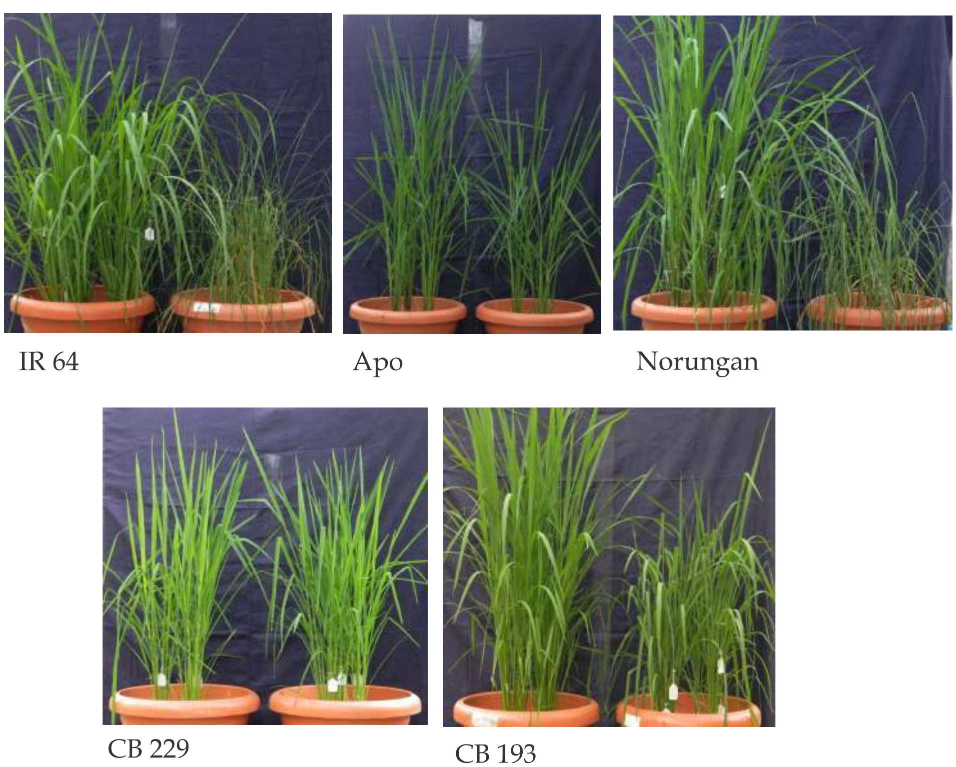

Fig. 1: Parents and Nils under irrigated (Left) and stress condition (Right) under pot culture experiment.

(22.051), stomatal conductance (0.270), transpiration rate (7.152), Ci/Ca ratio (0.597) whereas relative water content were high in NIL CB-229. When moisture stress increases during 58, 66, 72 and 78 DAS, the line CB-229 registered higher gas exchange parameters especially photosynthetic rate and also relative water content as resistant parent APO and check Norungan. This would clearly revealed that, the NIL line CB-229 maintained internal water status with normal physiological process of photosyntheis, stomatal conductance and transpiration rate could withstand under higher moister stress conditions and highly productive over prolonged drought (Centritto *et al*., 2009). Similar kind of results was also already reported by Gu *et al*. (2012) and Ji *et al*. (2012).

Table 1: Physiological parameters estimation in two Near Isogenic Lines [CB-193 ($DTY_{3.1}$ and $DTY_{8.1}$), CB-229 ($DTY_{2.2}$, $DTY_{3.1}$ and $DTY_{8.1}$)] of IR64 both under control and water stress condition (pot culture)

Genotypes	Soil Moisture (%)		Photosynthetic rate (μ mol CO_2 m^{-2} s^{-1})		Stomatal Conductance (mol H_2O m^{-2} s^{-1})		Transpiration Rate (mmol H_2O m^{-2} s^{-1})		Ci/Ca		Relative Water Content (%)	
52 DAS												
	C	S	C	S	C	S	C	S	C	S	C	S
CB-193 (2QTL)	96.43	65.56	23.260	22.051*	0.255	0.270*	7.468	7.152*	0.559	0.597*	98.59	95.72
CB-229 (3QTL)	89.52	64.09	28.887*	20.942	0.350*	0.252*	9.325*	6.660	0.589*	0.591*	98.11	97.65*
Norungan	90.82	65.76	21.138	21.543*	0.259	0.271*	7.117	7.182*	0.598	0.606*	99.36	97.32
APO	89.39	62.10	20.829	20.090	0.241	0.176	6.751	5.005	0.578*	0.472	99.05	98.31*
IR64	91.73	68.19	22.821	18.107	0.217	0.142	6.084	6.478	0.495	0.397	96.55	96.52
MEAN	91.58	65.14	23.39	20.55	0.26	0.22	7.35	6.50	0.56	0.53	98.33	97.10
SE	1.29	1.00	1.45	0.69	0.02	0.03	0.54	0.40	0.02	0.04	0.49	0.45
58 DAS												
CB-193 (2QTL)	96.43	65.56	32.856*	17.382	0.474*	0.247*	16.083*	6.519*	0.627*	0.653*	98.59*	95.72
CB-229 (3QTL)	78.68	61.53	25.761	20.025*	0.293	0.108	12.098	4.473	0.555	0.178	98.86*	97.22*
Norungan	80.98	60.05	20.928	20.432*	0.201	0.157	8.826	6.922*	0.496	0.384	97.02	97.00*
APO	83.78	54.91	23.302	17.190	0.248	0.236*	10.374	6.288	0.531	0.641*	97.88	96.09
IR64	81.16	62.85	21.817	16.293	0.284	0.184	11.297	5.534	0.599*	0.574	97.56	95.60
MEAN	84.21	60.98	24.93	18.26	0.30	0.19	11.74	5.95	0.56	0.49	97.98	96.33
SE	3.16	1.77	2.14	0.83	0.05	0.03	1.22	0.43	0.02	0.09	0.34	0.33
66 DAS												
CB-193 (2QTL)	91.74	41.01	31.614*	15.527	0.810*	0.090	13.700*	3.807	0.776	0.219	97.11	88.86
CB-229 (3QTL)	88.03	43.52	32.918*	19.751*	0.732	0.196*	12.768	4.389*	0.750	0.534*	93.42	91.53*
Norungan	69.55	39.69	27.755	17.391*	0.703	0.141	12.051	3.323	0.780	0.441	97.57*	86.32
APO	74.09	36.04	25.086	14.852	0.657	0.112	11.360	4.604*	0.787	0.392	97.35*	87.74
IR64	90.30	49.93	26.577	13.332	0.862*	0.151	12.950	4.499*	0.820	0.581*	97.25	88.30
MEAN	82.74	42.04	28.79	16.17	0.75	0.14	12.57	4.12	0.78	0.43	96.54	88.55
SE	4.55	2.31	1.50	1.11	0.04	0.02	0.40	0.24	0.01	0.06	0.78	0.86
72 DAS												
CB-193 (2QTL)	87.25	17.95	30.938	15.465*	0.642*	0.141*	14.695*	3.224	0.734*	0.502*	96.20*	82.52
CB-229 (3QTL)	79.08	27.49	32.672*	16.657*	0.608*	0.074	15.167*	3.072	0.702*	0.033	90.64	88.41*
Norungan	75.21	16.28	32.778*	13.332	0.498	0.151*	13.342	4.499*	0.648	0.581*	97.54*	79.18
APO	78.94	30.50	28.294	14.119	0.451	0.113	12.776	2.803	0.669	0.439	92.15	86.38*
IR64	80.10	34.16	29.375	12.352	0.539	0.066	14.657*	2.960	0.700	0.177	94.83	79.71
MEAN	87.25	25.28	30.81	14.39	0.55	0.11	14.13	3.31	0.69	0.35	94.27	83.24
SE	1.96	3.50	0.89	0.76	0.03	0.02	0.45	0.30	0.01	0.10	1.27	1.82

Genotypes	Soil Moisture (%)		Photosynthetic rate (μ mol CO_2 m^{-2} s^{-1})		Stomatal Conductance (mol H_2O m^{-2} s^{-1})		Transpiration Rate (mmol H_2O m^{-2} s^{-1})		Ci/Ca		Relative Water Content (%)	
77 DAS												
CB-193 (2QTL)	85.02	16.22	19.978	10.286*	0.331	0.110*	11.514*	4.102*	0.678*	0.556*	98.99	72.41
CB-229 (3QTL)	71.96	22.87	18.424	10.473*	0.268	0.066	9.801	2.678	0.646	0.294	99.38*	80.76*
Norungan	70.32	16.89	26.040*	4.685	0.363*	0.032	11.941*	1.337	0.632	0.351	98.19	63.52
APO	66.68	23.44	20.974	10.951*	0.373*	0.131*	12.213*	4.923*	0.698*	0.597*	99.36*	78.10*
IR64	75.39	27.65	17.937	6.851	0.238	0.047	8.336	1.935	0.620	0.344	99.19	66.93
MEAN	73.87	21.41	20.67	8.65	0.31	0.08	10.76	2.99	0.65	0.43	99.02	72.34
SE	3.12	2.15	1.45	1.23	0.03	0.02	0.74	0.67	0.01	0.06	0.22	3.25

C – Control, S – Moisture Stress, DAS – days after sowing

In the present investgation, several biometrical traits were observed in all genotypes under study which exhibited that, the NIL CB-229 had recorded higher number of productive tillers, root length, number of filled grains per panicle, spikelet fertility percentage, hundred grain weight and grain yield under moisture stress condition when compared to the NIL CB-193 (Table 2a,b). The QTL $DTY_{2.2}$ was responsible for increase in root length (MacMillan *et al*., 2006; Kamoshita *et al*., 2002) and root thickness (Champoux *et al*., 1995, Dixit *et al*., 2012), similar results were recorded in this study. The NIL CB-229 had registered an increase in root length and root thickness. In this study also, the NIL CB-229 possess QTL $DTY_{8.1}$ was associated with grain yield under stress condition. The similar result was already reported by Vikram *et al*. (2012). But the significant advantage of CB-193 is earlier in flowering and reduced plant height. Both the NILs of CB-193 ($DTY_{3.1}$ and $DTY_{8.1}$) and CB-229 ($DTY_{2.2}$, $DTY_{3.1}$ and $DTY_{8.1}$) were earlier in flowering with reduced plant height, which possess $DTY_{3.1}$ responsible for flowering date and plant height (Venuprasad *et al*., 2009).

Table 2a: Yield attributing traits of Near Isogenic Lines [CB-193 ($DTY_{3.1}$ and $DTY_{8.1}$), CB-229 ($DTY_{2.2}$, $DTY_{3.1}$ and $DTY_{8.1}$)] of IR64 both under control and water stress condition (pot culture)

Genotypes	DF			PH			NOPT			RL		
	C	S	Reduction %	C	S	Reduction %	C	S	Reduction %	C	S	Increasing %
CB-193 (2QTL)	75	62*	17.33	95	76*	40.00	24	13	45.83	8.8	9.6	9.09
CB-229 (3QTL)	75	66	12.00	112	95	30.36	23	15*	34.78	8.9	12.3	38.20
NORUNGAN	86	75	12.79	154	109	58.44	11	9	18.18	9.6*	16.2*	68.75
APO	81	73	9.88	110	87	41.82	7	6	14.29	9.2	12.9	40.22
IR 64	72*	64	11.11	97	82	30.93	24	11	54.17	8.6	9.4	9.30
Mean	77.8	68		114	89.8		18	10.8		9.02	12.08	
SE	2.52	2.55		10.70	5.72		3.70	1.56		0.17	1.25	

Table 2b: Yield attributing traits of Near Isogenic Lines [CB-193 ($DTY_{3.1}$ and $DTY_{8.1}$), CB-229 ($DTY_{2.2}$, $DTY_{3.1}$ and $DTY_{8.1}$)] of IR64 both under control and water stress condition (pot culture)

Genotypes	NFG			SPF			HGW			SPY		
	C	S	Reduction %	C	S	Reduction %	C	S	Reduction %	C	S	Reduction %
CB-193 (2QTL)	165	118	28.48	92.7*	66.3	28.48	2.62	2.41	8.02	15.23	6.36	58.24
CB-229 (3QTL)	274*	140	48.91	89.3	66.0	26.09	2.64	2.47	6.44	19.09*	8.46*	55.68
NORUNGAN	172	136	20.93	89.1	66.7	25.14	2.73	2.68*	1.83	6.93	4.56	34.20
APO	259*	172*	33.59	91.5	71.4	21.97	2.30	2.1	8.70	7.87	4.91	37.61
IR 64	157	86	45.22	89.2	47.5	46.75	2.82*	2.24	20.57	16.37	4.3	73.73
Mean	205.4	130.4		90.36	63.58		2.622	2.38		13.1	5.72	
SE	25.17	14.10		0.74	4.14		0.09	0.10		2.414	0.77	

Conclusion

This experimentation on controlled moisture condition under pot culture concluded that, the individual yield QTLs of drought *viz*., $DTY_{2.2}$, $DTY_{3.1}$ and $DTY_{8.1}$ was expressed in both NILs of CB-193 ($DTY_{3.1}$ and $DTY_{8.1}$), CB-229 ($DTY_{2.2}$, $DTY_{3.1}$ and $DTY_{8.1}$) when the situation of prolonged moisture stress exists. And also the NIL CB-229 performance in gas exchange parameters and yield contributiong traits were better with the cumulative effect of three yield QTLs of drought than CB-193 having two yield QTLs of drought. Therefore, gas exchange parameters and yield attributing traits favours the selection of superior genotypes under drought conditions makes further improvement in yield.

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