RESEARCH ARTICLE

RESPONSE TO DIRECT SELECTION FOR GRAIN YIELD IN INTERSPECIFIC POPULATION OF *ORYZA SATIVA* IR58025B X *ORYZA MERIDIONALIS* NG., MAPPING POPULATION UNDER IRRIGATED AND STRESS CONDITIONS

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ABSTRACT

Rice (*O. sativa* L.) is one of the world's most important crops, particularly in Asia, but increasingly in Africa and Latin America as well. It is one of the important food crops drastically affected by raise in global temperature and has an impact throughout worldwide on people who depend on rice production for their livelihoods and food security. The objective of this study was to evaluate the effectiveness of direct selection for grain yield under heat and irrigated conditions. 274 BC_2F_6 BILs were derived from a cross between *Oryza sativa* IR58025B and *Oryza meridionalis* Ng. (2n = 24, AA), a heat tolerant wild species to evaluate 18 yield and its related traits and for heat tolerance under irrigated and stress conditions. Analysis of variance and genetic estimates indicated there is substantial genetic variation among progenies under both stress and control conditions. The genotypic coefficient of variation ranged from 1.57 for canopy temperature to 77.29 for line yield per plot, whereas, the phenotypic coefficient of variation ranged from 4.31 for panicle temperature to 91.68 for spikelet fertility. The GCV ranged from 6.35 (panicle length) in control to 77.29 (line yield) in stress condition, the PCV ranged from 9.71 (panicle length) to 93.20 (line yield) in stress condition. Further, for physiological traits like flag leaf temperature, panicle temperature, canopy temperature and leaf area index the GCV ranged from 1.57 (canopy temperature) to 17.13 (leaf area index) in stress, the PCV ranged from 1.84 (panicle temperature to 27.05 (leaf area index) in stress. Broad sense heritability estimates varied from 0.34 (panicle temperature) to 0.86 (plant height) in control condition, and 0.12 (canopy temperature) to 0.77 (Days to 50% flowering) in stress condition. Hence, this species can be a novel source of natural genetic variation for the improvement of rice and simultaneously help in expansion of the cultivated gene pool of *O. sativa*.

INTRODUCTION

Rice is a major staple cereal cropping system of south and Southeast Asia. Plant's peaceful way of living is often disturbed by a number of environmental factors, among which abiotic factors are of crucial importance. Global warming has become a big concern in sustaining and improving agricultural productivity.

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High temperature is one of the most important abiotic stresses that reduce crop yield and quality (Peng *et al.*, 2004, Lin *et al.*, 2005). Global warming has increased due to rapid increase in atmospheric greenhouse gasses (Easterling *et al.*, 1997, Lee *et al.*, 2007). Over the past 100 years, the global average temperature has increased by 0.6^0 C and is projected to continue to rise at a rapid rate (Root *et al.*, 2003), with another 0.5 to 2.8^0 C increase predicted by the end of the 21st century (Meehle *et al.*, 2005, Vuuren *et al.*, 2008).

Table 1. Details of meteorological conditions during the phenotypic evolution

Season	Rainfall	Evapotranspiration	Temperature (°C)			RH (%)	Wind speed (Km/h)
	(mm)	(mm)	Mean	Min	max		
2012	32.1	970.6	28.1	9.2	42.2	51.1	4.5

Therefore any further increase in mean temperature during any stage may reduce the grain yield of rice estimated at 41% by the end of the 21st century. Hence, breeding rice varieties with heat tolerance and contribute for increase of overall productivity of rice is a big challenging tasks.

Increasing the yield of plants is a major thrust research area of crop improvement. The effect of heat on rice growth stages is exploited in various studies and it is found that the flowering stage is the most sensitive stage to high temperature (Sato *et al*., 1973, Satake and Yoshida 1978). High temperatures over 35[0] C at flowering stage cause high pollen and spikelet sterility, which leads to serious yield losses, low grain quality and low harvest index (Osada *et al*., 1973, Matsushima *et al*., 1982, Matsui *et al*., 1997a,b, Zhong *et al*., 2005). The main cause of spikelet sterility induced by high temperature at flowering stage is anther indehiscence. The anthers of heat tolerant cultivars dehisce more easily than those of susceptible cultivars under high temperature conditions (Satake and Yoshida 1978, Mackill *et al*., 1982, Matsui *et al*., 1997a,b, 2001). This is because of the tight closure of the lodicules by the cell layers, which delays spikelet opening and decreases spikelet fertility at high temperature (Matsui and Omasa, 2002). It was suggested that spikelet fertility at high temperature can be used as a screening tool for heat tolerance during the flowering stage (Prasad *et al*., 2006). Due to domestication, modern rice to be cultivated in hotter climate may be limited by its narrow gene pool (Zhu *et al*., 2007).

In wild progenitors still unexploited genetic variation is present (Wang *et al*., 1992), hence attempts to utilize it have been successful with wild species. *O. Meridionalis* Ng. has drought avoidance traits (Somanthri 2001, Brar & Kush 1997) and better adaptation strategies to avoid adverse climatic conditions than *O. sativa L.* (Second 1988), it also has good levels of tolerance to heat compared with *O. sativa* L. (Andrew *et al*., 2009) is a good source for root traits under moisture stress (Kalmesh *et al*., 2012). N22 cultivar was the most heat tolerant genotype (64–86% fertility at 38° C) and cultivars Azucena and Moroberekan the most susceptible (<8%) reported by Jagadish *et al*., 2008 and Moroberekan was the most heat-sensitive genotype (18% spikelet fertility at 38° C), while IR64 (48%) and N22 (71%) were moderately and highly heat tolerant reported by Jagadish *et al*., 2009 and there were significant differences among the genotypes in anther length and width, apical and basal pore lengths, apical pore area, and stigma and pistil length for spikelet fertility under heat stress reported by Jagadish *et al*., 2010. The purpose of the study was to evaluate yield, yield related traits, their assessment and association under heat stress and control conditions from 274 BILs progenies generated through a cross between IR58025B and *O. meridionalis* Ng. It has proved that *O. meridionalis* Ng. withstands abiotic stresses like it has heat and drought avoidance traits and better adaptation in adverse climate conditions than *O. sativa* L. and good source for root traits under moisture stress hence it has also chance to withstand

heat stress condition in adverse conditions, so that present population was developed and designed in such a way that to evaluate yield and its related traits to assessment and association under stress and control conditions.

MATERIAL AND METHODS

Experimental Location

The study was conducted at experimental farm of the Barwale Foundation, Maharajpet, Hyderabad, India, located at latitude 17[0]24' N and longitude 78[0]12' E and a altitude of 536 m above mean sea level. Details of the soil condition during the crop growth are presented in Table 1.

Plant material

Oryzameridionalis Ng. (IRGC101145) was used as donor parent, it is an annual diploid (2n = 24) wild species of northern Australia with AA genome and having compatibility with *O. sativa* species (Lu *et al*.,., 1997, 1998). IR58025B, a popular maintainer line in hybrid breeding programs was used as recurrent parent in this study.

Population development

The mapping population was derived from a cross between *O. sativa* IR58025B and *O. meridionalis* Ng. using advanced backcross method, which is a strategy widely adopted in transferring favorable alleles from phenotypically poor wild/ weedy species to elite cultivars/ lines (Tanksley *et al*., 1996). F_1 plants produced from the cross IR58025B X *O. meridionalis* Ng. Were selected based on phenotype and confirmed genotypically by using simple sequence repeat (SSR) markers which showed polymorphism between the parents. The F_1s were backcrossed to IR58025B recurrent parent (RP) to derive BC_1F_1 plants, these lines were backcrossed with recurrent parent to obtain BC_2F_1 seeds, from each BC_1F_1 plant were backcrossed with recurrent parent and from that 274 BC_2F_1 individuals generated. All the plants were allowed to self to get BC_2F_2 plants. 274 BC_2F_2 families were advanced to BC_2F_6 generation by subsequent selfing without applying any selection pressure. All the 274 families of the population along with its RP and checks were evaluated for heat tolerance under stress as well as control conditions.

Trial management

In both stress and control trials, basal fertilizer was applied at the rate of 50-40-40 kg NPK per ha, and were top-dressed twice with 30 kg N per ha at 2 and 6 weeks after planting. Weeds and insect pests were controlled by chemically to ensure healthy crop. Randomized complete block design (RCBD) method of planting was used for both stresses as well as control conditions.

Stress Field experiments procedure

In Stress trials, all 274 BC_2F_6 progenies along with recurrent parent seeds were sown in the nursery and 3-4 weeks old seedlings were transplanted to the main field. Staggered sowings and plantings were done in order to synchronize the flowering period of the crop at the same time and allow it to expose to maximum heat during the peak dry season. Each of the progenies and RP consisted of 30 plants in three rows of 10 plants each with spacing of 20 cm between plants and 30 cm between rows. After transplanting, standard agronomic practices were followed until the crop attains the reproductive stage, approximately 2-3 cm of standing water level was maintained in the field till the crop attained reproductive stage. Later in order to impose stress during the early flowering stage of the crop, complete standing water present in the field was drained out before taking the observations.

Control Field experiment procedure

In control trials, all 274 BC_2F_6 progenies along with recurrent parent seeds were sown in the nursery and 3-4 weeks old seedlings were transplanted to the main filed. Staggered sowings and plantings were done in order to synchronize the flowering period of the crop at the same time and allow it to expose to maximum heat during the peak dry season. Each of the progenies and RP consisted of 30 plants in three rows of 10 plants each with spacing of 20 cm between the plants and 30 cm between rows. After transplanting, standard agronomic practices were followed until the crop attained maturity and approximately 3-4 cm standing water level maintained until crop was ready for harvest. At the time of reproductive stage all observations were recorded in the presence of standing water in the field.

Phenotypic evaluation of population

Five plants were selected from the center at random from recurrent parent and each of the 274 BC_2F_6 families and RP in each replication and evaluated for the following 18 yield related traits: Plant height (*ph*) measured in centimeters (cm) from the soil surface to the tip of the tallest panicle (awns excluded), days to 50 per cent flowering (*df*) as number of days from sowing to panicle emergence in 50 percent of the plants, tiller number per plant (*tn*) was recorded as total number of tillers per plant at maturity, panicles per plant (*pn*) was recorded as total number of panicle bearing tillers in each plant at the time of harvest, panicle length (*pl*) was recorded as the length of the panicle measured from ciliate ring to the tip of the panicle excluding awns if any, flag Leaf Length (*fll*) was recorded as average of length of flag leaf from top to bottom from five plants, flag leaf width (*flw*) was recorded as the average of width of flag leaf approximately at its middle from five plants, grain number (GN) was calculated by counting number of filled spikelet's per panicle averaged over five randomly chosen panicles in each plant. spikelet number per panicle (*spp*) was recorded as total number of filled grains calculated by counting number of filled spikelet's per panicle over five randomly chosen panicles in each plant, spikelet fertility (*sf*) was total number of filled and unfilled grains recorded as counted from five randomly selected panicles and

mean of filled and unfilled grains per panicle calculated to estimate the percent fertile spikelet's in a panicle, test weight (*tw*) weight of 1000 randomly selected dried grains from each plant was recorded and expressed in grams as test weight, grain yield per plant (*gy*) the weight of the dried and cleaned grains from five plants was measured and average is recorded and expressed in grams (g), biomass (*bm*) was calculated as the average weight of the five well-dried plants whose panicles had been removed, specific leaf area (*sla*) was measured from the length and width of blades multiplies with 0.725 (correction factor) gives the leaf area. Observations related to assessment of impact of rise in temperature or heat on the crop was recorded by a hand-held infrared sensor (Davis, USA). We adopted a modified method of Fischer *et al*., 1998, for recording observations related to heat tolerance screening. Readings were recorded from late morning to early afternoon during cloudless periods (10:00 to 14:00 h), flag leaf temperature (*flt*) was recorded manually by holding the infra-red sensor at a distance of approximately 15cm from the middle of flag leaf, panicle temperature (*pt*) was recorded using infrared sensor by holding it at a distance of approximately 15 cm from the middle of panicle at flowering stage, canopy temperature (*ct*) was recorded by using infrared sensor by holding it at a distance of approximately 15 cm from a plant.

Statistical analysis

The data collected from control and heat stress condition and were the mean data subjected to analysis of variance using CROPSTAT version 7.2.3. Analysis of variance and covariance for all traits were done according by Panse and Sukhatme 1985. The phenotypic and genotypic coefficients of variability were estimated as per the Burton 1952. Broad-sense heritability was calculated using formula suggested by Lush (1940). The Correlation coefficient analyses were done according to Dewey and Lu (1959).

RESULTS AND DISCUSSION

In the present study results from the analysis of variance revealed significant difference among genotypes for all traits studied under stress as well as control conditions, indicating presence of considerable amount of genetic variation among the population. The large genetic variability among the population between two different moisture conditions towards different characters indicates the scope for improving the heat tolerance and its attributing traits. The mean, range and LSD 5% of the population for the heat related and yield attributing traits are shown in Table 1. However several transgressive segregants observed for yield related traits under both the conditions, were significantly higher than RP. This suggests the influence of *O. meridionalis* Ng. alleles under both conditions.

Coefficient of variances

The result shows that the significant genetic variation for all the traits is determined by phenotypic and genotypic coefficient of variation in Table 2.

Table 2. Estimation of GCV, PCV, h2 and GA of the IR58025B/ *O. meridionalis* Ng. population under stress and control conditions

TRAITS	GCV	PCV	h^2	GA
	Stress and Control-2012			
DFF (Stress)	15.86	18.83	0.77	25.36
DFF (Control)	10.06	11.57	0.85	16.51
FLT (Stress)	2.13	5.08	0.18	1.84
FLT (Control)	6.21	8.02	0.47	8.82
PT (Stress)	1.84	4.31	0.18	1.61
PT (Control)	4.91	8.47	0.34	5.87
CT (Stress)	1.57	4.55	0.12	1.12
CT (Control)	6.75	9.10	0.55	10.30
PHT (Stress)	13.60	16.26	0.66	23.43
PHT (Control)	10.55	14.12	0.86	13.24
TN (Stress)	17.37	23.45	0.46	26.70
TN (Control)	14.79	22.75	0.60	18.15
PN (Stress)	20.42	30.98	0.39	35.63
PN (Control)	14.41	19.39	0.55	18.10
FLL (STRESS)	12.50	17.03	0.38	11.56
FLL (CONTROL)	6.80	11.17	0.54	8.86
FLW (STRESS)	10.41	20.28	0.26	17.41
FLW (CONTROL)	6.80	11.17	0.37	8.86
SLA (STRESS)	17.13	27.05	0.40	20.94
SLA (CONTROL)	12.15	17.78	0.47	12.98
PL (Stress)	8.80	15.25	0.54	15.47
PL (Control)	6.35	9.71	0.62	10.07
SPY (STRESS)	23.06	49.12	0.22	43.37
SPY (CONTROL)	19.75	24.13	0.67	13.87
GN (Stress)	54.96	76.91	0.56	53.76
GN (Control)	21.74	30.76	0.70	29.98
TS (Stress)	16.12	22.26	0.26	13.01
TS (Control)	12.63	19.54	0.48	27.41
SF (Stress)	66.23	91.68	0.54	73.89
SF (Control)	14.89	17.89	0.68	27.20
TW (Stress)	62.46	92.16	0.37	64.42
TW (Control)	9.88	10.88	0.41	5.88
BM (Stress)	21.54	35.24	0.41	27.12
BM (Control)	18.77	22.06	0.72	18.92
LY (Stress)	77.29	93.20	0.57	78.55
LY (Control)	27.58	29.33	0.69	23.44

DFF: days to 50% flowering, FLT: flag leaf temperature (^{0} C), PT: panicle temperature (^{0} C), CT: canopy temperature (^{0} C), PHT: plant height (cm), TN: tiller number, PN: panicle number, FLL: flag leaf length (cm), FLW: flag leaf width (cm), SLA: specific leaf area, PL: panicle length (cm), SPY: single plant yield (gr), GN: grain number, TS: total spikelet, SF: spikelet fertility (%), TW: 1000 seed weight (g), BM: biomass (g), LY: line yield (t ha^{-1}).

The estimates of phenotypic coefficient of variation (PCV) were higher than those of genotypic coefficient variation for all the traits under control and heat stress conditions. GCV and PCV were higher in stress experiment when compared with control condition. The Genotypic coefficient of variation ranges from 1.57 for CT to 77.29 for line yield per plot, whereas phenotypic coefficient of variation ranged 4.31 for panicle temperature to 91.68 for spikelet fertility. Panicle temperature, flag leaf temperature, flag leaf length, flag leaf width, panicle length and days to 50% flowering showed low genotypic coefficient of variation. The highest genotypic coefficient of variation is for the line yield, spikelet fertility, 1000 grain weight and grain numbers. The lowest phenotypic coefficient of variation is for the panicle temperature, canopy temperature, flag leaf temperature, panicle temperature, flag leaf length, flag leaf width and days to 50% flowering. The highest phenotypic coefficient of variation was for the line yield, grain numbers, single plant yield, 1000 grain weight, spikelet fertility, biomass and panicle numbers. In this study difference indicated influence of environment and consequently greater genetic role of factors on the expression

of traits. All these observations are similar with the earlier reports by Mustafa and Elsheikh 2007 and Kole *et al.*, 2008 in rice. These observations for coefficient of variation for GCV and PCV were similar to that of Akinwale *et al.*, 2011 and Ullah *et al.*, 2011. The GCV ranged from 6.35 (Panicle length) in control to 77.29 (line yield) in stress condition, the PCV ranged from 9.71 (panicle length) to 93.20 (line yield) in stress condition for yield related traits. Further physiological traits like flag leaf temperature, panicle temperature, canopy temperature and leaf area index from that GCV ranged from 1.57 (canopy temperature) in stress to 17.13 (leaf area index) in stress, the PCV ranged from 1.84 (panicle temperature) in stress to 27.05 (leaf area index) in stress condition.

Heritability and genetic advance

Broad sense heritability estimates varied from 0.34 (panicle temperature) to 0.86 (plant height) in control condition, and 0.12 (canopy temperature) to 0.77 (days to 50% flowering) in stress condition (Table-2). In the present study, high heritability is observed for days to 50% flowering (0.77), plant height (0.66). High to moderate heritability is observed for line yield (0.57), grain yield (0.56), panicle length (0.54) and spikelet fertility (0.53) and low heritability is observed for canopy temperature (0.12) in stress condition. Under control condition, heritability is high for plant height (0.86), days to 50% flowering (0.85), high to moderate for tiller number (0.60), panicle number (0.55), canopy temperature (0.55), flag leaf length (0.54) and low for panicle temperature (0.34), flag leaf width (0.37). High heritability reported in rice (Akhtar *et al.*, 2011, Seyoum *et al.*, 2012, Saikumar *et al.*, 2014) suggests possibility of selection of superior genotypes on the basis of phenotypic performance. High to moderate heritability is reported for different quantitative traits studied in rice (Abarshahr *et al.*, 2011, Akinwale *et al.*, 2011, Berneir *et al.*, 2007, Sadeghi *et al.*, 2011, Saikumar *et al.*, 2014, Vikram *et al.*, 2011) and low heritability (Seyoum *et al.*, 2012, Saikumar *et al.*, 2014) indicates greater role of environment (heat stress) on the expression of the traits.

Present observations revealed that all the traits were influenced by heat stress environment, which is evident from the lower values of heritability estimates in heat stress when compared to control condition. The study revealed very low estimate of heritability for traits such as Biomass (Saikumar *et al.*, 2014), flag leaf temperature, line yield, canopy temperature and single plant yield were maximum extent by the environment, in comparison with the remaining traits. However, TW showed lower values of heritability in both conditions.

Correlation coefficients

The genetic and phenotypic correlation coefficients among traits showed that the significant higher genotypic correlation (Table-4) coefficient level than corresponding phenotypic correlation coefficient (Table-3) because the relationship is affected by environment at phenotypic level in population, indicating the low phenotypic correlation coefficient (Chaubey and Singh 1994, Ojo *et al.*, 2006).

Table 3. Phenotypic correlation coefficients between yield and its related traits of the IR58025B/ *O. meridionalis* Ng. population under stress and control conditions

STRESS AND CONTROL PCV-2012																		
	DFF	FLT	PT	CT	PHT	TN	PN	FLL	FLW	SLA	PL	SPY	GN	TS	SF	TW	BM	LY
DFF (STRESS)	1	0.03	0.22**	0.064	-0.19**	0.03	0.09	-0.17**	-0.101	-0.18**	0.02	-0.21**	-0.28**	-0.2**	-0.32**	-0.3**	0.02	-0.21**
DFF (CONTROL)	1	0.06	0.03	0.043	0.14*	0.13*	0.11*	0.051	0.051	0.064	-0.1	0.066	-0.14*	0.01	-0.16**	-0.29**	0.21**	-0.18**
FLT (STRESS)		1	0.89**	1.07**	0.104	-0.15**	-0.23**	0.19**	0.028	0.115	0.45**	-0.15**	-0.22**	-0.11	-0.34**	-0.759	0.35**	-0.32**
FLT (CONTROL)		1	0.75**	0.78**	0.072	-0.19**	-0.19**	0.044	0.044	0.102	0.112	0.021	0.103	0.1	0.013	0.015	0.01	-0.21**
PT (STRESS)			1	0.99**	0.042	-0.039	-0.10	-0.005	0.16**	0.009	0.69**	-0.11*	-0.11*	0.008	0.013	-0.57**	0.34**	-0.19**
PT (CONTROL)			1	0.81**	0.002	-0.25**	-0.15*	0.047	0.047	0.052	0.153	0.011	0.059	0.11*	-0.047	0.072	-0.034	-0.17**
CT (STRESS)				1	0.002	-0.20**	-0.36**	0.095	-0.11*	-0.056	0.48**	-0.17**	-0.15**	-0.14*	-0.15**	-0.75**	0.35**	-0.40**
CT (CONTROL)				1	0.057	-0.18**	-0.15**	0.014	0.014	0.085	0.128	0.074	0.069	0.092	-0.019	0.013	-0.02	-0.17**
PHT (STRESS)					1	-0.35**	-0.31**	0.73**	0.15**	0.61**	0.42**	0	0.28**	0.21**	0.3**	0.25**	0.21**	0.28**
PHT (CONTROL)					1	-0.14*	-0.21**	0.25**	0.25**	0.28**	0.15	0.13*	0.05	0.19**	0.08	-0.02	0.18**	0.17**
TN (STRESS)						1	0.97**	-0.44**	-0.35**	-0.49**	-0.67**	-0.27**	-0.028	-0.19**	0.44**	-0.31**	-0.053	0.135
TN (CONTROL)						1	0.64**	-0.18**	-0.18**	-0.18**	-0.17**	-0.11*	-0.096	0.02	-0.14	0.21**	0.046	-0.19**
PN (STRESS)							1	-0.39**	-0.23**	-0.40**	0.09	-0.097	0.12*	-0.03	0.14	-0.28**	0.24**	0.21**
PN (CONTROL)							1	-0.071	-0.071	-0.082	0.1	0.15**	0.04	0.13*	0.05	0.07	0.18**	0.13*
FLL (STRESS)								1	0.25**	0.86**	0.87**	-0.035	-0.21**	0.001	-0.56**	-0.28**	0.63**	0.18**
FLL (CONTROL)								1	1	0.68**	0.241	0.007	0.017	0.11*	-0.056	0.124	-0.017	0.18**
FLW (STRESS)									1	0.71**	-0.56**	0.17**	0.39**	0.43**	0.015	-0.59**	0.13*	0.18**
FLW (CONTROL)									1	0.68**	0.24**	0.007	0.017	0.11*	-0.056	0.12*	-0.017	0.17**
SLA (STRESS)										1	0.55**	0.065	0.097	0.26**	-0.35**	-0.51**	0.51**	0.17**
SLA (CONTROL)										1	0.27**	0.024	0.073	0.11*	0.002	0.053	0.023	0.19**
PL (STRESS)											1	0.79**	0.31**	0.025	0.21**	0.28**	0.18**	0.21**
PL (CONTROL)											1	0.16**	0.19**	0.21**	0.07	0.12	0.19**	0.21**
SPY (STRESS)												1	0.65**	0.57**	0.28**	0.88**	0.08	0.25**
SPY (CONTROL)												1	0.12	0.19**	0.05	0.11	0.16**	0.12*
GN (STRESS)													1	0.68**	0.6**	0.21**	0.11	0.42**
GN (CONTROL)													1	0.62**	0.51**	0.14	0.12	0.36**
TS (STRESS)														1	-0.18**	0.03	0.13	0.22**
TS (CONTROL)														1	-0.195**	0.038	-0.015	0.098
SF (STRESS)															1	0.54**	0.09	0.31**
SF (CONTROL)															1	0.16**	-0.03	0.21**
TW (STRESS)																1	-0.15**	0.38**
TW (CONTROL)																1	-0.11	0.31**
BM (STRESS)																	1	0.2**
BM (CONTROL)																	1	0.19**
LY (STRESS)																		1
LY (CONTROL)																		1

*, ** Significant at p = 0.05 and p = 0.01, respectively

Table 4. Genotypic correlation coefficients between yield and its related traits of the IR58025B/ *O. meridionalis* Ng. population under stress and control conditions

	DFF	FLT	PT	CT	PHT	TN	PN	FLL	FLW	SLA	PL	SPY	GN	TS	SF	TW	BM	LY
STRESS AND CONTROL GCV-2012																		
DFF (STRESS)	1	0	0.075	0.29**	-0.05	0.127	0.13*	-0.095	-0.034	-0.081	-0.14*	-0.033	-0.36**	-0.023	-0.39**	-0.29**	0.01	-0.3**
DFF (CONTROL)	1	0.05	0.031	0.034	0.16**	0.15**	-0.11*	0.12*	0.12*	0.12*	-0.56**	0.043	-0.61**	-0.13*	-0.45**	-0.56**	0.66**	-0.67**
FLT (STRESS)		1	0.79**	0.88**	0.06	0.031	0.017	0.039	-0.069	-0.018	-0.068	-0.11*	-0.095	-0.027	-0.072	-0.104	-0.081	-0.142*
FLT (CONTROL)		1	1.05**	0.95**	0.16**	-0.064	-0.10*	0.044	0.044	0.23**	0.45**	0.11*	0.17**	0.102	-0.023	0.022	0.015	-0.27**
PT (STRESS)			1	0.83**	0.036	0.071	0.07	0.014	0.01	0.017	-0.056	-0.003	-0.018	-0.033	0.018	-0.11*	0.053	-0.111
PT (CONTROL)			1	1.07**	0.19**	-0.006	-0.024	-0.25**	-0.25**	0.24**	0.38**	0.12*	0.25**	0.15**	-0.23**	0.029	0.048	-0.22**
CT (STRESS)				1	0.002	0.041	0.034	0.008	-0.023	-0.01	-0.062	-0.062	-0.063	-0.032	-0.032	-0.064	-0.045	-0.101
CT (CONTROL)				1	0.14*	0.008	-0.062	0.048	0.048	0.31**	0.38**	0.082	0.099	0.023	-0.065	-0.032	0.071	-0.18**
PHT (STRESS)					1	-0.19**	-0.18**	0.55**	0.17**	0.45**	0.81**	0.066	0.38**	-0.17**	0.31**	0.28**	0.02	0.29**
PHT (CONTROL)					1	-0.25**	-0.51**	0.53**	0.36**	0.75**	0.12*	0.13*	-0.04	0.042	-0.12*	-0.03	0.38**	0.16**
TN (STRESS)						1	0.84**	-0.22**	-0.15**	-0.23**	-0.094	-0.15*	-0.089	0.046	-0.053	0.16**	0.035	0.12
TN (CONTROL)						1	0.82**	-0.21**	-0.21**	-0.26**	-0.35**	-0.096	-0.14*	-0.011	0.012	0.24**	0.034	-0.24**
PN (STRESS)							1	-0.19**	-0.055	-0.15**	-0.21**	-0.059	-0.61**	0.082	-0.45**	-0.45**	0.41**	0.14*
PN (CONTROL)							1	-0.13*	-0.13**	-0.12*	-0.13*	-0.11*	-0.26**	0.058	-0.21**	0.14*	0.16**	0.14*
FLL (STRESS)								1	0.23**	0.77**	0.26**	0.051	-0.11*	-0.27**	0.027	0.31**	0.004	0.14*
FLL (CONTROL)								1	1	0.81**	0.48**	-0.02	0.19**	0.27**	-0.13*	0.034	-0.004	0.17**
FLW (STRESS)									1	0.77**	0.22**	0.35**	0.31**	0.066	0.087	0.056	0.21**	0.101
FLW (CONTROL)									1	0.81**	0.48**	-0.02	0.19**	0.27**	-0.13*	0.034	-0.004	0.17**
SLA (STRESS)										1	0.29**	0.26**	0.13*	-0.13*	0.067	0.22**	0.13*	0.15**
SLA (CONTROL)										1	0.54**	0.057	0.19**	0.19**	0.019	0.02	0.003	0.14*
PL (STRESS)											1	0.19*	0.3**	-0.095	0.26**	0.28**	0.03	0.11*
PL (CONTROL)											1	0.31**	0.31**	0.27**	0.14*	0.67**	-0.36**	0.66**
SPY (STRESS)												1	0.89**	0.12*	0.13*	-0.074	0.44**	0.19**
SPY (CONTROL)												1	0.81**	-0.11*	-0.049	-0.011	0.27**	0.19**
GN (STRESS)													1	0.63**	0.85**	0.76**	-0.29**	0.76**
GN (CONTROL)													1	0.45**	0.76**	0.21**	-0.24**	0.61**
TS (STRESS)														1	0.13*	-0.074	0.44**	0.19**
TS (CONTROL)														1	0.26**	-0.18**	-0.054	0.15**
SF (STRESS)															1	0.86**	-0.31**	0.81**
SF (CONTROL)															1	0.12*	0.2**	0.81**
TW (STRESS)																1	-0.31**	0.67**
TW (CONTROL)																1	-0.07	0.51**
BM (STRESS)																	1	0.19**
BM (CONTROL)																	1	0.21**
LY (STRESS)																		1
LY (CONTROL)																		1

*, ** Significant at p = 0.05 and p = 0.01, respectively

Grain yield (GY) is significantly and positively correlated at both phenotypic (p) and genotypic (g) level with PH (P = 0.17 to 0.28, g = 0.16 to 0.29), PN (p = 0.13 to 0.21, g = 0.14), FLL (p = 0.18, g = 0.14 to 0.17), SLA (p = 0.17 to 0.19, g = 0.14 to 0.15), PL (p = 0.21, g = 0.11 to 0.66), SPY (p = 0.12 to 0.25, g = 0.19), GN (p = 0.36 to 0.42, g = 0.61 to 0.76), SF (p = 0.21 to 0.31, g = 0.81), TW (p = 0.31 to 0.38, g = 0.51 to 0.67), BM (p = 0.19 to 0.2, g = 0.19 to o.21), under which conditions whereas GY is significantly positive correlated with TN (p = 0.12, g = 0.14) under stress condition and significant negatively correlated with TN (p = -0.19, g = -0.24) under control condition and FLW (p = 0.17 to 0.18) of phenotypic correlation is significant with GY whereas genotypic correlation in stress conditions in non-significant with GY and TS (g = 0.15 to 0.19). Genotypic coefficient correlation is significant under both conditions whereas phenotypic correlation is non-significant with the GY under control conditions. DFF (p = -0.21 TO -0.18, G = -0.30 TO -0.67), FLT (p = -0.21 to -0.32, g = 0.14 to -0.27), PT (p = -0.17 to -0.19, g = -0.11 to -0.22) is negatively correlated with GY under both conditions. Canopy temperature (p = -0.17 to -0.40) phenotypic correlation is negatively correlated with GY under both conditions except genotypic correlation is non-significant with GY under stress condition.

Negative correlation between GY and DFF has been reported by Garrety and O'Toole *et al*., 1994, Lanceras *et al*., 2004, Abarshahr *et al*., 2011, Varma *et al*., 2012, Saikumar *et al*., 2014. The Positive correlation between GY and PH, GN, SF, TW, BM has been also previously reported by Lanceras *et al*., 2004, Bernier *et al*., 2007, Laffite *et al*., 2006, Vikram *et al*., 2011, Saikumar *et al*., 2014, for plant height and tiller number Nayak *et al.,* 2001 and Shanthi and Singh 2001, Sawant *et al*., 1995, for panicle length Yolanda and Yoland and Vijendra Das LD 1995, DeepaSankar *et al*., 2006, Singh *et al*., 2006 and Venkata Lakshmi *et al*., 2014. Canopy temperature was negatively correlated with yield, similar results were reported by Hirayama *et al*., 2006, Talebi 2011, Saikumar *et al*., 2014, Grain yield positive correlation with the GN, TN, TW was earlier reported by Mohammed *et al*., 2007, M. G. Akinwale *et al*., 2011.

Grain yield negative correlation with the tiller number under control condition was earlier reported by Zahid *et al*., 2006. Grain yield was found to be positively significantly correlated with plant height, panicle number per plant and biomass at both genotypic and phenotypic levels indicating the importance of these characters for yield improvement in this population. The results are in agreement with Nayak *et al*., 2001 and Chaudhary and Motiramani 2003 for panicle number and Kole *et al*., 2008, and also grain yield positively correlated with biomass and 1000 grain weight. The results are in agreement with the Sokoto *et al*., 2012. Negative correlation coefficient of days to 50% flowering, flag leaf temperature, panicle temperature, canopy temperature with grain yield indicates the reduce yield due to increase in temperature.

Conclusion

The results from this investigation indicate that *O. meridionalis* Ng. has not only yield-enhancing alleles under normal, well-watered conditions, but also alleles which can help withstand heat stress under increased temperature under stress condition. Hence, this species can be a novel source of natural genetic variation for the improvement of rice and simultaneously help in expansion of the cultivated gene pool of *Oryza sativa*.

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