

Original Research Article

Genetic variation, heritability and relationship between **inbred lines** performances under drought stress and **irrigation** conditions in rice.

ABSTRACT

Aims: Genetic variability and heritability for agronomic traits are key component in broadening the gene pool and as selection criteria in any rice breeding programs. In present study we estimated genetic variation and heritability of traits, examined relationships among traits and their effects on grain yield under water stressed and non-stressed conditions and distinguished cultivars that are drought tolerance, high yield potential and those that combined both high yield potential and drought tolerance.

Study design: Field experiment was arranged in a completely randomized block design.

Place and Duration of Study: Study was carried in field research center Hainan of the Institute of Crop Science Chinese Academy of Agricultural Sciences China PR. from 2012-2014.

Methodology: Two parents Minghui63 and 02428 were crossed to develop 717 lines. Based on spikelet fertility ≥ 50 , 140 lines were selected for present study. Under drought stress field was drained at panicle initiation stage and maintained dry until maturity. In irrigation water was applied whenever necessary until maturity. At maturity, ANOVA, Dunnetts' t tests, correlation and path analysis were performed for 24 traits.

Results: Correlation coefficient of trait performances between water regimes was positive and ranged between 0.3 to 0.9. Drought tolerance, yield potential and both drought tolerance and yield potential lines were distinguished. Trait genetic variation, heritability and their contribution to the final grain yield varied over genetic background, water regimes and year. Heritability in *japonica* type was higher under irrigation compared to drought stress. In *indica* background heritability was higher under drought stress in 2013, and varied in 2014. Lower values of residue effects were recorded for *japonica* type compared to *indica* background and under drought stress compared to irrigation. High filled grain number, high 1000-grain weight, moderate panicle number, short flowering time and high plant height could be selection criteria for breeding high grain yield under drought conditions. While high spikelet number coupled with high spikelet fertility, high tiller number, long panicle length, moderate plant height, and moderate flowering time are necessary for breeding high yield potential.

Conclusion: These results provide a platform for dissecting genes for high yield potential, genes for drought tolerance and genes for both yield potential and high drought tolerance.

Keywords: : Heritability, Genetic variations, *Oryza sativa* L. Drought tolerance, Relative trait performance reduction, Yield potential, Residual effects.

1. INTRODUCTION

Rice is grown all over the tropics, subtropics, semi-arid tropics and temperate regions of the world. It is anticipated that by 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world background could be under conditions of water stress [1]. This water scarcity threatens the food security of thousand millions of people who entirely depend on rice as the primary source of nutrition. Yet very little yield gain occurs in rainfed rice systems that occupy much of the 63.5 million hectares of rice planting areas most of which is in tropical Asia, Africa, and Latin America [2][3]. Breeding approaches to develop rice varieties with better yields in drought-prone environments should focus on broadening genetic pool which has narrowed because of the

massive international exchange of germplasm [4]. Hence it is imperative that a detailed understanding of genetic information of yield traits such as their heritability, genetic and environmental effects should be addressed properly before performing any genetic improvement programs [5]. Putative traits that enhance drought stress tolerance are many and some do not show enough genetic variation and heritability. In addition these traits interact among themselves. In other words causal factors are not acting independently. Under limited resource both financial and manpower it is important to separate correlation coefficients into components of direct (influence of causal effect directly on dependant variable) and indirect effects (influence of causal effect on dependant via another causal effect) to identify only traits of large effect on grain yield as selection criteria and for genetic manipulation. Moreover many researchers neglect the empirical fact that drought does not occur every season in a target environment. Therefore drought tolerant cultivar should not be one that is drought tolerant but low in yield potential in favorable season, instead cultivar that respond to favorable conditions and produce economically useful yield under drought conditions as well. It is also worth noting that greatest yield loss due to drought stress occurs during reproductive stage. In vegetative stage plant may acclimatize by producing osmolytes and heat shock proteins, however, reproductive organs particularly pollen and stigma have no such ability [6]. In that regard drought resistant (DR) in this study is viewed as the ability of a cultivar to maintain higher grain yield in drought stress as well as normal irrigation conditions compared to recurrent parent, while yield potential is the upper limit of yield not constrained by water, nutrients, or pests [7]. Studies have shown that there is a low but positive correlation between yield under stress and yield potential. A genetic correlation of 0.8 between yield under stress and non-stress have been reported [8]. This indicates that much of the yield under drought is accounted for by yield potential. And varieties with high yield potential had an advantage over varieties with lower yield potential even with moderate drought stress that resulted up to only 50% loss in grain yield [7]. Therefore for successful genetic improvement of rice variety for each category (drought tolerance, yield potential and both drought tolerance and yield potential), it is first essential to identify traits with major effects on grain yield across water regimes and genetic background for rice variety on each category and then undertake a comprehensive study to understand heritability, genetics and environment effects of each trait. In present study we evaluated the performances of BILs under normal irrigated conditions as well as under drought stress to distinguish cultivars with genes for tolerance from those that simply have high yield potentials and cultivars that combine both stress tolerance with responsiveness to favorable conditions. In addition we estimated genetic variation and heritability of traits and examined relationships among traits and their effects on grain yield under water stressed and non-stressed conditions

2. METHODOLOGY

2.1 Study material

Minghui 63 (MH63) an *indica* was crossed with 02428 a *japonica*. The F_1 hybrids were simultaneously backcrossed twice to both parents to produce two BC_2F_1 populations. At the same time, the F_1 hybrids were self pollinated to generate F_2 populations. Both the BC_2F_1 and F_2 were advanced by single seed descent from year to year until BC_2F_8 and F_6 respectively. Finally, two sets of reciprocal inbred lines, consisting of 226 lines (BC_2F_8) with the MH63 background (MH63_BILs), 229 lines (BC_2F_8) with the 02428 background (02428_BILs) and 262 ($F_2:8$) recombinant inbred lines (RBILs) were selected for the study.

2.2 Methods

2.2.1 Field management and drought stress application

The preliminary screening of the bulk 717 BILs and RIL backgrounds for drought tolerance (DT) was conducted in 2011-12 in Hainan during the dry season. Based on spikelet fertility (SF) ≥ 50 , 140 lines mainly from BILs were selected for present study. All selected BILs and

their parents were planted under both normal irrigation (IR) and drought stress conditions (DS) in Hainan for two years 2013 and 2014. Field experiment was arranged in a completely randomized block design with 3 and 2 replications for drought stress in 2013 and 2014 respectively, and 2 replications under normal irrigation for both 2013 and 2014 years. In each plot 10 plants were transplanted in a single row with spacing of 25 by 20 cm. At each plot parents were inserted in every 30 lines for MH63_BILs and 40 lines for 02428_IL in each plot as checks. The fields was managed normally with a total of 260 kg N ha⁻¹ applied (about 80 kg N ha⁻¹ as the basal fertilizer and about 60 kg N ha⁻¹ applied each time at 14, 30, and 60 d after transplanting. For drought stress field were drained when plants enter the stage of panicle initiation stage (roughly after 30 days after transplanting). Field was maintained dry until all panicles exert completely. After all the plants had panicle exerted completely irrigation was applied only once to rescue plants that were dying. Any rain that fallen during drought stress application period was recorded. In the irrigated control, irrigation was applied whenever necessary until all lines matured.

2.2.2 Phenotyping

In both drought stress (DS) and well watered conditions (IR) at maturity, 5 representative plants in 2013 and 8 plants in 2014 in each row were measured for Heading Date (HD), Plant Height (PH), Spikelet number per panicle (SNP), filled grain number per panicle (FGN) spikelet fertility (SF), thousand grain weight (TGW) grain yield per plant (GY) grain length (GL), grain width (GW), grain length width ratio (GLW), grain thickness (GT) grain length thickness ratio (GLT) grain width thickness ratio (GWT), Flag leaf length (FLL), leaf width (FLW) and flag leaf rolling (FLR) for well watered plants in 2013. For drought stress in addition to HD, PH, TN, PL, SNP, FGN, SF, GY, TGW, GL, GW, GLWR, GLT, GWT leaf tip drying, leaf rolling and recovery after first day of re-watering was measured. In 2014 HD, PH, TN, PL, SNP, FGN, SF, GY, TGW, GL, GW, GLWR, FLL, FLW and FLR were measured in both drought stress and normal irrigation.

2.2.3 Analysis

Analysis of variance (ANOVA) using SAS PROC GLM (SAS Institute 2002) analyzed the data from two seasons to exam trait variation attributable to differences between the DT treatments, among different BILs within each background, and among BILs from different backgrounds. Dunnetts' t tests was used to compare difference between BILs and parents. Relative trait performance reduction (RR) was calculated according to the formula: average trait of each IL under irrigation (Xi) and average trait of each line under drought (Xd); $RR = (Xi - Xd)/Xi \times 100$. Total phenotypic variability (R^2) explained by each source of variation for each trait was calculated according $R^2 = SS/CT \times 100$ Where SS=sum of square and CT corrected total. Heritability was calculated according to the formula: $h^2_m = \sigma_g^2 / \sigma_g^2 + \sigma_e^2$. Where genetic variance $\sigma_g^2 = (MS_g - MS_e)/r$, variance due to errors $\sigma_e^2 = MS_e/r$, r = number of replications. MS_g is considered as total phenotypic variation and MS_e is an estimate of non-genetic variation. To investigate the inter-relationships among the variables and their direct and indirect contributions to yield performance under well-watered and water stressed conditions, entry means of variables that showed high genetic variation were subjected to correlation and path analyses according to [9].

3. RESULTS AND DISCUSSION

3.1 Drought Resistant Genotypes

Drought resistant line in this present study means individual line that had high grain yield per plant (GY) compared to the recurrent parent under terminal drought stress for two consecutive seasons. In the year 2013 and 2014, MH63_IL an *indica* background showed

that 27 and 24 lines were drought tolerant respectively. 14 lines DQ_15, DQ_34, DQ_68, DQ_82, DQ_146, DQ_212, DQ_214, DQ_215, DQ_219, DQ_225, DQ_227, DQ_230, DQ_231 and DQ_232 were drought tolerant for two consecutive seasons. Out of these 14 lines, only 4 lines (28%) DQ_34, DQ_82, DQ_219 and DQ_227 had high yield in both drought stress and normal irrigation conditions for two consecutive seasons. Hence these are the lines that had genes for both yield potential and yield under drought stress. Lines DQ_146, DQ_212, DQ_230 and DQ_232 did not record higher yield potential for two seasons but had higher yield under drought for two consecutive dry seasons. These lines can be regarded as having genes for high yield under drought but no genes for high yield potential. Under normal irrigation conditions (IR) in 2013, 12 lines had higher yield compared to recurrent parents. Of these, 8 lines (66%) were drought tolerant as well. In 2014 under well watered conditions 17 lines had higher yield compared to recurrent parents. Of these, 12 lines (70%) were drought tolerant as well. 8 Lines DQ_12, DQ_13, DQ_19, DQ_34, DQ_82, DQ_207, DQ_219 and DQ_227 had higher yields for two consecutive seasons under normal irrigation. Out of these, 4 lines (50%) DQ_12, DQ_13, DQ_19 and DQ_207 had high yield potential for two consecutive years but were not drought tolerance hence they had genes for yield potential but not for drought tolerance. The correlation coefficient between the yield potential and the yield under drought was 0.3 and 0.5 in 2013 and 2014 respectively. Other traits such as HD, PH, PN, PL, SNP, FGN, SF, TGW, GL, GW, GLW, the correlation coefficient between water regimes were 0.9vs0.8, 0.8vs0.8, 0.5vs0.3, 0.6vs0.4, 0.6vs0.7, 0.7vs0.6, 0.5vs0.2, 0.6vs0.5, 0.8vs0.8, 0.8vs0.4 and 0.8vs0.4 in 2013 and 2014 under drought and normal irrigations respectively. Correlation coefficients were, 0.3, 0.8 and 0.3 for leaf length, width and rolling in 2003 and 0.6, 0.7 and 0.6 for grain thickness, length thickness ratio and width thickness ratio respectively in 2014. All drought tolerant lines in *indica* background had early flowering (HD) and high plant height, compared to recurrent parent a mechanism called drought escape. Escape strategy relies on successful reproduction before the onset of severe stress.

In 02428_IL a *japonica* background 20 and 17 lines were drought tolerant in the year 2013 and 2014 respectively. 7 lines DQ_237, DQ_288, DQ_386, DQ_389, DQ_390, DQ_393 and DQ_461 were drought tolerant for two consecutive seasons. These 7 lines except DQ_389 had higher yield compared to recurrent parent in both drought stress as well as normal irrigations conditions for two consecutive seasons. Thus they were the lines with both yield potential and drought tolerance. In normal conditions in 2013, 51 lines had higher yield potential compared to recurrent parent. Of these, 16 lines (31%) were drought tolerant as well. In 2014 in normal conditions 41 lines had higher yield compared to recurrent parents whereas 14 lines (34%) were drought tolerant as well. 35 lines had high yield potential compared to recurrent parent for two consecutive seasons. Of these 35 lines 16 lines (45%) DQ_257, DQ_258, DQ_267, DQ_325, DQ_345, DQ_356, DQ_399, DQ_414, DQ_422, DQ_430, DQ_433, DQ_440, DQ_441, DQ_443, DQ_460 and DQ_488, had no higher yield under drought stress thus contains genes for yield potential but not for drought tolerance. The correlation coefficient of specific traits performance between well watered and drought stress conditions for GY, TGW, HD, PN, PH, PL, SNP, FGN, SF, GL, GW and GLW were 0.5vs0.5, 0.3vs0.4, 0.5vs0.7, 0.3vs0.5, 0.7vs0.5, 0.5vs0.5, 0.7vs0.6, 0.9vs0.6, 0.4vs0.6, 0.8vs0.9, 0.8vs0.9 and 0.8vs0.9 in 2013 and 2014 respectively. Other traits such as grain thickness, grain length thickness ratio, grain width thickness were 0.7, 0.8, 0.6, ratio in 2013 respectively. Correlation coefficient between drought and irrigation conditions were 0.7, 0.7 and 0.6 for leaf length, leaf width and leaf rolling respectively in 2014. In this background all of the drought tolerant lines had late flowering time (HD) and moderate high plant height compared to recurrent parent. These results reveal that there is positive relationship between traits performance under water stress and under well water conditions for all traits. Correlations coefficients differed among the traits and between the years ranging from 30% to over 90%. This suggests that plants with high yield potential can perform better than low yield potential under drought stress. Same result were reported by [7] [8]. These

homologous lines selected in each category can act as genetic source for breeding or understanding genetic analysis underlying drought tolerance, yield potential and both drought tolerance and yield potential varieties

3.2 Genetic variation under drought stress and normal irrigation conditions

Traits with high genetic variation, heritability and strong correlations with grain yield under drought and low seasonal variability are desirable for making progress in plant breeding for drought tolerance [5]. From our study total variation for all measured traits were significant under both water regimes and seasons (Table 1). ANOVA indicated the presence of high genetic variability. Suggesting that selection on the basis of phenotype alone could be effective for the improvement of these traits. Similar results have been reported by [10] [11] [12] [13] [14] [15] [19]. When data were analyzed separately as treatment per season, using one-way analysis of variance, all traits showed significant variations in both water regimes and in both years. Such results have been reported by [16][17]. Variation was higher under irrigation conditions compared to drought stress for all traits in *japonica* type but lower for TN, SNP, FGN, GY, and GW in *indica* type.

Table 1. Total variations (R^2) explained by season (S), Treatment (T), genotype (G), genotype X season interaction (G*S) and genotype X treatment interaction (G*T) for the traits evaluated derived from sum of square (SS) and corrected factor (CT). R^2 less than 5% is insignificant, S.V; source of variation.

S. V	02428_IL(Japonica type)					MH63_IL(Indica type)				
	S	T	G	G*S	G*T	S	T	G	G*S	G*T
HD	8.0	1.9	33.5	8.8	11.0	25	16.4	41	5.8	3.6
PH	0.3	68.1	15.5	2.7	1.9	3.1	64.0	19.7	1.9	1.2
PL	8.2	45.4	20.2	2.1	5.2	2.8	36.3	30.9	4.2	11.1
TN	11.1	43.6	15.4	3.8	5.8	33.4	8.2	23.5	3.8	6.3
SNP	12.6	49.8	19.2	2.3	3.9	5.8	26.1	40.4	6.7	8.1
FGN	5.9	48.1	22.2	2.4	5.3	4.3	33.8	40.0	5.1	7.3
SF	3.2	10.3	37.2	4.5	10.5	1.2	24.3	31.9	7.7	11.8
TGW	0.0	30.6	24.1	6.7	9.4	5.5	33.2	26.0	6.6	5.0
GY	0.4	62.3	12.2	3.6	4.4	0.7	65.6	14.4	4.1	5.0
GL	2.6	0.5	76.8	3.2	3.7	15.4	10.3	53.3	5.4	2.8
GW	1.0	5.9	68.2	2.4	4.1	4.4	10.2	47.7	5.2	8.3
GLW	1.5	0.6	81.4	2.0	3.1	10.3	0.0	59.3	7.8	5.1

3.3 Heritability and performance of BILs under different water regimes

Adequate water supply is critical to plant survival and growth whereas its deficit suppresses leaf expansion and tillering, reduces photosynthetic rate and leaf area due to early senescence and ultimately reduce grain yield [18]. Plant genotypes vary in response to water stress. Variations are due to the combined actions of genetic and environments. The proportion of variance observed among BILs that is due to genetic differences is called heritability. The estimates of heritability act as predictive instrument in expressing the reliability of phenotypic value. Therefore, high heritability helps in effective selection for a particular character. Heritability was classified as low (below 0.3), medium (0.3-0.6 and high (above 0.6) according to [19]. Trait-specific heritability obtained from the study under irrigation and water stresses over the two seasons are presented in Table 2 and Table 3. In general traits studied in the present investigation expressed medium to high heritability estimates ranging from 0.3 to over 0.9. In MH63_IL background, in 2013 higher heritability for all traits for both treatments were recorded. Equal heritability under both drought stress and normal irrigation were shown by HD, PH, PL, FGN and TN. Traits such as TN, SNP,

SF, GL, GW, GLW, GT, GLT and GWT, had higher heritability under drought stress compared to normal irrigation. In 2014, the lowest heritability was showed by grain width ($h^2_m = 0.3$) and tiller number TN ($h^2_m = 0.4$) under drought, while spikelet fertility $h^2_m = 0.4$ and tiller number ($h^2_m = 0.5$) had the lowest heritability under irrigation. Heritability was higher under normal irrigation condition compared to drought stress for HD, PH, PL, SF, GL, GLW and FLL, while lower under normal irrigation than under drought stress for TN, SNP, FGN, GY and GW. In *indica* background, heritability was generally higher in drought stress compared to normal irrigation and slightly higher in 2013 compared to 2014. These would suggest heritability were affected by treatment and seasons.

In 02428_IL background presented in Table 3, heritability was higher in 2013 compared to 2014 for all traits. In 2013 the lowest heritability was showed by grain width (GY) ($h^2_m = 0.5$) and tiller number TN ($h^2_m = 0.6$) under both water regimes, while for 2014 lowest heritability was showed by GY $h^2_m = 0.3, 0.4$) under drought and irrigation. In contrast to *indica* type, heritability in *japonica* type was higher under normal irrigation for all traits in all seasons compared to drought stress. Higher heritability recorded would mean these traits could be assessed precisely in the genotypes evaluated. Of all traits in both backgrounds GY and FGN and SNP were most affected by drought. Relative reduction (RR%) for the grain yield in *indica* type was 67 vs. 61 in 2013 and 76 vs. 71% for 2014 for the parent and BILs respectively. Likewise RR for the grain yield in *japonica* background was 69 vs 75% in 2013 and 42 vs. 56 for 2014 for the parent and BILs respectively. Variation on yield reduction between 2013 and 2014, in both backgrounds probably came from difference in stress intensity, duration, timing, or developments stage at which stress was applied. It might also have a risen from the year variations per se such as diurnal, temperature, humidity etc or even from experimental errors. In general relative reduction (RR) for the grain yield was high in 2013 and low in 2014 for *japonica* but vice versa in *indica* type. Moreover *indica* expressed early water deficit through leaf tip drying while *japonica* expressed early water deficit through leaf rolling (Fig1). These differences might imply that these two subspecies might have different drought tolerance mechanisms as it was for heading date and plant height mentioned in section 3.1 above of present study. One way ANOVA indicates that genetic variance (σ^2_g) (Table 2&3) for both treatments and in both seasons was higher than variance due to (error σ^2_e) for all traits indicating a lower experimental error across the backgrounds, treatment and seasons. To determine putative traits that enhance yield potential and yield under drought we performed both correlation analysis and path analysis.

287 **Table.2.** MH63_IL *Indica* type mean performances of recurrent parent (P) and backcross introgression inbred lines (BILs) genetic variance (σ^2_g), non-genetic variances (σ^2_e) heritability (h^2_m) and relative trait performance reduction (RR%) of measured traits in two contrasting
288 treatments(T) drought stress (DS) and normal irrigation(IR) in 2013 and 2014. HD; heading date, PH; plant height (cm), PL; panicle length
289 (cm), TN; tiller number, SNP; spikelet number per panicle, FGN; filled grain number per panicle, SF spikelet fertility(%), TGW 1000-grain
290 weight(g), GY; grain weight per plant (g/plant) delayed leaf senescence, GL; grain length(μ), GW; grain width (μ), GLW; grain length width
291 ratio GT grain thickness (μ), GLT; grain length thickness ratio, GWT; grain width thickness ratio, FLL; flag leaf length (cm) FLW flag leaf
292 width (cm) and FLR; flag leaf rolling.
293
294

MH63_IL PERFORMANCE UNDER DS & IR IN 2013											MH63_IL PERFORMANCE UNDER DS & IR IN 2014										
FACTORS		P	BILs			RR%		VARIANCES			FACTORS		P	BILs			RR%		VARIANCES		
Trait	T		mean	Min	Max	P	BILs	σ^2_g	σ^2_e	h^2_m	Trait	T		Mean	Min	Max	P	BILs	σ^2_g	σ^2_e	h^2_m
HD	DS	121	116	97	127	-11	-9	60.3	0.5	0.9	HD	DS	129	122	97	137	-7	-3	57.7	7.4	0.8
	IR	109	106	92	118			39.6	0.6	0.9		IR	121	118	112	125			11.9	0.8	0.9
PH	DS	65.8	65	50	90	22	22	48.6	1.7	0.9	PH	DS	67	67	97	103	30	27	32.5	10	0.7
	IR	84.8	84	67	107			31.8	3.7	0.9		IR	95.1	92	74	114			42.9	2.5	0.9
PL	DS	19.4	19	14.1	26	16	12	3.68	0.1	0.9	PL	DS	18.5	19	15	27	24	16	2.84	0.7	0.7
	IR	23.1	22	17.7	26.1			2.3	0.1	0.9		IR	24.5	23	18	27			3.42	0.4	0.8
TN	DS	7.0	6.7	4.0	10	23	14	1.1	0.1	0.8	TN	DS	10	9.2	3	16	7.0	15	1.49	1.4	0.5
	IR	9.1	7.8	4.0	12			1.2	0.7	0.6		IR	10.8	11	6.5	17			0.89	1.1	0.4
SNP	DS	72.3	78	42	216	44	36	917	16	0.9	SNP	DS	59	67	33	135	28	26	470	34.9	0.9
	IR	129	121	70.4	328			623	189	0.7		IR	81.9	91	45	139			215	56.2	0.7
FGN	DS	41.7	54	19	142	58	43	760	13	0.9	FGN	DS	46	46	16	110	37	38	339	30.7	0.9
	IR	98.9	94	50.2	166			539	19	0.9		IR	72.9	75	32	128			249	46.6	0.8
SF	DS	58	67	31	92	25	15	124	6.7	0.9	SF	DS	77.4	68	42	87	13	16	30.7	39.5	0.4
	IR	76.9	78	32.7	94.7			94.7	12	0.8		IR	89	82	49	97			53.7	9.1	0.8
TGW	DS	24.4	24	10.5	33.8	16	18	10.7	3.7	0.7	TGW	DS	22.2	22	6.4	29	22	18	10	1.2	0.8
	IR	29	30	23.6	38.8			6.1	0.2	0.9		IR	28.6	27	22	34			4.23	0.5	0.8
GY	DS	7.4	7.3	3.2	17.5	67	61	6.5	0.2	0.9	GY	DS	6	6.5	0.7	20	76	71	17.1	2.9	0.8
	IR	22.3	19	8.1	32.3			17.6	0.9	0.9		IR	25.5	23	6.6	43			21.5	9.72	0.6
GL	DS	9.7	9.4	7.7	10.3	0.0	2.0	0.1	0.0	0.9	GL	DS	9	8.8	7.3	9.7	8.0	6.0	0.16	0.02	0.8
	IR	9.7	9.6	8.1	10.3			0.1	0.0	0.8		IR	9.8	9.4	7.9	10			0.18	0.01	0.9
GW	DS	2.6	2.7	2.4	3.1	4.0	4.0	0.02	0.0	0.9	GW	DS	2.7	2.8	2.4	3.3	4.0	3.0	0.01	0.0	0.7
	IR	2.7	2.8	2.4	3.7			0.04	0.0	0.8		IR	2.8	2.9	2.6	3.6			0.01	0.02	0.3
GLW	DS	3.6	3.5	2.8	4	3.0	2.0	0.07	0.0	0.9	GLW	DS	3.5	3.2	2.7	3.8	0.0	3.0	0.03	0.01	0.8
	IR	3.7	3.4	2.7	4.1			0.07	0.0	0.8		IR	3.5	3.3	2.7	3.7			0.05	0.0	0.9
GT	DS	2.0	2.0	1.7	2.2	0.0	0.0	0.01	0.0	0.9	FLL	DS	17.1	20	13	36	38	28	5.19	3.7	0.5
	IR	2.0	2	1.8	2.5			0.01	0.0	0.7		IR	27.4	27	20	37			9.0	1.7	0.8
GLT	DS	5.0	4.8	3.7	5.9	0.0	0.0	0.12	0.0	0.9	FLW	DS	1.9	1.8	1.5	2.3	5.0	5.0	0.02	0.0	0.8
	IR	5.0	4.8	3.4	5.4			0.07	0.0	0.8		IR	2	1.9	1.6	2.4			0.02	0.0	0.8
GWT	DS	1.3	1.4	1.1	1.7	7.0	0.0	0.01	0.0	0.9	FLR	DS	1.7	1.7	1.1	2.2	11	11	0.02	0.0	0.8
	IR	1.4	1.4	1.1	1.8			0.01	0.0	0.8		IR	1.9	1.9	1.5	2.3			0.02	0.0	0.8

295 Table.3 02428_IL *Japonica* type mean performances of recurrent parent (P) and backcross introgression inbred lines (BILs) genetic
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 298 panicle length (cm), TN; tiller number, SNP; spikelet number per panicle, FGN; filled grain number per panicle, SF spikelet fertility(%), TGW
 299 1000-grain weight(g), GY; grain weight per plant (g/plant) delayed leaf senescence, GL; grain length(μ), GW; grain width (μ), GLW; grain
 300 length width ratio GT grain thickness (μ), GLT; grain length thickness ratio, GWT; grain width thickness ratio, FLL; flag leaf length (cm) FLW
 301 flag leaf width (cm) and FLR; flag leaf rolling.
 302

02428_IL population performances under DS & IR 2013											02428_IL population performances under DS & IR 2014										
FACTORS		P	BILs			RR%		VARIANCES			FACTORS		P	BILs			RR%		VARIANCES		
Trait	T		Mean	Min	Max	P	BILs	σ^2_g	σ^2_e	h^2_m	Trait	T		Mean	Min	Max	P	BILs	σ^2_g	σ^2_e	h^2_m
GY	DS	5.7	5.0	1.8	12	69	75	1.0	0.9	0.5	GY	DS	11	8.2	0.5	23	42	56	9.2	4.7	0.3
	IR	19	20	11	30			10	3.1	0.8		IR	18	18	4.2	41			20	12	0.4
TGW	DS	19	20	0.8	33	16	19	18	1.9	0.9	TGW	DS	18	19	12	26	20	24	4.9	0.2	0.7
	IR	22	24	19.2	34			5.5	0.4	0.9		IR	22	25	17	39			6.3	1.3	0.7
HD	DS	100	106	87	127	2.9	-3.7	52	16	0.8	HD	DS	108	108	100	117	0.1	0.1	13	1.4	0.9
	IR	103	102	88	119			17	1.6	0.9		IR	108	108	89	120			10	2.0	0.8
PH	DS	60	61	22	88	31	30	44	7.6	0.9	PH	DS	66	65	43	82	20	25	24	22	0.5
	IR	87	87	67	110			45	3.7	0.9		IR	83	86	68	109			33	9.3	0.8
TN	DS	5.0	4.6	0.8	8.4	47	49	0.5	0.3	0.6	TN	DS	10	7.2	3.1	14.2	7.8	27	1.4	0.8	0.6
	IR	9.5	9.0	5.0	14			2.1	0.7	0.7		IR	10	9.8	5.8	15.1			2.0	0.7	0.8
PL	DS	18	17	13	22	17	20	1.5	0.6	0.7	PL	DS	20	19	15	23	11	13	1.4	0.7	0.7
	IR	21	21	17	25			1.8	0.4	0.8		IR	22	22	18	26			2.3	0.3	0.9
SNP	DS	107	92	44	205	39	49	261	118	0.7	SNP	DS	135	130	58	228	28	33	606	217	0.7
	IR	174	182	107	309			1015	261	0.8		IR	187	195	95	319			1178	346	0.8
FGN	DS	80	64	2	163	49	58	281	121	0.7	FGN	DS	122	104	17	205	26	36	748	323	0.7
	IR	158	153	53	276			1334	200	0.9		IR	165	162	60	287			1085	384	0.7
SF	DS	72	68	3.4	91	21	19	156	51	0.8	SF	DS	88	78	20	98	2.2	4.9	145	52	0.7
	IR	91	83	36	98			95	11	0.9		IR	90	83	47	97			67	18	0.8
GL	DS	6.8	7.2	6.0	9.2	-2	1.2	0.3	0.0	0.9	GL	DS	6.4	7.0	6.1	8.8	0.9	1.3	0.2	0.1	0.8
	IR	6.9	7.3	6.1	9.2			0.4	0.0	0.9		IR	6.5	7.1	6.1	9.2			0.3	0.0	0.9
GW	DS	3.4	3.3	2.1	3.7	2.2	2.9	0.1	0.0	0.9	GW	DS	3.4	3.3	2.4	3.7	4.4	4.9	0.0	0.0	0.8
	IR	3.5	3.4	2.2	4.0			0.1	0.0	0.7		IR	3.5	3.5	2.4	3.8			0.1	0.0	0.9
GLW	DS	2.0	2.2	1.8	4.0	-4	-1.5	0.1	0.0	0.9	GLW	DS	1.9	2.1	1.8	3.6	3.5	3.7	0.1	0.0	0.9
	IR	2.0	2.2	1.7	4.1			0.1	0.0	0.9		IR	1.9	2.2	1.7	3.7			0.1	0.0	1.0
GT	DS	2.2	2.1	1.4	2.5	-3	-1.0	0.0	0.0	0.8	FLL	DS	22	23	14	44	26	24	6.5	3.2	0.7
	IR	2.1	2.1	1.8	2.6			0.0	0.0	0.8		IR	30	30	21	36			8.8	1.3	0.9
GLT	DS	3.2	3.4	2.6	5.3	1.3	2.1	0.2	0.0	0.9	FLW	DS	1.7	1.7	1.1	2.1	13	12	0.0	0.0	0.7
	IR	3.2	3.5	2.7	5.2			0.2	0.0	0.9		IR	1.9	1.9	1.4	2.9			0.0	0.0	0.7
GWT	DS	1.6	1.5	1.2	2.3	5.0	3.8	0.0	0.0	0.6	FLR	DS	1.6	1.5	0.8	2.8	2.2	5.6	0.0	0.0	0.6
	IR	1.6	1.6	1.1	1.8			0.0	0.0	0.8		IR	1.6	1.6	0.8	2.1			0.0	0.0	0.8

303 **Figure 1** Shows variation in expressing early water deficit between the two subspecies.
 304 MH63_IL (*indica* background)relays water deficit through leaf tip drying while 02428_IL
 305 (*japonica* background) expresses water deficit through leaf rolling.
 306



307
 308
 309

3.4 Pearson's Linear Correlation

310 Correlation is a measure of the degree of relationship between two variables. Pearson's
 311 linear correlation test for the grain yield (GY) under drought stress and normal irrigation is
 312 presented in Table 4. The test revealed that flowering time and plant height were more
 313 important determinants of grain yield under drought stress than under normal irrigation. For
 314 example correlation coefficients for HD under drought stress were -0.36, -0.22, -0.32, and
 315 0.37 against -0.21, -0.07, -0.13 and -0.14 under normal irrigations. The negative correlation
 316 for the heading date observed means that early flowering plants had higher yield compared
 317 to late flowering plants. This suggests plants completed their reproductive life cycle before
 318 drought stress became severe. A drought resistance mechanism called escape [21].
 319 Higher plant height had influence on GY, the influence was higher under drought stress
 320 compared to well watered conditions in 2013 and but vice versa in 2014. Under drought
 321 stress plant height could be associated with deep roots. Deep and effective root systems
 322 enable plants to penetrate hard soils thereby gain access to deeper water. This
 323 phenomenon coupled with closure of stomata and leaf rolling is referred to as dehydration
 324 avoidance [21] [22]. Conversely PN had moderate positive effect on GY in *indica* type (0.26
 325 vs 0.24) under normal irrigation but not under drought stress (0.06, 0.03). For *japonica* type
 326 PN had positive influence on GY under drought stress in 2013. It is known that drought
 327 stress at reproductive stage has no effect on tiller number, consequently leading to less
 328 detrimental effect on yield [23]. Yield component traits, SNP, FGN, SF, TGW were the
 329 primary determinants of grain yield under both water regimes, seasons and backgrounds.
 330 Their correlation coefficients tended to be higher under drought stress compared to normal
 331 irrigation. For instance the correlation coefficients for SNP under drought were 0.70, 0.70,
 332 0.78 and 0.78 against 0.40, 0.50, 0.61, and 0.56 under normal irrigation. Grain size traits
 333 (thickness, length and width), generally had moderate effect on grain yield under drought
 334 stress but not under normal irrigation. Flag leaf is where large percentage of carbohydrates
 335 in the grains are produced. This is because the yield is a product of source-sink relationship.
 336 Green tissues (Source) such as leaf, stem, or even root makes photosynthetic assimilates
 337 carbon compounds (carbohydrates) through interactions with light. Light makes green
 338 tissues to convert mineral carbon to organic carbon. Then the assimilates move towards sink
 339 (grain). Flag leaf is the most exposed green tissue to the sun light thus contribute to over
 340 70% of accumulated carbohydrates in grain. In this research flag leaf length (FLL), flag leaf
 341 width had influence on GY under drought as well as under normal irrigation. **Pearson**
 342 **correlation** indicated complex inter-relationships among other traits. These inter-relationships
 343 among traits, each may contribute positively or negatively to the observed coefficients

344 between GY, thus we split coefficient of correlations into direct and indirect components
 345 using path analysis.

346

347 Table 4. Correlation coefficients between GY and traits performance under drought stress
 348 and normal irrigation conditions for 2013 and 2014 in MH63_IL and 02428_IL populations.

2013					2014				
Trait	MH63-Indica		02428-Japonica		Trait	MH63-indica		02428-Japonica	
	Ds	IR	DS	IR		DS	IR	DS	IR
HD	-0.36****	-0.21*	-0.22*	-0.07	HD	-0.32***	-0.13	-0.37****	0.14
PH	0.52****	0.32***	0.45****	0.22**	PH	0.51****	0.58****	0.12	0.4****
PL	0.41****	0.51****	0.49****	0.14	PL	0.69****	0.3***	0.52****	0.41****
PN	0.06	0.26***	0.54****	0.05	PN	0.03	0.24**	0.01	0.12
SNP	0.59****	0.19*	0.46****	0.37****	SNP	0.76****	0.53****	0.58****	0.42****
FGN	0.75****	0.4****	0.70****	0.5****	FGN	0.78****	0.61****	0.76****	0.56****
SF	0.75****	0.36****	0.62****	0.46****	SF	0.36****	0.46****	0.68****	0.49****
TGW	0.54****	0.28***	0.49****	0.11	TGW	0.29****	0.42****	0.49****	0.21**
GL	0.16*	0.22***	-0.02	0.08	GL	0.17	0.15	-0.05	-0.14
GW	-0.26***	0.16	0.23***	-0.09	GW	0.001	0.04	0.26***	0.02
GLW	0.28****	-0.03	-0.09	-0.05	GLW	0.12	0.06	-0.12	-0.03
GT	0.47****	0.02	0.36****	0.1	FLL	0.41****	0.33***	0.24**	0.25**
GLT	-0.2**	0.11	-0.21**	-0.09	FLW	0.09	0.31***	0.23**	0.2**
GWT	-0.52****	0.16	-0.14*	0.001	FLR	-0.1	0.22**	0.09	0.02

349

350 3.5 Path analyses for direct and indirect effects

351 Path analysis for grain yield GY under both drought stress and normal irrigation is presented
 352 in Table 5&6. According to linear correlation analysis presented in Table 4; GL, GW, GLWR,
 353 GLTR, GWTR, FLW, and FLR did not show consistent correlations with the GY across water
 354 regimes, seasons and backgrounds thus were omitted for path analysis. Heritability
 355 estimates using standardized data did not differ greatly from the actual heritability estimates
 356 for any trait, or season. Same result was reported by [5]. Path analysis for MH63_IL an
 357 *indica* type presented in Table.5 reveals that under both water regimes, all the traits except
 358 HD had positive correlations with the GY. All traits had strong influence on GY except
 359 panicle number. Partitioning correlation coefficient into direct and indirect effects showed
 360 that FGN followed by PN PL and TGW had direct positive influence on GY, while SNP and
 361 SF had negative direct influence on GY under drought dress. Under irrigation conditions in
 362 2013, SNP, SF, PN and PL had positive direct effect on GY while in 2014, GY was strongly
 363 directly influenced by FGN and PN followed by PH and TGW but directly negatively affected
 364 by SNP and SF. Under drought stress all traits had significant indirect influence on GY via
 365 FGN except HD and PN that had negative indirect effect on GY via FNG. In 2013, under
 366 irrigation, no significant indirect effects traits had on GY via FGN, but in 2014 all traits except
 367 HD and PN had indirect positive influence on GY via FGN. In this background, these results
 368 generally illustrates that PN and PL are important in both water regimes. Under drought
 369 stress high TGW and FGN are the primary determinants of grain yield while many SNP and
 370 low SF negatively affect grain yield. Under irrigation high SNP coupled with higher SF are
 371 the primary determinants of grain yield. Thus high grain yield under drought stress can be
 372 achieved by few tiller number, moderate panicle length, heavier grains and highly filled
 373 grains. All drought tolerant plants expressed drought escape, thus short flowering time, high
 374 plant height and ability to resist leaf tip drying Fig. 1 are also important traits for selection.
 375 For high grain yield under well watered conditions many tiller number, long panicle length,
 376 high spikelet number coupled with high spikelet fertility and moderate plant height, moderate
 377 heading date are important.

378 Table.5 Path analysis partitioning genotypic correlation with grain yield into direct (bold) and indirect effects of yield enhancing traits under drought stress
 379 and normal irrigation for 2013 and 2014 in MH63_IL *indica* type population, R= residual effect

Drought stress 2013 (R.0.378)											Drought Stress 2014 (R.0.473)										
Trait	GT	TGW	SF	FGN	SNP	PN	PL	PH	HD	GY	Trait	FLL	TGW	SF	FGN	SNP	PN	PL	PH	HD	GY
GT	0.087	0.097	-0.037	0.74	-0.283	0.006	0.006	-0.024	-0.086	0.506	FLL	0.037	-0.029	-0.018	0.46	-0.086	0.002	0.235	0.04	0.009	0.650
TGW	0.027	0.319	-0.062	0.849	-0.334	0.018	0.056	-0.155	-0.029	0.689	TGW	0.011	-0.096	-0.021	0.19	-0.029	-0.002	0.173	0.023	0.005	0.253
SF	0.029	0.177	-0.112	1.196	-0.343	-0.005	0.027	-0.132	-0.045	0.792	SF	0.006	-0.018	-0.114	0.48	-0.052	0.003	0.084	0.013	0.011	0.413
FGN	0.038	0.161	-0.079	1.685	-0.722	-0.077	0.044	-0.21	-0.055	0.785	FGN	0.022	-0.024	-0.072	0.768	-0.122	-0.038	0.223	0.033	0.015	0.806
SNP	0.032	0.138	-0.05	1.574	-0.773	-0.091	0.047	-0.214	-0.043	0.62	SNP	0.025	-0.022	-0.047	0.737	-0.127	-0.046	0.244	0.037	0.014	0.815
PN	0.002	0.024	0.002	-0.559	0.305	0.232	-0.01	0.04	0.008	0.045	PN	0.001	0.001	-0.001	-0.144	0.029	0.201	-0.039	-0.008	0.006	0.046
PL	0.006	0.203	-0.034	0.841	-0.417	-0.026	0.088	-0.239	0.018	0.438	PL	0.026	-0.049	-0.029	0.508	-0.092	-0.024	0.337	0.05	0.007	0.734
PH	0.007	0.17	-0.051	1.218	-0.571	-0.032	0.072	-0.291	0.02	0.544	PH	0.019	-0.03	-0.02	0.338	-0.062	-0.02	0.223	0.075	-0.003	0.520
HD	-0.052	-0.065	0.035	-0.647	0.23	0.014	0.011	-0.041	0.143	-0.373	HD	-0.009	0.012	0.032	-0.301	0.046	-0.033	-0.059	0.006	-0.038	-0.344
Normal irrigation 2013 (R.0.517)											Normal irrigation 2014 (R.0.415)										
Trait	GT	TGW	SF	FGN	SNP	PN	PL	PH	HD	GY	Trait	FLL	TGW	SF	FGN	SNP	PN	PL	PH	HD	GY
GT	0.072	0.008	-0.021	-0.011	0.039	-0.106	-0.061	-0.013	0.144	0.05	FLL	0.127	0.039	-0.025	0.187	-0.117	0.106	0.019	0.007	0.004	0.347
TGW	0.032	0.018	0.054	-0.006	-0.015	-0.055	0.105	0.02	0.138	0.293	TGW	0.019	0.269	-0.15	0.324	-0.068	-0.043	0.012	0.106	0.005	0.474
SF	-0.003	0.002	0.500	-0.044	-0.021	-0.065	0.004	0.031	-0.006	0.398	SF	0.008	0.100	-0.404	0.956	-0.231	-0.092	0.009	0.165	-0.015	0.495
FGN	0.011	0.001	0.298	-0.073	0.233	-0.216	0.059	0.074	0.024	0.411	FGN	0.016	0.060	-0.267	1.446	-0.686	-0.155	0.005	0.267	0.014	0.701
SNP	0.009	-0.001	-0.033	-0.053	0.32	-0.199	0.074	0.069	0.026	0.211	SNP	0.02	0.025	-0.124	1.322	-0.751	-0.141	0.003	0.249	0.025	0.627
PN	-0.016	-0.002	-0.067	0.032	-0.131	0.488	0.059	-0.037	-0.006	0.321	PN	0.033	-0.028	0.091	-0.545	0.357	0.511	0.004	-0.124	-0.006	0.292
PL	-0.011	0.005	0.005	-0.011	0.059	0.072	0.402	0.067	-0.049	0.54	PL	0.08	0.104	-0.118	0.257	-0.077	0.053	0.03	0.07	-0.024	0.375
PH	-0.007	0.003	0.104	-0.037	0.151	-0.122	0.185	0.146	-0.077	0.347	PH	0.002	0.076	-0.177	1.028	-0.497	-0.136	0.006	0.376	-0.01	0.669
HD	-0.037	-0.009	0.01	0.006	-0.029	0.011	0.069	0.04	-0.283	-0.222	HD	-0.005	-0.012	-0.059	-0.198	0.185	0.025	0.007	0.036	-0.1	-0.121

380
 381 Table.6 Path analysis partitioning genotypic correlation with grain yield into direct (bold) and indirect effects of yield enhancing traits under drought stress
 382 and normal irrigation for 2013 and 2014 in MH63_IL *indica* type population, R= residual effect.

Drought 2013 (R. 0.216)											Drought stress 2014(R.0.185)										
Trait	GT	SF	FGN	SNP	PL	PH	PN	HD	TGW	GY	Trait	FLL	SF	FGN	SNP	PL	PH	PN	HD	TGW	GY
GT	0.152	-0.131	0.335	-0.059	-0.002	-0.002	0.131	0.012	0.008	0.445	FLL	-0.028	0.025	0.250	-0.036	-0.037	0.102	-0.032	0.005	0.025	0.274
SF	0.050	-0.396	0.887	-0.090	0.006	0.047	0.183	-0.015	0.016	0.688	SF	-0.008	0.094	0.573	-0.048	-0.020	0.101	0.018	-0.027	0.048	0.730
FGN	0.044	-0.304	1.156	-0.361	0.019	0.070	0.097	-0.006	0.010	0.726	FGN	-0.009	0.071	0.760	-0.125	-0.042	0.179	-0.011	-0.037	0.022	0.808
SNP	0.019	-0.074	0.871	-0.479	0.023	0.062	-0.021	0.007	0.002	0.409	SNP	-0.007	0.031	0.653	-0.145	-0.045	0.184	-0.027	-0.042	0.003	0.605
PL	-0.008	-0.059	0.497	-0.258	0.043	0.105	0.043	-0.002	0.006	0.368	PL	-0.012	0.022	0.370	-0.075	-0.086	0.236	-0.006	-0.019	0.018	0.448
PH	-0.002	-0.131	0.572	-0.211	0.032	0.142	0.092	-0.024	0.008	0.479	PH	-0.009	0.029	0.420	-0.082	-0.063	0.324	0.042	-0.055	0.013	0.620
PN	0.049	-0.179	0.278	0.025	0.005	0.032	0.404	0.001	0.010	0.625	PN	0.005	0.010	-0.051	0.023	0.003	0.081	0.170	-0.050	0.022	0.214
HD	-0.033	-0.108	0.131	0.058	0.002	0.061	-0.008	-0.056	0.005	0.052	HD	-0.001	-0.022	-0.239	0.052	0.014	-0.153	-0.072	0.117	-0.059	-0.364
TGW	0.059	-0.289	0.559	-0.037	0.013	0.054	0.194	-0.014	0.022	0.559	TGW	-0.003	0.020	0.074	-0.002	-0.007	0.019	0.017	-0.030	0.227	0.315
Irrigation 2013 (R. 0.362)											Irrigation 2014 (R. 0.316)										
Trait	GT	SF	FGN	SNP	PL	PH	PN	HD	TGW	GY	Trait	FLL	SF	FGN	SNP	PL	PH	PN	HD	TGW	GY
GT	0.127	0.017	-0.002	-0.037	-0.003	-0.002	-0.063	-0.048	0.112	0.101	FLL	0.015	-0.086	0.710	-0.389	0.113	-0.081	0.037	0.026	-0.019	0.325
SF	0.005	0.472	0.098	0.229	0.000	0.004	-0.218	0.016	-0.060	0.545	SF	0.004	-0.367	1.152	-0.218	0.021	-0.050	0.023	0.017	-0.036	0.547
FGN	-0.002	0.327	0.141	0.629	0.007	0.027	-0.408	-0.005	-0.126	0.591	FGN	0.005	-0.209	2.017	-1.090	0.052	-0.159	0.055	0.009	-0.072	0.609
SNP	-0.007	0.155	0.128	0.695	0.010	0.034	-0.423	-0.014	-0.127	0.450	SNP	0.005	-0.066	1.830	-1.202	0.055	-0.168	0.055	0.004	-0.062	0.450
PL	-0.010	-0.005	0.026	0.173	0.039	0.039	-0.110	0.021	0.010	0.183	PL	0.008	-0.037	0.492	-0.309	0.215	-0.030	0.065	0.034	0.027	0.465
PH	-0.003	0.019	0.038	0.234	0.015	0.100	-0.206	0.039	-0.019	0.217	PH	-0.003	0.046	-0.813	0.513	-0.016	0.394	-0.019	-0.029	-0.001	0.072
PN	-0.012	-0.152	-0.086	-0.436	-0.006	-0.031	0.674	-0.010	0.002	-0.057	PN	0.004	-0.058	0.754	-0.452	0.095	-0.052	0.146	0.010	0.004	0.452
HD	-0.038	0.047	-0.005	-0.062	0.005	0.025	-0.043	0.159	-0.010	0.077	HD	0.004	-0.058	0.175	-0.042	0.067	-0.106	0.014	0.108	-0.011	0.150
TGW	0.047	-0.094	-0.059	-0.295	0.001	-0.006	0.005	-0.005	0.301	-0.105	TGW	-0.002	0.072	-0.791	0.407	0.032	-0.002	0.003	-0.006	0.183	-0.103

Path analysis for 02428_IL a *japonica* type presented in Table 6 reveals that under drought stress all traits had positive influence on GY except heading date that affected GY negatively. In 2013, GT, PN, HD, and TGW did not have large impact on grain yield under irrigation. In 2014, all traits except PH, HD and TGW had strong effect on grain yield. Partitioning correlation coefficients into direct and indirect effects, showed that FGN had the strong positive direct effect on grain yield followed by panicle number and plant height. SNP and SF had negative effect and remaining traits affected GY indirectly via FGN. Under irrigation, in 2013, SF, SNP, PN and TGW had strong positive direct influence on GY. In 2014, positive direct influence on GY came from FGN followed by PH, and PL. SF and SNP had negative direct influence on GY. All traits except plant height and 1000-grain weight had negative indirect influence on GY via FGN. All traits had negative indirect effect on GY via SNP except plant height and 1000-grain weight. Generally path analysis partitioning revealed that all measured traits had significant positive correlations coefficients with the GY under drought as well as irrigation conditions, in both seasons except flowering date (HD) which had negative correlations with GY (Table 5&6). Filled grain number FGN followed by effective panicle number are the primary positive determinant of grain yield under both drought and irrigation conditions. Under irrigation, direct negative influence of SNP and SF on GY is counterbalanced by strong positive association with FGN (Table6). Many SNP required high SF in order to bring positive influence on GY. Low SF requires high FGN to influence GY. Grain thickness and flag leaf length are more important under drought stress compared to irrigation conditions in influencing GY, where both influence GY indirectly via strong association with FGN. The proportion of grain yield or residual effects (R) not accounted for by the variables studied under drought and irrigation conditions for two seasons and in both backgrounds are presented as 'R' in Table 5&6. In these studies residual effect were 0.378 and 0.473 under drought stress 0.517 and 0.415 under irrigation for the year 2013 and 2014 in MH63_ILbackgrounds indicating that 63, 53, 49 and 59% percentages of the factors influencing GY were accounted for by these 10 factors studied. Residue effect for the 02428_ILbackground were 0.216, 0.185 under drought and 0.362 and 0.316 under irrigations implying that 79, 82, 64 and 69% respectively of the factors influencing yield were contributed by these 10 traits covered in this research [24] [25]. Lower values for the residue effect for *japonica* type compared to *indica* and in 2013 compared to 2014 would suggest that the extent of contribution of a particular trait on grain yield was affected by environment and perhaps genetic background.

4. CONCLUSION

This study shed light on the genetic information of grain yield and related traits such as their heritability, genetic and environmental effects in the two sets of BILs from a cross between MH63(an *indica*) and 02428 (a *japonica*). Drought tolerant lines with better yields in *indica* had early heading date and higher plant height whereas delayed heading date and moderate plant height in *japonica*. Moreover *japonica* background had low residual effect compared to *indica* suggesting these two population had different drought resistance mechanism or responded differently to environment and seasonal effects. Because of GXE interactions some traits of drought tolerant lines in one season performed poorly the following season. Therefore, selection should focus on different traits in multiple years under water deficit stress and non-stress conditions. High filled grain number, high 1000-grain weight, moderate panicle number, short flowering time and high plant height could be selection criteria for breeding high grain yield under drought conditions. High spikelet number coupled with high spikelet fertility, high tiller number, long panicle length, moderate plant height, and moderate flowering time are necessary for breeding high yield potential plants. Further investigations will focus on identifying QTLs with effect on grain yield under drought, irrigation conditions and both drought and irrigations separately in these two reciprocal backcross introgression inbred lines.

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