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Studies on Correlation and Heritability of Popular Bread Wheat Genotypes Under Water Stress Condition

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Abstract. The experiment was conducted to determine drought tolerance of wheat genotypes under water stress conditions at Botanical Garden, Department of Plant Breeding and Genetics, Sindh Agriculture University, Tandojam during 2017-2018. The experiment was laid out in split plot design with three replications. Two irrigation regimes i.e. non-stress and water stress were considered as main plots and genotypes as sub-plots. The mean squares from analysis of variances showed that treatments were significant for most of the traits yet genotypes were significant for all the traits such as spike length, grains/spike, seed index, grain yield/plant, biological yield/plant and harvest index. Treatment x genotype interactions was also significant for most of the traits except spike/length. In non-stress, Marvi, TD-1, Kiran-95 and TJ-83 recorded higher mean performance for spike length, grains/spike, seed index, grain yield/plant, biological yield/plant and harvest index, while in water stress conditions, generally genotypes like TD-1, TJ-83, NIA-Sundar, Kiran-95 and Galaxy recorded higher mean values for spike length, grains spike, seed index, grain yield/plant, biological yield/plant and harvest index. The wheat genotypes like NIA-Sunder, TJ-83, Galaxy and Benazir recorded minimum reductions for majority of the traits, thus proved their water stress tolerance. The correlation coefficient revealed that in stress conditions, grain yield was significantly and positively associated with number of grains/spike (r = 0.62*), seed index (r = 0.48*), biological yield/plant (r = 0.91**) and harvest index (r = 0.80**). High heritability estimates were recorded in non-stress (ranged from h^2=84.50 to 99.10%) as well as in water stress (ranged from h^2= 88.28 to 98.22%) for all the studied traits. On the basis of minimum reductions in water stress, the genotypes such as NIA-Sunder, TJ-83, Galaxy and Benazir were considered as drought tolerant hence they could be grown in water stress environment.

Keywords: correlation, heritability estimates, yield traits, water stress, wheat genotypes

Introduction

Wheat is the prime source of staple food to Pakistani and most of the developing countries in the world. It provides food to 36% of the global population and contributes 20% of food calories (Khan and Naqvi, 2011). It is the most important and widely adopted cereal crop in Pakistan. Wheat is grown under various agro-climatic conditions, i-e temperate to irrigated and dry to high rain-fall areas and from warm, humid to dry and cold environments (Chimdesa, 2014). Wheat is one of the four main agricultural crops in Pakistan which are being grown on an area of around 9.0 million hectares (very close to 40% of the country's total cultivated land). Wheat crop is forecast at 26.3 million metric tons, slightly down to last year's record. Its exports are expected to reach 1.0 million metric tons in both 2017/18 and 2018/19 with the aid of a generous export subsidy (Raza, 2018). It is popularly known as 'Stuff of life or King of the cereals' because of the large acreage, high productivity and the prominent position it holds in the international food grain trade (Clayton *et al.*, 2015).

Water deficiency is a major constraint in arid and semi-arid regions worldwide that is limiting the area under cultivation, consequently crop production. It is also common for many abiotic stresses to occur at the same time and damage the crops. For example, the occurrence of high temperatures are common during periods of limited water availability (Sutton, 2006). Water deficit affects every facet of plant growth and the yield through modifying the anatomy, morphology, physiology, biochemistry and finally the productivity of crop (Lisar *et al.*, 2012). The drought tolerance of wheat is a complex process with respect to specially physiology of plant.

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Thus in order to characterize the drought tolerance, several parameters need to be taken into consideration together like fertilization and the grain filling processes (Forgone, 2009). Therefore, field experiments have their own value for evaluating different wheat cultivars against different abiotic stresses, especially drought conditions.

The success of breeding program largely depends on the choice and exploitation of potential parental genotypes for hybridization followed by selection of favourable gene combinations. Knowledge of genetic variability and heritability are dependable tools to the plant breeders for genetic improvement of crop plants (Chimdesa, 2014). Genetic variability among wheat genotypes can be estimated based on quantitative traits and can be divided into heritable and non-heritable variations. Broad sense heritability estimate is defined as the ratio of total genetic variance, including additive, dominance and epistasis to the phenotypic variance, while heritability in narrow sense estimates only the additive portion of the total phenotypic variance (Riaz and Chowdhry, 2003). Knowledge of heritability helps plant breeder in predicting the behaviour of successive generations for making desirable selections, which is one of the important tools in crop improvement. Kisana *et al*. (2008) studied five wheat crosses and observed high heritability and genetic advance for plant height and grain yield. Das and Rehman (1984) recorded high heritability for grains per spike and grain yield. Haq *et al*. (2008) observed high heritability and genetic advance in grains per spike and grain yield per plant. Kahrizi *et al*. (2010) studied 12 advanced durum wheat cultivars and two checks and found high heritability for plant height and peduncle length. Gulnaz *et al.* (2011) recorded high heritability and genetic advance (80%, 11.28, respectively) for plant height. Khan *et al*. (2011) noted high heritability for plant height and days to heading. Ijaz *et al*. (2013) reported high heritability and genetic advance for plant height, flag leaf area, 1000-grain weight, number of tillers per plant and grain yield per plant. Correlation is the simultaneous variation in two variables. It is often desirable to observe and measure the relationship between two characters. Correlation may be positive when increase in one trait causes simultaneous increase in the other, while negative correlation reflects the increase in one character is associated with a decrease in the other (Bhutto *et al*., 2005).

The selection of genotypes with increased productivity is an essential part of plant breeding programs. The identification and selection of genotypes according to their morphological and physiological traits are effective approaches to breeding for higher yields (Mohammad *et al*., 2008; Majumder *et al*., 2008). Therefore, information about the genetic potential of various genotypes and inheritance pattern of various characters and degree of association of yield with various morpho-yield traits are important aspects for breeder to launch a breeding program wisely and enhance the yield to a desirable extent (Ahmad *et al*., 2008). The objective of present study therefore was to investigate the water stress tolerance of wheat genotypes.

Materials and Methods

The experiment was conducted at Botanical Garden, Department of Plant Breeding and Genetics, Sindh Agriculture University, Tandojam during 2017-2018 so, as to determine the drought tolerance of wheat genotypes under water stress conditions. The experiment was conducted in split plot design with three replications. Two irrigation regimes, non-stress and water stress were considered as main plots and cultivars as sub-plots and the experiment was arranged in randomized complete block design. The non stress treatment received six irrigations (650mm), whereas water stress treatment received five irrigations (one irrigation was dropped at anthesis stage, thus received 542mm). Four rows were planted in plot size of 8 x 8 meters. Ten wheat genotypes such as SKD-1, Kiran-95, Benazir, Aas-2002, Marvi, Sehar, TJ-83, NIA-Sunder, TD-1 and Galaxy were evaluated for six quantitative traits *viz*. spike length (cm), number of grains/spike, 1000-grain weight (g), grain yield/plant (g), biological yield/plant (g) and harvest index (%). The collected data were statistically analyzed using analysis of variance according to (Gomez and Gomez, 1984). Correlation coefficients were determined following the procedures of Raghavrao (1983) and heritability in broad sense was estimated as suggested by Allard (1960). The inorganic fertilizer given and cultural practices were adopted as suggested for wheat crop.

Results and Discussions

Present studies were aimed to determine the effect water stress on different wheat genotypes for various quantitative traits. The results are discussed here under.

Analysis of variance. The mean squares from analysis of variances are presented in Table 1 and separate ANOVA for non stress and water stress treatments is presented in Table 2. The combined ANOVA showed that the treatments and genotypes were significant for all the traits such as spike length, grains/spike, seed index, grain yield/plant, biological yield/plant and harvest index. However, treatment x genotypes (T x G) interactions were significant at 1% probability level for most of the traits except spike length. The separate ANOVA of non stress and water stresses also indicated that the genotypes were significant for all the traits. These results suggested that genotypes performed differently over the treatments for most of the traits. Our results are in conformity with those of Fouad (2018) who also reported significant differences for environments, genotypes, years, environments x genotypes and years x genotypes interactions for the studied traits. Similar results were obtained by Naimat *et al*. (2018) who also noted significant variability among the genotypes for majority of the traits studied, while Neeru *et al*. (2017) observed significant genotypic differences among the traits in two testing environments.

Mean performance of wheat genotypes. The data recording the mean performance of wheat genotypes for various quantitative traits grown under non-stress and water stress conditions were presented in Tables 3-5. The results are discussed and described here under with separate sub-headings.

Spike length (cm). The information in respect to spike length of all genotypes are presented in Table 3 showed that among the genotypes, Marvi, TD-1 and Kiran-95 remained as top three genotypes with spikes measured as 14.33, 12.33 and 11.37cm respectively in non-stress condition. In water stress condition, genotypes Marvi, Galaxy and TD-1 with 11.33, 10.55 and 10.07 cm recorded longer spikes, thus performed as best group of genotypes. However, Galaxy, Benazir and Aas-2002 reduced spikes by -0.66, -1.28 and -1.31cm respectively under water stress conditions. Naimat *et al*. (2018) they reported that spike length ranged from 9.2 to 13.1 cm,

Table 1. Mean squares from analysis of variance for various quantitative traits of wheat genotypes grown in non-stress and water stress conditions.

Traits	Mean squares					
	Replication (D.F.=2)	Treatment (T) (D.F. =1)	Error (a) (D.F.=2)	Genotypes (G) (D.F.=9)	T x G (D.F.=9)	Error (b) (D.F.=36)
Spike length	0.29	70.69**	0.29	14.12**	1.18 ns	0.79
Grains/spike	0.14	2601.73**	2.06	165.48**	22.96**	0.90
Seed index	0.93	1649.97**	4.41	33.81**	29.61**	0.93
Grain yield/plant	0.35	233.76**	2.23	20.07**	1.85**	0.56
Biological yield/plant	0.27	306.50**	7.73	45.96**	13.91**	2.75
Harvest index	4.50	1348.34**	4.43	71.89**	13.20**	3.83

*** = significant at 1and 5 % probability level respectively; ns=non-significant.

Table 2. Treatment wise mean squares from analysis of variance for various quantitative traits of wheat genotypes grown in non-stress and water stress conditions.

Traits	Mean squares					
	Non-stress			Water stress		
	Replication (D.F.2)	Genotypes (D.F.9)	Error (D.F.18)	Replication (D.F.2)	Genotypes (D.F.9)	Error (D.F.18)
Spike length	0.51	7.70**	0.93	0.07	7.60**	0.65
Grains/spike	1.60	112.32**	0.77	0.59	76.12**	1.02
Seed index	3.12	23.07**	0.92	2.20	40.34**	0.93
Grain yield/plant	0.82	8.91**	0.43	1.75	13.01**	0.68
Biological yield/plant	2.58	19.59*	2.11	5.42	40.27**	3.38
Harvest index	3.55	19.82**	1.73	5.37	65.27**	5.91

*** = significant at 1% and 5% probability levels respectively.

Table 3. Mean performance for spike length and number of grains/spike of wheat genotypes grown under non stress and water stress conditions

Genotypes	Spike length (cm)		R.D.*	Number of grains/spike		R.D.*
	Non-stress	Water stress		Non-stress	Water stress	
Galaxy	11.21	10.55	-0.66	51.43	43.00	-8.43
Benazir	10.39	9.11	-1.28	60.00	45.33	-14.67
Aas-2002	10.71	9.40	-1.31	51.00	39.33	-11.67
Marvi	14.33	11.33	-3.00	54.07	35.00	-19.07
NIA-Sunder	9.77	7.67	-2.10	54.00	46.00	-8.00
TD-1	12.33	10.07	-2.26	64.00	48.00	-16.00
SKD-1	8.30	6.33	-1.97	49.00	37.13	-11.87
TJ-83	11.27	8.00	-3.27	51.00	41.33	-9.67
Seher-2006	10.18	7.00	-3.18	48.00	34.00	-14.00
Kiran-95	11.37	8.67	-2.70	65.00	46.67	-18.33
Mean	10.99	8.81	-2.17	54.75	41.58	-13.17
LSD at 5% (T)	-0.66		1.11		LSD at 5% (G)	
LSD at 5% (G)	-1.28				2.04	
LSD at 5% (G x T)	-1.31				1.57	

R.D* = Relative decrease under water stress over the non-stress.

Table 4. Mean performance for seed index (1000 grain weight) and grain yield/plant of wheat genotypes grown under non stress and water stress conditions

Genotypes	Seed index (1000-grain weight, g)		R.D.*	Grain yield plant (g)		R.D.*
	Non-stress	Water stress		Non-stress	Water stress	
Galaxy	41.00	32.00	-9.00	11.13	5.33	-5.80
Benazir	40.21	30.00	-10.21	11.35	8.33	-3.02
Aas-2002	39.97	29.00	-10.97	9.45	6.00	-3.45
Marvi	44.00	25.67	-18.33	10.71	5.00	-5.71
NIA-sunder	40.13	35.27	-4.86	10.65	7.67	-2.98
TD-1	44.00	33.00	-11.00	14.58	10.76	-3.82
SKD-1	38.61	26.00	-12.61	11.44	8.96	-2.48
TJ-83	35.33	33.00	-2.33	12.90	9.30	-3.60
Seher-2006	37.11	24.00	-13.11	9.22	5.00	-4.22
Kiran-95	42.18	29.73	-12.45	13.60	9.20	-4.40
Mean	40.25	29.77	-10.48	11.50	7.56	-3.94
LSD at 5% (T)	2.33			1.66		
LSD at 5% (G)	1.12			0.87		
LSD at 5% (G x T)	1.59			1.23		

R.D* = Relative decrease under water stress over the non-stress.

number of grains/spike ranged from 50.5 to 70.0, 1000 grain weight ranged from 32.0 to 48.3 g and grain yield ranged from 2516.5 to 5155.0 Kg/ha. Bhutto *et al.* (2016) they observed that variety Sarsabz gave more grains/spike (63.13), TJ-83 gave highest seed index (47.260), and was next ranker in spike/length (12.07), grains/spike (59.86) and grain yield/plant (9.86) among the genotypes.

Number of grains/spike. Water stress caused significant reduction in grains/spike (Table 3). In non stress condition, on an average of 54.75 grains/spike was recorded, while in water stress condition an average of 41.58 grain/spike was formed which resulted in decline of -13.17 grains/spike due to water stress. NIA-Sunder, Galaxy and Aas-2002 recorded a minimum decline of -8.00, -8.4 and -11.67 respectively in number of grains

Table 5. Mean performance for biological yield plant-1and harvest index of wheat genotypes grown under non stress and water stress conditions.

Genotypes	Biological yield/plant (g)		R.D.*	Harvest index (%)		R.D.*
	Non-stress	Water stress		Non-stress	Water stress	
Galaxy	23.67	13.67	-10.00	47.02	38.97	-8.05
Benazir	23.67	21.33	-2.34	48.00	39.08	-8.92
Aas-2002	20.43	18.07	-2.36	46.30	33.40	-12.90
Marvi	23.33	14.67	-8.66	45.91	33.99	-11.92
NIA-sunder	22.33	22.00	-0.33	47.70	34.90	-12.80
TD-1	26.67	23.67	-3.00	54.65	45.48	-9.17
SKD-1	23.38	20.77	-2.61	48.94	43.14	-5.80
TJ-83	26.75	22.13	-4.62	48.29	41.92	-6.37
Seher-2006	19.32	14.33	-4.99	47.72	34.78	-12.94
Kiran-95	26.67	20.38	-6.29	50.99	45.08	-5.91
Mean	23.62	19.10	-4.52	48.55	39.07	-9.47
LSD at 5% (T)	3.08			2.33		
LSD at 5% (G)	1.94			2.29		
LSD at 5% (G x T)	2.74			3.23		

R.D* = Relative decrease under water stress over the non-stress.

spike due to water stress at anthesis. In non stress conditions, Kiran-95,TD-1 and Benazir performed better with 65.00, 64.00 and 60.00 grains/spike, while in water stress, their rank order changed little bit but NIA-Sunder,TD-1 stood at first (48.00 grains) followed by Kiran-95 (46.67) and NIA-Sunder (46.00) by setting more number of grains/spike. Naimat *et al*. (2018) reported 50.5 to 70.0 grains/spike under water stress conditions.

Seed index (1000 grain weight, in g). The results recording the mean performance of varieties for seed index is presented in Table 4 which indicated that genotypes like TD-1, Marvi and Kiran exhibited a good performance and recorded seed index of 44.00, 44.00 and 42.18 g in non-stress but their rank order was changed in water stress conditions where varieties such as NIA-Sunder, TD-1, and TJ-83 with 35.27, 33.00 and 33.00g recorded higher seed index. The genotype TJ-83 showed a minimum reduction of -2.33g in seed index under stress conditions followed by NIA-Sunder (-4.86g) and Galaxy (-9.00g), while Marvi recorded maximum (-18.33g) reduction in seed index under water stress condition. Similar results were obtained by Naimat *et al*. (2018) who obtained desirable seed index under water stress conditions.

Grain yield/plant (g): Water stress at anthesis caused substantial reduction in grains yield/plant (Table 4). Furthermore, an average of -3.94g grains yield/plant was reduced due to water stress.

The genotypes like TD-1, Kiran-95 and TJ-83 performed better in non-stress with 14.58, 13.60 and 12.90g grain yield/plant respectively. While Seher recorded minimum of 9.22 and 5.00g grain yield/plant in both the environments respectively. The genotypes, SKD-1, NIA-Sunder and Benazir exhibited a little decline of -2.48, -2.98 and -3.02g in grains yield/plant due to water stress while Galaxy gave maximum (-5.80g) decline in water stress as compared to non stress condition. More or less our findings are in consonance with the findings of Naimat *et al*. (2018) who also found that grain yield ranged from 2516.5 to 5155.0 Kg/ha under stress condition while Bhutto *et al*. (2016) noted that TJ-83 gave highest grain yield/plant (9.86) among the genotypes.

Biological yield/plant (g). Significant decrease in biological under water stress at anthesis was noted among the genotypes (Table 5). Furthermore, an average of -4.52g decrease in biological yield/plant was observed due to water stress. The genotypes like TJ-83, TD-1 and Kiran-95 performed better in non-stress with 26.75, 26.67 and 26.67g biological yield/plant respectively, while Seher recorded minimum (19.32g) biological yield/plant in non stress. The same genotypes such as

TD-1, TJ-83 and NIA-Sundar also performed better (23.67, 22.13 and 22.00 g respectively) for biological yield/plant in water stress conditions. The genotypes NIA-Sunder, Benazir and SKD-1 exhibited a smaller decline of -0.33, -2.34 and -2.61g respectively in biological yield/plant due to water stress, while Galaxy showed maximum (-10.00g) decline in water stress as compared to non stress condition.

Harvest index (%). The mean values regarding harvest index of all wheat genotypes is presented in Table 5, which indicated that considerable amount of reduction in harvest index due to water stress at the time of anthesis. On an average, -9.47% harvest index was reduced due to water stress. Among the genotypes, TD-1, Kiran-95 and SKD-1 performed better in non-stress (54.65, 50.99 and 48.94% respectively), while in water stress, they recorded 45.48, 45.08 and 43.14% harvest index respectively. The genotype Aas-2002 recorded minimum (46.30 in non-stress and 33.40% in stress) harvest index in both the environments respectively. The genotypes SKD-1, Kiran-95 and TJ-83 showed minimum declines of -5.80, -5.91 and -6.37% in harvest index due to water stress, while Seher-2006 showed a maximum (-12.94%) decline owing to water stress.

Correlation coefficient (r). The extent of associations of grain yield with other yield contributing traits in stress and water stress are presented in Fig. 1. The results indicated that in water stress conditions, grain yield/plant was significantly and positively associated with grains/spike (r=0.62**), seed index (r= 0.48*), biological yield/plant (r=0.91**) and harvest index (r= 0.80**). Similar to stress conditions, grain yield/plant, under non stress conditions was also significantly and positively correlated with grains/spike (r= 0.67**), biological yield/plant (r= 0.93**) and harvest index (r= 0.74**) except that it was non significantly correlated with seed index (r= 0.28). In nonetheless, spike length showed non significantly positive association with grain yield (r= 0.25) in non stress and non significant but negative correlation (r= - 0.19) in water stress conditions. Our results are in agreement with those obtained by Saima *et al*. (2017). They reported that crop yield is the resultant product of component characters which is not under the control of any single gene, therefore it is necessary for plant breeders to know the relationship between two traits. Khan *et al.* (2017) observed to have significantly positive association of grain yield with most of the important yield related traits such as 1000-grain weight and grains per spike. These results suggested that all the traits showing significant correlation with grain yield needs better attention in future wheat breeding programs for increasing grain yield of wheat crop.

Heritability (h^2b.s. %). The results regarding the heritability estimates in broad sense for various traits of wheat genotypes grown in non-stress and water stress

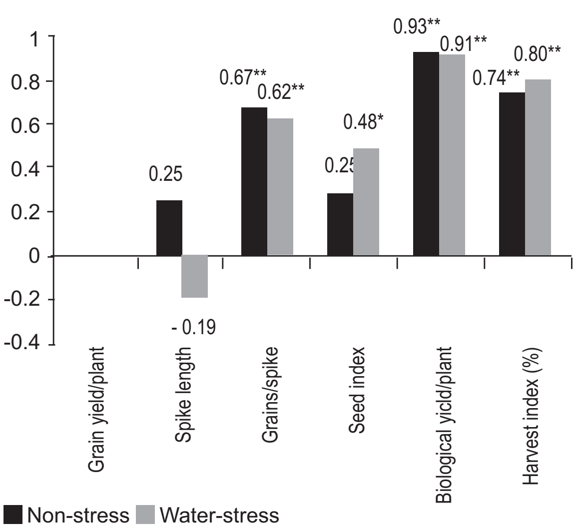

Fig. 1. Correlation coefficent (r) of grain yield with other contributing trails in non-stress and water stress condition.

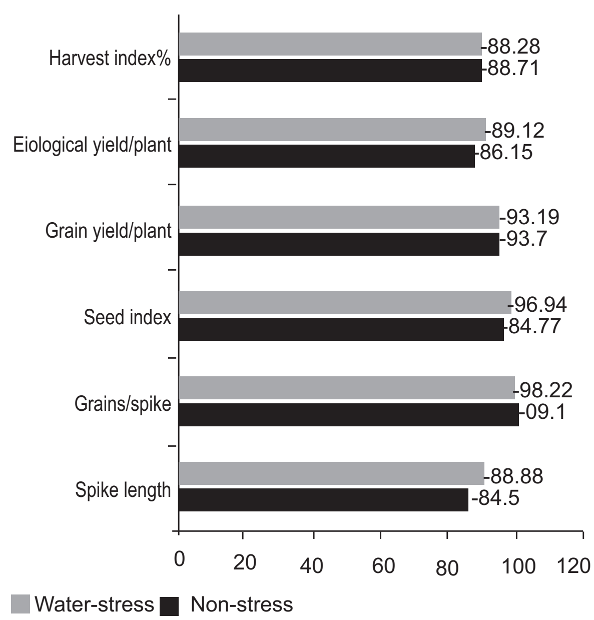

Fig. 2. Heritablity in broad sense for grain yield and its contributing traits of wheat genotypes grown in non-stress water stress.

condition are presented in Fig 2. The results indicated that in water stress conditions, high heritability was recorded for all the traits like spike length (h^2= 88.88%), grains/spike (h^2= 98.22%), seed index (h^2= 96.94%), grain yield/plant (h^2= 93.19 %), biological yield/plant (h^2= 89.12 %) and harvest index (h^2= 88.28 %), where as in non stress, high heritability were also recorded for spike length (h^2= 84.50%), grains/spike (h^2= 99.10%), seed index (h^2= 99.10%), grain yield/plant (h^2= 93.70%), biological yield/plant (h^2= 86.15%) and harvest index (h^2= 88.71%). Ilyas *et al*. (2010) also reported high heritability coupled with high genetic advance for grain yield and 1000 -grain weight. So, these characters are more useful in wheat breeding program for obtaining higher yield. Present results also revealed high heritability for spike length, grains/spike, seed index, grain yield/plant, biological yield/plant and harvest index (Fig. 2) in both the environments. Babar *et al*. (2016) noted low to high heritability for all the traits studied except kernel weight per spike which showed moderate to high value. Therefore, selection could be practiced among wheat genotypes to improve grain yield per plant. Sheraz and Hassan (2017) studied 27 genotypes for estimation of heritability, genetic advance and association of yield and yield related traits in wheat. For all the studied traits, mean squares showed the presence of significant variation ($P \leq 0.01$) among the genotypes. Neeru *et al*. (2017) observed moderate magnitude of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) for grain yield per meter square and effective tillers per meter and grain filling duration under timely and for grain yield per meter and effective tillers per meter under late sown condition. Above mentioned traits also showed high heritability in both the environments.

Conclusion

The mean squares from analysis of variance showed that treatments and genotypes were significant for most of the traits such as spike length, grains/spike, seed index, grain yield/plant, biological yield/plant and harvest index. In water stress, TD-1, Marvi, Aas-2002 and Galaxy showed higher values for spike length, grains/spike, seed index, grain yield/plant, biological yield/plant and harvest index. High heritability were recorded in non stress as well as in water stress for all the traits. The genotypes such as TD-1, Marvi, Kiran-95, Aas-2002 and Galaxy were labeled as drought tolerant hence they may be grown in water stress environments or in breeding programmes to develop more drought tolerant breeding material.

Conflict of Interest. The authors declare no conflict of interest.

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