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Water a Response Factor to Screen Suitable Genotypes to Fight and Traverse Periodic Onslaughts of Water Scarcity in Spring Wheat (*Triticum aestivum* L.)

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Abstract: Pakistan lies in semi arid to arid region with neither sufficient nor reliable rainfall. Indeed country agriculture depends on Indus river irrigation system which maintains the integrated irrigation network of Indus basin irrigation system. Under the burgeoning population pressure, the water resources are depleting at high speed. Climate change and speedy competition for irrigation purposes will further increase the water utmost needs. Plant water stress results from the interaction of soil water status, evaporation demand, physiological and genetic factors. The genetic approaches are being able to significantly improve water stress tolerance in wheat. The field based approaches have been resulted for the improvement and conservation of diverse and potentially additive tolerance model comprising genetic interactions. Best combination among diverse genotypes with increasing yield and yield contributing traits of spring wheat in the face of climate change and scarce water may be the best success to ensure food security and law and order. The tension between tradition and innovation provides fuel for pushing on the frontiers of progress and never calling it quits.

Key words: Burgeoning · Climate · Genetic · Irrigation · Population · Water stress

INTRODUCTION

Pakistan containing area is considered as the cradle of the earliest known civilization of South Asia, the Indus valley civilization. Pakistan has a mighty river Indus which is considered as lifeline of Pakistan and Pakistan irrigation system mainly runs on river Indus and its tributaries, The Indus originates from Tibet the everlasting glacial streams of the Himalayas and runs along with the entire length of Pakistan, about 2,900 km (1,800 mi). The principal tributaries of the Indus are the rivers Sutlej, Beas, Chenab, Ravi and Jhelum which merge in southern Punjab to form the Panjnad (“Five Rivers”). In present world water has gained a commodity of a great strategic importance of any country. The per capita share of water can be used an indicator to measure the level of the countries welfare and prosperity. Under the pressure of burgeoning population it is the need of hour to increase the agricultural production and the farm income by improving the irrigation infrastructure [1, 2]. Economic use of water always remained a vital issue among farmers, scientists, hydrologists and policy makers. However the economic use of irrigation water can fetch maximum yield returns [3, 4].

Water Conservation: The growing population pressure and shaking economy accumulated effects have diverted the world attention for efficient water conservation techniques. The fresh water resources throughout the world are depleting. The main cause seemed to be the lack of rainfall, unpredictable onslaught of drought and climatic conditions. To save nature as well as agriculture and to ensure food security water conservation has gained the momentum. The global water crisis is alarming

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the sustainable agriculture, mostly the Asian countries will suffer, where irrigated agriculture accounts for 90% of total diverted fresh water [5]. These technologies are the cheap, easiest and time tested however possible only if each and every sphere of life realize its moral duty to save water even in low flow toilets, smart showers, economic residential as well as commercial washing, precision agriculture and efficient recycling [6].

Map showing river Indus and its tributaries
Courtesy: Pakistan Water Gateway (http://www.waterinfo.net.pk)

Water-conserving technologies in outdoor may include water probes, on-site sensors that may depict weather conditions, predict climate change, its occurrence and evapotranspiration data, irrigation scheduling, use of rain water collection system, landscape irrigation, soil grading, seed bed preparation and designing, artificial mulching, need based crop cultivation, proper fertilization and composting.

Irrigation Scheduling: Irrigation scheduling is a farmer friendly technique by which a wise decision may be made, when to irrigate, how and how much to irrigate. Its main purpose is to maximize irrigation efficiencies by irrigating exact amount of water needed by crop to run its daily requirements and to stock up the soil moisture to the desired level. All of irrigation scheduling procedures consists of efficient monitoring indicators to determine the exact amount of water to apply to the field and the exact timing for application.

Water, Wheat and Human Being: The history of water, wheat and human being have grown and remain subsist, in a very close and mutual association. The water and wheat travelled side by side from Fertile Crescent to the upper reaches of Tigris-Euphrates drainage basin, the famous and authenticated center of diversity. Even now both have achieved the basic necessity and staple food for the majority of world as well the essential commodity of the world trade. During the last century agriculturist particularly plant breeders paid the intelligence and have ensured wheat yield to safeguard the food availability. Pakistan's economy is mainly based on agriculture, due to 215share in GDP and 45% labour force employer [7]. Among cereals, the wheat has pride of place and wheat alone contributes 12.5% value addition in agriculture and it is 2.6% of the total Gross Domestic Product (GDP) of Pakistan. In Pakistan wheat cultivation showed a decrease of 2.6 percent during 2011-12 over last year area. The yield also showed a 6% negative growth mainly due to water scarcity [8]. The main reason behind this decline is the cultivation of unsuitable wheat varieties, periodic water stress conditions and adverse climatic conditions [9]. By an efficient screening, the potential genotypes may be selected [9, 10, 11], that can be crossed and utilized in succeeding generation to give rise a food security. By any estimate, the wheat in most of the world particularly in Pakistan is crucial to fill the empty stomach of escalating population [12]. In global street the food availability is severely threatened by amplified food demand and diminution water supply [13].

Genetic Variability of Wheat: Along with the water conservation techniques and proficient irrigation scheduling, the study of wheat screening to get promising genotypes [14, 15] for further use in succeeding generation. The obtained genetic variability will contest water trauma to guarantee quality food safety [16]. The researcher mainly concerned in sequence on the genetic systems scheming morphological traits coupled with mathematical and appropriate statistical approach [17] and to get defined estimates of additive and dominance genetic variances. The improved genetics packed in a seed, easily be adapted by improved agricultural practices, inputs availability, infrastructure, access to markets and skill in crop and soil management. The present research was therefore envisaged to determine the vagaries of different environments to ascertain economic traits in wheat reflecting yield potential along genetic survey to recognize the mode of gene action revealed by exotic and locally wheat varieties, under irrigated and water stress conditions.

Table 1: 49 possible crosses between lines and testers

Nesser x 9244	Dharwar Dry x 9252	Bakhar-2002 x 9316	Inqulab-91 x 9258
Nesser x 9247	GA-2002 x 9244	Bakhar-2002 x 9021	Inqulab-91 x 9267
Nesser x 9258	GA-2002 x 9247	Bakhar-2002 x 9252	Inqulab-91 x 9316
Nesser x 9267	GA-2002 x 9258	Chakwal-86 x 9244	Inqulab-91 x 9021
Nesser x 9316	GA-2002 x 9267	Chakwal-80 x 9247	Inqulab-91 x 9252,
Nesser x 9021	GA-2002 x 9316	Chakwal-86 x 9258	Kohistan-97 x 9244
Nesser x 9252	GA-2002 x 9021	Chakwal-86 x 9267	Kohistan-97 x 9247
Dharwar Dry x 9244	GA-2002 x 9252	Chakwal-86 x 9316	Kohistan-97 x 9258
Dharwar Dry x 9247	Bakhar-2002 x 9244	Chakwal-86 x 9021	Kohistan-97 x 9267
Dharwar Dry x 9258	Bakhar-2002 x 9247	Chakwal-86 x 9252	Kohistan-97 x 9316
Dharwar Dry x 9267	Bakhar-2002 x 9258	Inqulab-91 x 9244	Kohistan-97 x 9021
Dharwar Dry x 9316	Bakhar-2002 x 9267	Inqulab-91 x 9247	Kohistan-97 x 9252
Dharwar Dry x 9021			

MATERIALS AND METHODS

Suitable genotypes paved the path for good crop stand and sustainable yield. In present study the experiment was conducted in University of Agriculture, Faisalabad. The experimental material comprised of one diverse cluster of genotypes i.e one CIMMYAT, one Indian and five Punjab Government varieties namely Nesser (CIMMYT), Dharwar Dry (India), GA-2002, Bakhar-2002, Chakwal-86, Inqilab-91 and Kohistan-97 and 9244, 9247, 9258, 9267, 9316, 9021 and 9252 (University of agriculture Faisalabad, Pakistan germplasm). These genotypes were crossed by adopting the line x tester mating fashion as described by Kempthorne [18]. The following crosses were made by manual emasculation and pollination to get 49 wheat hybrids (Table 1).

During the next crop season the experimental site was precisely levelled to ensure even distribution of water and inputs. Two experiments, one under normal irrigated conditions and another under water stress conditions (simulated by totally withholding irrigation after sowing) were laid out in a triplicate randomized complete block design, separated by 1.5 m buffer zone to avoid water seepage.

All F_1s (Table 1) along with their parents were sown with a dibble in lines 30 cm apart keeping Plant-to-plant distance 15 cm to check the genetic and environmental effects.. Two seeds per hole were planted retaining the healthy looking seedling of the two after germination. Each treatment was represented by a single line 5 m long containing 33 plants. Over and above, a few more experimental lines were also raised at the start and end of each replication to neutralize boarder effects. The rest of the agronomic treatments, i.e. hoeing, weeding and fertilization etc of the site were applied as in a usual routine, save irrigation given only to the normal sown experiment. Data recorded were analyzed according to analysis of variance technique as described by Steel *et al*. [19]. Estimates of genotypic, phenotypic and environmental variances was calculated according to the formula:

$$\sigma^2_p = \sigma^2_g + \sigma^2_e$$

While estimates of Broadsence heritability h^2_{BS} were calculated for both normal irrigation stress conditions by following formula:

$$h^2(_{BS}) = \sigma^2_g/\sigma^2_p$$

RESULT AND DISCUSSION

According to International Water Management Institute (IWMI) [20], under prevailing water shortage many developing nations may have to import more than a quarter of their food items by 2050 unless and until they divert their selves to adopt arid and rain-fed agriculture. Satellite picture of earth showed 2/3 of the planet is full of water. We should not be excited that 97% of these waters are brackish and unusable for agriculture as such. Desalination cost is uneconomical by most of the world. So we have to depend on remaining 3%, out of which 2% are in the form of snow, ice and inaccessible cold regions. Resultantly less than 1% of the earth waters as fresh and readily available for all of our daily, commercial and agricultural needs. In present study we used calculated amount of water to irrigate normal and water stress plot under study.

Water Applied to Normal Irrigation Experiment: The normal irrigation experiment was given measured quantity of water and calculations were made per plot according to [21].

Plot length	=	21 m
Plot Width	=	5 m
Plot Area	=	21 m x 5 m = 105 m^2
Depth of irrigation applied	=	50 mm = 0.05 m
Value of water required	=	Plot area x Depth of water applied
	=	105 m^2 x 0.05 m = 5.25 m^3
Water applied in liters. As 1 m3	=	1000 litres

For 50 mm depth of water the amount of water required/plot = 5.25 x 1000 = 5250 liters Total water applied to each plot were recorded with the help of a cut-throat flume using the formula:

Qt	=	Ad
t	=	Ad/Q
t	=	Application time (hours)
A	=	Field area of plot (ha)
d	=	Depth of Irrigation application (m)
Q	=	Flow rate (m^2/Second)

An adequate supply of water is essential for proper plant growth and water stress results in reduction of plant organs as well as plant yield [10, 12, 16]. In present study, 63 wheat genotypes were evaluated in two different environments. The data measured on different morphological characteristic were analyzed. Mean square values from the analysis of variance under normal irrigation and water stress conditions are given in (Table 2).

Highly significant differences were observed for parents, crosses and parent vs crosses among wheat genotypes. The trait number of tillers per plant had important role in economic yield.

Under normal irrigation condition, the exotic genotype Dharwar Dry and its derivative cross combination revealed maximum positive values and emerged as water stress tolerant genotype.

The results of present study are in agreement with Kang *et al*. [22]; Pirdashti, [23]; Ahmad *et al*. [24].

According to Table 3, among lines maximum number of tillers per plant were produced by Dharwar dry (12.07) and Bakhar-2002 (12.06), followed by Kohistan-97 (11.77), whereas the minimum number of tillers per plant (9.96) was observed for GA-2002. Under water stress condition, maximum number of tillers per plant was produced by genotypes Dharwar Dry (10.50) and Nesser (10.17), followed by Kohistan-97 (10.07) while the minimum tillers per plant was produced by genotype GA-2002 (8.83). Spike length was measured maximum in genotypes Dharwar Dry (16.02 cm) and Inqilab-91 (14.10 cm) followed by GA-2002 (14.02 cm). Under water stress condition spike length was maximum in genotypes Dharwar Dry (14.77 cm) and Inqilab-91 (13.17 cm) followed by Nesser (11.67 cm), whereas minimum spike length was measured in genotype Bakhar-2002 (10.33cm). Maximum 1000-grain weight was attained by genotype, Dharwar Dry, (38.32g) and Nesser (37.78g) followed by GA-2002 (36.64g), whereas minimum weight was observed for Inqilab-91 (26.71g) under normal irrigation condition while under water stress condition 1000-grain weight was maximum in genotypes Nesser (32.07g) and Kohistan-97 (32.01g) followed by GA-2002 (30.48g), while Inqilab-91 exhibited the minimum value (21.57g). Maximum economic yield was recorded for genotype Dharwar Dry (27.30g) and Nesser (27.10g) followed by Kohistan-97 (19.03g), while Bakhar-2002 gave minimum economic yield (13.24g) under normal irrigation condition while under water stress condition the genotypes Nesser (21.85g) and Dharwar Dry (21.81g) produced maximum economic yield, followed by the genotype Kohistan-97 (14.47g). Minimum economic yield was recorded in genotypes Bakhar-2002 (10.01g) under water stress conditions. Among testers, (Table 3) under normal irrigation maximum number of tillers per plant were produced by the genotypes 9247 (10.10) and 9267 (10.07) followed by the genotype 9258 (9.93). The minimum number of tillers was found for the genotype 9252 (9.17). Under water stress condition, number of tillers per plant was maximum in genotypes 9267 (8.50) and 9021 (8.01) followed by 9316 (7.67) while minimum as recorded for genotype 9244 (6.13). Under normal irrigation the male parents (testers) spike length remained maximum for the genotypes 9252 (11.01 cm) and 9247 (10.50cm) followed by 9267 (10.50 cm). Minimum spike length was found for genotype 9258 (9.83 cm). Under water stress condition maximum spike length was occurred for genotypes 9316 (9.67 cm) and 9021 (9.33 cm) followed by 9247 (9.10 cm), whereas a minimum value was recorded for this trait in genotype 9258 (8.53 cm). Under normal irrigation conditions, 1000-grain weight was recorded as maximum in genotypes 9247 (35.03g) and 9244 (32.16g) followed by 9021 (30.57g), while, the genotype 9252 showed minimum value (26.09g). 1000-grain weight was maximum under water stress condition for genotypes 9244 (22.68g) and 9247 (22.58g) followed by 9267 (22.33g). The 1000-grain weight was minimum recorded for genotype 9252 (19.18g). Among testers the grain yield the most important trait, was observed to be maximum for the genotypes 9244 (20.80g) and 9247 (19.77g) followed by genotype 9252 (19.41g) while the minimum value was recorded for the genotype 9021 (16.23g). The genotypes 9247 (12.34g) and

Table 2: Analysis of variance(ANOVA), Mean squares values of fourteen parents and their hybrids in wheat under contasting normal irrigation and water stress conditions

		N	WS	N	WS	N	WS	N	WS
Source of variation	d.f.	NTP	NTP	SL	SL	TGW	TGW	GY	GY
Replications	2	0.74	1.66	0.70	2.01	140.92**	27.67	8.51	3.92
Genotypes	62	2.50**	4.68**	3.50**	4.69**	54.50**	51.53**	37.11**	29.06**
Parents	13	3.52**	5.80**	11.10**	11.33**	48.67**	56.11**	46.05**	52.13**
Parents x crosses	1	2.65*	4.72*	0.03	0.11	0.09	11.27	8.44	25.99**
Crosses	48	2.22**	4.38**	1.52**	2.99**	57.21**	51.13**	35.28**	22.88**
Parent 1	6	3.89	10.55**	4.29**	20.57**	123.99*	94.02	96.88**	72.82**
Parent 2	6	3.05	5.64	2.25*	1.32**	99.09*	69.88	101.63**	49.60**
P1 x P2	36	1.80**	3.19	0.93	0.34	39.09**	40.86**	13.96**	10.09**
Error	124	0.67	0.97	0.88	0.86	15.98	10.05	5.70	1.80

*,** significant at 5% and 1% probability level, respectively, N. Normal Irrigation condition, WS. Water stress condition, NTP. No.of tillers/plant, SL. spike length, TGW. Thousand grain wt, GY. Grain yield

Table 3: Mean values of lines and testers under normal and water stress conditions

Lines & Tester	N	WS	N	WS	N	WS	N	WS
Genotypes	NTP	NTP	SL	SL	TGW	TGW	GY	GY
Nesser	11.67	10.17	13.17	11.67	37.78	32.07	27.10	21.85
Dharwar Dry	12.07	10.50	16.01	14.77	38.32	28.11	27.30	21.81
GA-2002	9.96	8.83	14.02	11.43	36.64	30.48	16.98	12.40
Bakhar-2002	12.06	9.01	12.50	10.33	35.49	28.21	13.24	10.01
Chakwal-86	11.40	9.17	13.03	11.07	32.50	28.67	16.83	12.30
Inqilab-91	11.50	9.43	14.10	13.17	26.71	21.57	15.97	12.06
Kohistan-97	11.77	10.07	13.33	10.50	34.09	32.01	19.03	14.47
9244	9.43	6.13	10.37	9.07	32.16	22.68	20.80	11.63
9247	10.10	7.01	10.50	9.10	35.03	22.58	19.77	12.34
9258	9.93	7.40	9.83	8.53	30.14	22.21	17.47	10.53
9267	10.07	8.50	10.50	8.67	28.43	22.33	18.67	9.97
9316	9.60	7.67	10.03	9.67	28.67	21.50	18.93	11.10
9021	9.50	8.01	10.40	9.33	30.57	20.74	16.23	10.60
9252	9.17	6.43	11.01	7.63	26.09	19.18	19.41	10.47

N. Normal Irrigation condition, WS. Water stress condition, NTP. No.of tillers/plant, SL. spike length, TGW. Thousand grain wt, GY. Grain yield

Table 4: Estimates of phenotypic variance (σ^2p), genotypic variance (σ^2g), environmental variance (σ^2e) and broad sense heritability along with standard errors (h^2BS±SE) among wheat genotypes for indicated traits under normal irrigation and water stress conditions

	N	WS	N	WS	N	WS	N	WS
Traits	σ^2P	σ^2P	σ^2g	σ^2g	σ^2e	σ^2e	h^2BS±SE	h^2BS±SE
NTP	1.277	2.204	0.609	1.238	0.668	0.966	0.477±0.11	0.561±0.12
SL	1.754	2.139	0.873	1.277	0.881	0.862	0.498±0.11	0.597±0.13
TGW	28.818	23.880	12.839	13.825	15.979	10.055	0.445±0.11	0.578±0.12
GY	16.172	9.381	10.467	7.582	5.705	1.779	0.647±0.13	0.808±0.15

N. Normal Irrigation condition, WS. Water stress condition, NTP. No.of tillers/plant, SL. spike length, TGW. Thousand grain wt, GY. Grain yield

9244 (11.63g) were recorded as highest grain yielder followed by 9316 (11.10g), whereas genotype 9267 (9.97g) produced the lowest grain yield under water stressed condition.

Estimates of Genetic Variances under Normal Irrigation and Water Stress Conditions: Knowledge of genetic mechanism controlling the inheritance of a plant trait in different environmental setups helps the plant breeder in designing and efficiently implementing his crop improvement programs. Additive genetic effect in autogamous wheat species is more important for yield and yield-related traits in the absence of unpredictable interaction effects in both environments owing to better prospects of early selection of desirable traits without having to untying knots introduced by non-additive elements. According to the differences between variances under normal irrigation and water stress condition (Table 4), the traits, number of tillers per plant, spike length, 1000-grain weight and grain yield revealed higher values genetic effects and non-additive type of gene action, while under water stress condition characters like number of tillers per plant, 1000-grain weight and grain yield showed non-additive type of gene action while spike length trait showed additive type of gene action. Similar results have been revealed by Hussain *et al*. [25].

The gene action was altered with the change in irrigation condition (water stress) for trait spike length. These results are in agreement with Chowdhry *et al*. [26], Inamullah *et al*. [27], Memon *et al*. [28]. A high level of heritability was recorded in the present study for the characters spike length, grain yield, ranging between 44 and 64% under normal irrigation condition whereas, under water stress condition the heritability ranged between 56 and 80%.

High heritability in spike length was reported by Afiah *et al*. [29], for 1000 grain weight, Zhao *et al*. [30] and for grain yield by Farshadfar *et al*. [31] and Memon *et al*. [28]. Whereas, medium heritability values for number of tillers per plant were reported by Mehta *et al*. [32], Afiah *et al*. [29], Memon *et al*. [28].

High broad-sense heritability estimates indicated a preponderance of the additive variation in the total genetic variability while medium to low heritability suggests that environmental effects accounted for a major portion of total phenotypic variation as also described by Farshadfar *et al*. [31]. Plant traits associated with water stress tolerance additionally having high ranges of heritability with additive genetic effects would be selected at an earlier stage of the breeding program to water stress problems. It is therefore suggested that potential genotypes should be studied further for the stability of characters under wider ranges of environmental stress equipped with a viable strategic wherewithal.

Irrigation and Scheduling in Wheat: It was also noted during this study that extra irrigation goes waste so farmers should emphasis on precise irrigation to save water. Irrigations should be done at right time and in adequate quantity by calculation [21]. It is also recommended that first irrigation should be given at crown root stage i.e. 20-25 days after sowing and second irrigation at tillering stage which will come on 40-45 days after sowing. Third and fourth irrigation can be combined if shortage otherwise give at node formation stage i.e. 60-65 days after sowing and flowering stage i.e. 80-85 days after sowing. If there is sufficient water than ok otherwise combine fifth and sixth irrigation at milk formation stage i.e. 100-105 days after sowing and grain filling stage i.e. 115-120 days after sowing. It is further added that irrigation interval should be decided according to soil condition and water availability. Similar results have been earlier reported by Chowdhry *et al*. [33] Vojdani, [34] and Noorka *et al*. [12].

During Restricted Irrigation Possessions:

- If we have only three irrigations availability than best approach to ensure good crop stand will be the irrigation at critical growth stages crown root stage, spike surfacing and milky grain configuration stage.
- If we have only two irrigations than the best critical stages should be covered that are the crown root stage and flowering stage.
- In worst condition, if we have one and only irrigation water than we should use it to irrigate the most critical condition of crown root stage.

The best water harvesting should be ensures by properly leveled, equal size beds and uniform distribution of irrigation water.

Prime Conclusion: In many parts of the world, water scarcity is increasing and many people are now trying to reduce amount of water for agriculture use without losing crop productivity just to make more water available for urban, commercial and for the environment. This drives the demand to scientists to produce such type of water conservation techniques, screening methodologies, irrigation scheduling, genetic modification and farmer friendly technologies to produce enough food for coming generations with the same or even less amount of water available to present agriculture without compromising food security under the changing set of climatic conditions. Food security is closely linked with law and orders situation which not only shake a country but region even globe.

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