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IMPROVEMENT OF BREAD WHEAT FOR LOW WATER REQUIREMENTS THROUGH CONVENTIONAL AND MUTATION BREEDING

BY

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ABSTRACT

Twenty one wheat genotypes evolved through hybridization and mutation breeding techniques at Nuclear Institute of Agriculture, Tando Jam, Pakistan were evaluated under water stress conditions along with four check varieties. Four experiments were conducted in a randomized complete block design (RCBD) with 3 replications using four different irrigation levels. Water stress imposed by withholding irrigation at various critical growth stages of wheat crop, i.e., at tillering, pre-anthesis and post-anthesis etc. Effects of water stress on phenological (days for heading, days for maturity, grain filling period), morphological (plant height, 1000-grain weight, grain yield) and meteorological data on daily minimum and maximum temperatures prevailed during crop season were studied. Significant effects of water stress were observed on various yield and yield components. Newly evolved genotypes showed higher tolerance to water stress and had potentials to produce more grain yield than check varieties. At single irrigation, grain yields ranged between 1805 to 3730 kg/ha. Four genotypes MSH-22, BWS-77, 8/7 and 28/4 produced significantly (P<0.01) higher grain yield than drought-tolerant check variety Margalla-99; 6 than Sarsabz; 20 than Chakwal-86 and all were high yielding than Thori (awnless variety). Similarly, comparatively greater yields were obtained with the application of two irrigations, i.e., at tillering and preanthesis stage. Most of the test entries showed more impressive performance as compared to the drought tolerant check varieties. Grain yield ranged from 1744 to 4025 kg/ha. The 1000- grain weight ranged from 35.2 g to 48.6 g at two irrigations. The high yielding genotypes 8/7 showed less reduction in the 1000-grain weight (48.6 g) and ranked first among all the entries. This genotype has also shown more grain weight at the single irrigation experiment as well; hence possessing more drought tolerance than all other entries.

INTRODUCTION

Wheat is one of the most important food crops of Pakistan. It is the staple food of nearly 35 % of the world population and demand for wheat will grow faster than for any other major crop. Asia produces more than the half of the total world production of wheat. The major sharer of which are South Asia (96.7 mt) and China (89 mt), (Anonymous, 2003). It is because it suits well in the cropping pattern of Asia. The forecasted global demand for wheat in the year

2020 varies between 840 and 1050 million tons (Kronstad, 1998). To reach this target, global production will need to increase 1.6 to 2.6 % annually from the present production level of 560 million tons (Rajaram, 2000). Water supply is often the most critical factor limiting crop growth and yield in rain fed areas and the most expensive input of irrigated crops. The groundwater table is also persistently declining due to excessive use of irrigation water through pumping groundwater by the farmers, which unnecessarily maximizes crop transpiration and soil evaporation and increases the proportion of nonbeneficial soil water consumption (Zhang *et al.*, 2002; 2004). Therefore, crop production usually requires maximizing yields on limited available water resources (Abbate *et al.*, 1997; 2004). Achieving genetic increases in yields under rain fed conditions has always been a difficult challenge for plant breeders. A major challenge for breeders in dry land agriculture is to devise the most effective strategy for maximizing genetic gain. Passioura (1977) proposed that when water is limiting then grain yield is a function of (i) the amount of water used by the crop, (ii) how efficiently the crop uses this water for biomass growth, i.e., the water-use efficiency above-ground biomass/water use, (iii) the harvest index, i.e., the proportion of grain yield to above-ground biomass. Since these three components are likely to be largely independent of each other, then an improvement in any one of them should result in an increase in yield.

Water deficit affects every aspect of plant growth and the yield modifying the anatomy, morphology, physiology, biochemistry and finally the productivity of the crop (Turner and Begg, 1981; Akram *et al.*, 2004). Global changes pose significant challenges to agriculture, but also provide opportunities to boost crop yields in water-limited environments. Yield of water-limited crops is determined by water capture, water-use efficiency and harvest index "HI" (Polley, 2002). The basic constraints in the development of agriculture in our country are inadequate and unreliable irrigation supplies, widespread occurrence of water-logging and salinity and low level of modern farm inputs. Inadequate and unreliable water supplies results in low cropping intensities and are responsible for low yield. It is estimated that to feed the increasing population, 40% more food would be required by the year 2025 (Anpnymous 2003). This stresses the need to increase the productivity of available limited water resources. Irrigated agriculture uses about 97% of available water and provides aver 90% of agricultural produce. The country experienced severe drought during the years 2000-01 and 2001-02, which drastically affected the production of various agricultural crops. In the subsequent three years (2002-03 to 2004-05), there was relatively more availability of irrigation water, which reflected positive impact on overall production of various agricultural crops. Drought stress from anthesis to maturity, especially if accompanied by high temperatures, hastens leaf senescence and reduces mean kernel weight (Royo *et al.*, 2000). The reduction in production of wheat at global level (Anonymous, 2003) stresses the need to develop genotypes with consistent performance over a wider range of environments. Various polygenic attributes have been proposed which can be introduced to withstand the situation. Combination of traits in a plant, which minimize the deleterious effects and maximize the advantageous effects results in the real success of a plant. It has been argued that one of the reasons for low (HI) in dry environments is that leaf area is excessive, resulting in too much water being used early by the crop (Richards, 1983; Richards and Townley-Smith 1987). There are several ways that the pattern of leaf area development in wheat may be altered by genetic selection for different plants types that may result in an improved HI and higher rain-fed wheat yields.

Grain yield in wheat is dependent on assimilates produced by current photosynthesis in the post-anthesis period, post-anthesis carbohydrates stored temporarily in vegetative organs before being re-translocated to the grain, and assimilates translocated from stored carbohydrates in the vegetative plant parts produced during the pre-anthesis period (Regan *et al.,* 1993). The contribution of pre-anthesis assimilates to final yield can be up to 30% (Bidinger *et al.,* 1977). The ability to effectively translocate assimilates from stems and leaves to the developing grain are desirable for maximizing grain yield production in water-limited environments (Turner and Begg, 1981). Midseason drought, experienced under rainfed conditions, reduced mainly the number of spikes per square meter and kernels per spike, traits that develop during the period most sensitive to drought stress, i.e., from double ridge to anthesis (Shpiler and Blum, 1991). Also, Giunta *et al.* (1993) reported that severe water deficit around anthesis produces serious effects on wheat yield, reducing the number of spikes and spikelets and therefore, causing a decrease in plant fertility. In this regard screening for more drought tolerant wheat varieties, which are able to produce an acceptable yield under one or two irrigations after rainfall ceases in spring, has become a new strategy in cereal breeding research programs (Najfian, 2003; Najfian *et al.,* 2004). The breeding efforts were therefore, undertaken to evolve wheat genotypes, which possess tolerance to water stress and can be able to produce higher yields with one or two irrigations. Mutation breeding has also significant impact along with conventional breeding approaches in cereals (Mauszynski, 2000). Genetic variability has been created in wheat through hybridizations and mutation breeding. The aim of the present research work was to evaluate the performance of newly developed wheat genotypes under water stress conditions with comparison to local drought tolerant commercial wheat varieties. Yield, being a polygenic character is controlled by various yield associated traits and the environment. Some yield associated traits were studied in this study. On the basis of these results, the breeders can be able to select high yielding genotypes with desired traits and better tolerance to produce more yields under water stress conditions. It is observed from the present findings that the genotypes developed through hybridization and radiation-induced mutations have potential to produce higher yields under low water conditions as compared to commercial check varieties. The selected genotypes will be further evaluated.

MATERIALS AND METHODS

To evaluate the performance of newly evolved wheat genotypes, twenty-one drought-tolerant mutants/advanced lines evolved through indirect use of muatagenesis and hybridizations were screened along with four local check wheat varieties, i.e., Sarsabz, Thorhi (awnless variety), Margala-99 and Chakwal-86 under water stress conditions. The experiments were sown in normal planting time (13th November) at the experimental farm of Nuclear Institute of Agriculture (NIA), Tando Jam. Trials were conducted in a randomized complete block design (RCBD) with 3 replicates. Each experiment was surrounded with 2.5 m buffer zone, where the non-experimental material was planted. Each genotype was sown with 4 rows, 3 m long in 3.6 m^2 plots. Genotypes were evaluated in four different experiments, subjected to various irrigation levels viz., single irrigation, two, three and four irrigations to various experiments during entire cropping season. The irrigation to different experiments withholds during various critical growth stages such as heading, pre-anthesis and post anthesis stages etc. The first experiment was subjected to only single irrigation applied during tillering (05th December) after 23 days of sowing. No further irrigation was applied to this experiment till maturity. The second experiment was subjected to two irrigations; one after 23 days of sowing at tillering stage (05th December) and the other applied during pre-anthesis stage (13th February) after 67 days interval of first irrigation. No other irrigations was applied to this experiment at any growth stage. The third experiment was treated with 3 irrigations viz., first at tillering (5th December), second at pre-anthesis (heading stage, 19th January), 43 days after the first irrigation, and the third was applied during post-anthesis (20th February), on 5th December, 31 days after the second irrigation. In the fourth and well-irrigated experiment, four irrigations were applied viz., first at tillering (after 23 days after sowing), second, on 2nd January 28 days after the first (during pre-anthesis; at booting to heading stage); third on 13 February, 41 days after the second irrigation and irrigation applied during post-anthesis (milky-dough stage) and fourth on 6th March 23 days after the third irrigation, during post-anthesis (dough stage). The observations were recorded on grain yield and its associated yield components i.e., plant height (cm), spike length (cm), spikelets/spike, number of grains/spike, number of grains/spikelet, main spike yield (g), 1000-grain weight (g), single grain weight (g) and grain yield/plot. Phenological data on, days to heading, days to maturity and grain filling period of each genotype at each treatment were also recorded. Meteorological data (daily minimum and maximum temperatures and humidity) during cropping season was noted. The data was statistically analysed by analysis of various method and the means were compared by Duncan's Multiple Range Test (D'MRT).

RESULTS AND DISCUSSION

Grain Yield

Grain yield of wheat genotypes was affected under water stress; it ranged between 1805 kg/ha to 3730 kg/ha with single irrigation. Four genotypes MSH-22, BWS-77, 8/7 and 28/4 produced significantly ($P<0.01$) higher grain yield (3730, 3519, 3288, 3188 kg/ha) than the check variety Margala-99 (3130 kg/ha); 16 genotypes had more yield than Sarsabz; 20 than Chakwal-86 and all were high yielding than Thori (awnless). Mutant line BWM-84, BWS-78 including check variety Thori and Chakwal-86 produced significantly the lowest yield; could be more sensitive to water stress (Table 1). It is estimated that grain yield in wheat can be reduced by up to 43-50% under drought conditions (Garcia del Moral *et al.*, 2003). With two irrigations, most of the test entries showed better performance as compared to check varieties. Grain yield (kg/ha) ranged from 1744 kg/ha in Thori to 4025 kg/ha in 9/5 genotypes. Other high yielding genotypes were 10/8 (3827 kg/ha), 28/4 (3847 kg/ha), 25/1 (3713 kg/ha), ESW-9525 (3636 kg/ha) followed by 8/7. Among the local check varieties, Sarsabz produced more grain yield (2802 kg/ha) at low water availability (two irrigations). Fourteen advanced genotypes had significantly higher grain yield than Sarsabz, indicated more tolerance to water stress environments (Table 2).

Genotype 30/5 produced significantly the highest grain yield (4425 kg/ha) followed by ESW-9525 (4290 kg/ha) and MSH-22 (4111 kg/ha) with three irrigations. Other high yielding genotypes were SI-9590, 8/7, BWQ-4 and BWS-78, produced 4050, 3875, 3886 and 3872 kg/ha grain yield respectively. The low grain yield was recorded in BWM-3, MSH-36, BWM-84, Thori and Chakwal-86. Grain yield of the three irrigation experiment ranged from 2672-4425 kg/ha in genotypes. However, most of the genotypes performed better than local checks at three irrigations (Table 3). In the fourth experiment, four irrigations were applied to this experiment during various growth stages of crop. Genotype ESW-9525 produced significantly higher grain yield (4600 kg/ha) followed by 30/5 (4313 kg/ha) and MSH-22 (4052 kg/ha). These genotypes may be recommended for favorable environments where adequate irrigation is available. Other high yielding genotypes were BWQ-4, MSH-17, MSH-36, SI-91195, 25/5, 9/5, BWS-78 and local checks Sarsabz and Margalla-99. The lowest grain yield was obtained by the local check Thori (1105 kg/ha) with 4 irrigations (Table 4).

1000-grain weight

The one thousand grain weight, an important yield-contributing trait, was significantly affected in wheat genotypes under water stress conditions. However, most of the newly developed mutant and advance lines had higher 1000-grain weight as compared to all local checks varieties; hence possesses more tolerance to water stress under stress. Genotypes 37/6 had the highest (43.0 g) 1000-grain weight, followed by 8/7 (42.7 g), 30/5 (42.2 g), BWS-77 (41.5 g), BWM-84 (41.5 g), 9/5 (41.3 g) and BWM-3 (40.9 g) at severe water stress (single irrigation). Kernel weight in these genotypes was not affected by water stress, indicating high stability for this trait under stress conditions, possibly due to the high proportion of translocated preanthesis reserves for grain filling when photosynthetic source is limited by stress (Bidinger *et al.,* 1977; Blum *et al.,* 1994). Four genotypes viz., Chakwal-87, ESW-9525, MSH-17 MSH-37 and Thori were found more sensitive for the trait 1000-grain weight under water stress. Taking mean comparison for 1000-grain weight of local check varieties, Sarsabz had higher 1000-garin weight (40.0 g) indicated less responsive to drought than other check varieties. Similarly, the newly developed drought tolerant variety Khriman (SI-91195) more tolerant to drought as compared to local check varieties. With single irrigation, the 1000-grain weight of genotypes ranged from 35g to 43.0 g. Seven genotypes had more 1000-grain weight (>40.0 g) than Sarsabz, 14 than Margala-99 (>38.9 g), 17 than Thori (>36.9 g) and all than Chakwal-86 (>33.6 g) (Table 1).

Table (1): Overall mean performance of different yield components of wheat genotypes as affected by water stress (Single irrigation).

Genotypes	Days to heading	Days to maturity	Grain filling period	Plant height (cm)	1000-grain weight (g)	Grain yield (kg/ha)
BWM-3	58.0 jk	121.0 efgh	63.0 ab	94.0 bcdef	40.9 cde	3071 abcd
7/8	65.5 hi	120.0efghij	54.5 def	98.0 abcde	42.7 ab	3288 abc
5/9	77.5 bcd	126.0 abcd	48.5fghijkl	93.5 bcdef	41.3 bcd	3111 abcd
37/6	75.5 cde	124.0 bcde	48.5fghijkl	100.5 abcd	43.0 a	2757 abcd
8/10	79.5 bc	124.0 bcde	44.5 kl	98.5 abcde	39.1 fg	2855 abcd
25/1	80.0 b	128.0 ab	48.0 ghijkl	93.5 bcdef	39.7 ef	2995 abcd
28/4	67.0 gh	119.0 fghij	52.0 efghi	80.5 ghi	38.9 fg	3188 abcd
30/5	79.0 bcd	123.0 cdef	44.0 kl	103.0 abc	42.2 abc	2909 abcd
25/5	79.5 bc	125.5 abcd	46.0 ijkl	90.5 bcdef	39.0 fg	3043 abcd
ESW-9525	73.0 ef	124.0 bcde	51.0 efghij	85.5 fgh	35.0 jk	2932 abcd
SI-91195	65.0 hi	122.0 defg	57.0 cde	92.0 cdefg	40.1 def	2853 abcd
SI-9590	76.5 bcd	124.0 bcde	47.5hijkl	94.5 bcdef	36.4 hij	3020 abcd
MSH-14	76.0 bcd	119.0 fghi	42.5 l	92.5 cdef	39.6 efg	2301 abcd
MSH-17	75.0 de	121.0 efghi	45.5 jkl	88.5 efgh	35.2 j	2868 abcd
MSH-36	57.5 jk	118.0 ghij	60.5 abcd	72.0 i	35.4 ij	2335 abcd
MSH-22	70.0 fg	123.0 cdef	54.0 defg	91.0 degh	37.9 gh	3730a
BWQ-4	73.0 ef	122.0 defg	49.0 fghijk	97.5 abcde	40.4 def	2786 abcd
BWS-77	63.5 hi	117.0 hij	53.5 defgh	105.0 ab	39.2 fg	3519 ab
BWM-84	56.5 k	118.0 ghij	61.5 abc	100.0 abcd	41.5 abc	1817 cd
BWS-78	61.5 ij	119.5 ghij	57.0 cde	84.0 fgh	41.5 abc	2115 bcd
BWM-47	51.0 l	116.0 j	65.0 a	92.5 cdef	38.8 fg	2428 abcd
Sarsabz	57.5 jk	117.5 ij	59.0 bcd	84.5 fgh	40.0 def	2868 abcd
Thori	84.5 a	127.0 abc	42.5 l	107.0 a	36.9 hi	1805 cd
Margala-99	58.5 jk	119.0 fghij	60.5 abc	80.0 hi	38.9 fg	3129 abcd
Chakwal-86	85.0 a	129.5 a	44.5 kl	92.5 cdef	33.6 k	2028 cd

With two irrigations, one thousand grain weight ranged from 35.2 g to 48.6 g. The high yielding genotypes 8/7 showed less reduction in 1000-grain weight (48.6 g) and ranked first among all the entries. The same genotype has also shown more grain weight with the single irrigation experiment; hence possesses more drought tolerance than all other entries. Other genotypes viz., BWM-3, BWM-47, 37/6, BWQ-4 and BWS-78 had more 1000-grain weight which ranged from 43 to 45.8 g, might possess more tolerance to water stress conditions. Two test entries ESW-9525 and SI-9590 including check variety Chakwal-86 were found more sensitive to water stress conditions, as their 1000-grain weight was highly reduced (35.2-38.9 g) as compared with the rest of entries (Table 2).

There were variations in the thousand-grain weight of wheat grains observed under three irrigation treatments. Minimum 1000-grain weight (37.5 g) was observed in SI-9590 followed by ESW-9525 (38.6 g), Chakwal-86 (38.7 g) and awnless local variety Thori (39.7 g); this might be more sensitive to water stress which prevailed during the various crop growth stages. Maximum 1000-grain weight (49.1 g) was recorded in high yielding genotype 8/7. The same genotype also produced maximum 1000-grain weight with the single and two-irrigation experiments. The consistency in more 1000-grain weight in genotypes 8/7 suggests its stability and tolerance to water stress environments. However, it was observed that the majority of the test entries have potentials to produce more 1000-grain weight (>40 g), hence, possessing more tolerance to water shortage. Nine lines (BWM-3, 10/8, 30/5, SI-91195, MSH-14, BWQ-4, BWM-84, BWS-78 and BWM-47) had higher 1000-grain weight (more than 44.0g) after 8/7 (Table 3).

Table (2): Overall mean performance of different yield components of wheat genotypes as affected by water stress (two irrigations).

Genotypes	**Days to heading**	**Days to maturity**	**Grain filling period**	**Plant height (cm)**	**1000-grain weight (g)**	**Grain yield (kg/ha)**
BWM-3	63.5 kl	125.0 def	61.5 abc	92.5 bcd	45.8 b	2625 cde
7/8	64.5 jk	122.0 efgh	57.5 bcde	94.0 abcd	48.6 a	3378 abcde
5/9	74.0 efg	124.5 def	50.5 efgh	90.5 cde	40.7 hi	4025 a
37/6	74.0 efgh	127.0 bcd	53.0 defg	95.0 abc	44.5 bc	3072 abcde
8/10	77.5 bcde	124.5 def	47.0 ghi	100.5 abc	39.6 ij	3828 ab
25/1	80.5 abcd	131.5 a	51.0 efgh	93.0 abcd	42.0 efgh	3714 abc
28/4	68.0 ghij	120.0 gh	52.0 efgh	87.0 de	42.4 defg	3846 ab
30/5	74.5 def	126.0 cde	51.5 efgh	100.5 abc	42.6 def	2959 abcde
25/5	81.0 abc	125.0 def	44.0 hi	91.0 bcde	42.0 efgh	3964 a
ESW-9525	76.0 cdef	124.5 def	48.5 fghi	89.0 cde	38.7 j	3636 abc
SI-91195	65.5 ijk	126.0 cde	60.5 abcd	86.5 de	41.6 efgh	3009 abcde
SI-9590	83.0 ab	125.0 def	42.0 i	87.5 de	38.9 j	3528 abcde
MSH-14	71.0 fghi	122.5 efgh	51.5 efgh	87.5 de	41.7 efgh	2982 abcde
MSH-17	73.0 efgh	126.0 cde	53.0 defg	82.5 def	39.1 j	3552 abcd
MSH-36	56.5 mn	122.0 efgh	65.5 a	71.5 f	41.0 gh	2448 bcdef
MSH-22	67.5 hijk	124.0defg	56.5 cdef	87.5 de	42.7 def	3228 abcde
BWQ-4	70.5 fghij	126.0 cde	55.5 cdef	88.5 cde	43.7 cd	2845 bcde
BWS-77	62.5 klm	124.5 def	62.0 abc	103.5 ab	41.3 fgh	2664 cde
BWM-84	56.5 mn	121.0 fgh	64.5 ab	90.5 cde	42.9 de	2277 fgh
BWS-78	62.0 klm	122.5 efgh	60.5 abcd	89.5 cde	43.7 cd	2803 bcde
BWM-47	52.0 n	118.5 h	66.5 a	85.0 de	44.5 bc	2440 efgh
Sarsabz	58.0 lmn	123.5 defg	65.5 a	84.5 de	40.8 hi	2802 bcde
Thori	84.5 a	129.5 abc	45.0 ghi	105.0 a	39.0 j	1745 h
Margala-99	55.0 n	122.5 efgh	67.5 a	79.0 ef	41.6 efgh	2473 def
Chakwal-86	86.5 a	130.5 ab	44.0 hi	86.5 de	35.2 k	2034 gh

Seven advanced lines produced more 1000-grain weight than Sarsabz, nine than Margalla-99 and all were high yieldes than Thori and Chakwal-87 with the four-irrigation experiment. The 1000-grain weight of all the genotypes was increased in this well-watered experiment as compared to the other experiments (the water-stressed experiments). The trait ranged between 39.0 g in ESW-9525 to 50.6 g in 8/7 genotype. No significant effect on the 1000-grain weight was observed in any genotype when four irrigations were supplied and all the genotypes had 1000-grain weight more than 40.0 g (Table 4).

Table (3): Overall mean performance of different yield components of wheat genotypes as affected by water stress (three irrigations).

Genotypes	Days to heading	Days to maturity	Grain filling period	Plant height (cm)	1000-grain weight (g)	Grain yield (kg/ha)
BWM-3	62.5fghi	122.5efgh	60.5 bcd	97.5 defg	44.9 def	2672 hij
7/8	65.5 fg	124.5efgh	59.0 bcde	101.5cdef	49.1a	3875 abcde
5/9	75.5 de	124.0efgh	48.5jklm	100.0cdef	43.1 hij	3606 abcde
37/6	77.5 cd	127.0abcde	49.5 ijkl	106.5 bc	40.3 k	3553 abcde
8/10	86.0 a	126.0cdef	39.5 o	103.5 cd	44.2 fgh	3779 abcde
25/1	80.5 bc	131.5 a	51.0 hijk	96.5 defg	43.3ghij	3538 abcde
28/4	67.0 f	124.5efgh	57.5 cdef	93.0 ghi	40.9 k	3642 abcde
30/5	77.5 ccd	129.5abcd	52.0 ghij	112.0 ab	44.3 fgh	4425 a
25/5	83.0 ab	130.0 abc	47.5 klmn	97.0 defg	42.3 j	3208 cdef
ESW-9525	76.0 b	126.5bcde	50.1 ijkl	96.0 efgh	38.6 lm	4290 ab
SI-91195	66.0 f	125.5cdef	59.5 bcde	100.0cdef	47.3 bc	3486 bcde
SI-9590	83.5 ab	127.0abcd	43.5 mno	93.5 ghij	37.5 n	4050 abcd
MSH-14	78.0 cd	126.0cdef	48.0 jkl	99.5 cdef	45.0 def	3792 abcde
MSH-17	71.5 e	125.0defg	53.5 efgh	90.5 hijk	41.0 k	3285 abcde
MSH-36	61.5 ghi	124.5efgh	63.0 bc	84.5 k	42.7 ij	2806 fghi
MSH-22	67.0 f	122.0fghi	55.0 defg	90.0 ijk	43.0 hij	4110 abcd
BWQ-4	74.0 de	127.0abcd	53.0 fghi	97.0 defg	44.7 efg	3886 abcde
BWS-77	66.0 f	124.0efgh	58.0 cdef	116.0 a	43.8fghi	3164 defg
BWM-84	58.5 i	119.5 i	61.0 bcd	105.0 c	48.4 ab	2731 ghij
BWS-78	64.0 fgh	121.0 ghi	57.0 cdef	95.5 fghi	45.8 de	3872 abcde
BWM-47	54.0 j	123.0efgh	69.0 a	101.0cdef	46.3 cd	3002 efgh
Sarsabz	60.5 hi	125.5cdef	65.0 ab	95.5 fghi	43.3ghij	3185 defg
Thori	85.0 a	126.5bcde	41.5 no	112.0 ab	39.7 k	2627 ij
Margala-99	61.5 ghi	120.5 hi	59.0 bcd	87.0 jk	43.3ghij	3377 bcdef
Chakwal-86	85.5 a	131.0 ab	47.0 lmn	103.0 cde	38.7 lm	2125 j

Days to heading (D.H)

The commercial check varieties Thori and Chakwal-86 took more days (84-85 days) to heading than other genotypes with the single irrigation (Table 1). Similarly, both local check varieties and the three advance lines 25/1, 25/5 and SI-9590 took more days to ear emergence than all other entries with two irrigations (Table 2). With three irrigations, days to ear emergence in genotypes ranged from 54 to 86 days. Six genotypes 10/8, 25/1, 25/5, SI-9590, Thori and Chakwal-86 required more days (>80 days) to ear emergence (Table 3). Days to heading with four irrigations ranged from 54-87. Four advance lines (0/8, 25/1, SI-9590, MSH-17) including two local checks Thori and Chakwal-86 took more days to heading (80.5-87) (Table 4).

Days to maturity (D.M)

A wide variation was observed regarding the maturity period among the genotypes. Days to maturity ranged from 118-131 days. Seven lines (8/7, 28/4, MSH-14, MSH-36, BWM-84, BWS-78 and BWM-47) including check Margala-99 matured earlier than other genotypes; took less than 122 days to mature (Table 2). Three genotypes 25/1, Chakwal-86 and Thori took more days to maturity at two irrigation treatment. Days to maturity of genotypes ranged from 119-131 days. BWM-84, Margala-99, BWS-78, MSH-22 and BWM-3 matured earlier within 119-122 days. It was noted that the tall genotypes 25/1, 25/5 and Chakwal-86 took more days to mature (Table 3). Days to maturity of genotypes ranged from 120-132. Eight lines showed early maturity than Sarsabz, 6 than Margalla-99, 14 than Thori and all matured earlier than Chakwal-86 (Table 4).

Table (4): Overall mean performance of different yield components of wheat genotypes at four irrigations.

Genotypes	Days to heading	Days to maturity	Grain filling period	Plant height (cm)	1000-grain weight (g)	Grain yield (kg/ha)
BWM-3	61.0 hi	122.5 ef	61.5 bc	98.5 abcdef	45.7 def	3446 abcde
7/8	70.0 ef	126.0 bcd	56.0 cde	98.0 abcdef	50.6 a	2738 de
5/9	78.5 d	125.0 cdef	46.5 ghi	95.0 cdefg	45.9 de	3774 abcd
37/6	80.5 cd	129.5 abc	49.0 fgh	102.0 abcde	43.2 ghij	3017 cde
8/10	85.0 ab	129.0 abc	44.0 hi	103.5 abc	48.2 bc	2645 de
25/1	84.5 abc	131.0 ab	46.5 ghi	96.0 bcdefg	43.9 ghi	3128 cde
28/4	70. ef5	129.5 abc	60.0 bcd	89.0 gh	41.8 j	3165 bcde
30/5	78.5 d	131.0 ab	52.5 efg	104.5 ab	47.0 cd	4313 ab
25/5	76.5 bcd	129.0 abc	46.5 ghi	98.5 abcdef	42.5 ij	3728 abcd
ESW-9525	78. d5	131.0 ab	52.5 efg	92.0 fgh	39.0 k	4600 a
SI-91195	64.5 ef	128.5 abc	59.5 bcd	94.5 defg	46.2 d	3629 abcd
SI-9590	85.5 ab	1265 bcde	41.0 i	91.0 fgh	40.1 k	3046 cde
MSH-14	78.5 d	125.5 cdef	47.0 ghi	101.0 abcde	42.9 hij	3411 bcde
MSH-17	83.5 abc	126.0 bcd	42.5 hi	94.5 defg	42.0 j	3777 abcd
MSH-36	59. i3	122.5 ef	63.5 ab	76.5 I	44.2 g	3750 abcd
MSH-22	72.5 e	126.0 bcd	54.0 def	96.5 bcdefg	42.9 hij	4051 abc
BWQ-4	73.5 e	120.5 f	47.5 fghi	97.0 fgh	45.9 d	3915 abc
BWS-77	66.5 fg	125.5 cdef	59.0 bcde	104.5 a	44.6 efg	3479 abcde
BWM-84	58.5 I	123.0 ef	64.5 ab	101.0 abcde	48.7 b	3533 abcde
BWS-78	65.5 gh	122.0 ef	57.5 bcde	94.0 defgh	46.8 c	3625 abcd
BWM-47	54.5 j	123.0 ef	68.5 a	103.5 abc	46.4 d	3100 cde
Sarsabz	62.5 ghi	126. bcde	63.5 ab	93.5 efgh	44.3 fgh	3643 abcd
Thori	85 0 ab	129.0 abc	44.0 hi	102.5 abcd	43.0 hij	1106 f
Margala-99	64.0 gh	124.0 def	60.0 bcd	85.5 h	43.8 ghi	3624 abcd
Chakwal-86	87.0 a	132.0 a	45.0 hi	88.5 gh	42.0 j	2429 e

Grain filling period (G.F.P)

With a single irrigation, grain filling period ranged from 42 to 65 days. Mutant lines BWM-47 and BWM-3 took significantly more days to grain filling (65 and 63 days) followed by BWM-84 (61 days), MSH-36 (59 days) and Margala-99 (Table 1). Grain filling period had a significant positive direct effect kernel weight, especially under irrigated conditions. This probably resulted from increased photosynthesis when grain filling occurs under the mild stress experienced in the irrigated experiments at both temperature regimes (Blum, 1983). Various studies showed that water deficit around anthesis may lead to a loss in yield by reducing spike and spikelet number and the fertility of surviving spikelets (Guinta *et al.*, 1993). In addition, drought stress from anthesis to maturity, especially if accompanied by high temperatures, hastens leaf senescence, reduces the duration and rate of grain filling, and hence reduces mean kernel weight (Royo *et al.*, 2000). Grain filling period of wheat genotypes ranged from 42-67.5 days at two irrigation treatment (Table 2). The check variety Margala-99 took a long time (67.5 days) for grain development followed by BWM-47, BWM-84, BWS-77, MSH-36 and BWM-3 (which took more than 60 days to GFP). It was observed in the present study that most of the lines which gave high grain yield with higher tolerance to drought, used more than 50 days to grain fill period (Table 2). With three irrigations, days to grain filling period ranged from 39 days in 8/10 to 69 days in BWM-47 (Table 3). Eighteen lines took significantly (P> 0.01) more days to grain filling period than the check varieties Thori and Chakwal-86. Four lines took more days than Margala-99 (Table 3). Similar results were obtained for GFP under four irrigation experiment, the difference was not statistically between three and four irrigation treatments.

Plant height

All the high yielding advance genotypes had semi dwarf plant height. Plant height ranged from 72.0 cm (MSH-36) to 107 cm (Thori). The low grain yield produced by Thori with single irrigation could be due to more plant height (Table 1)

As a conclusion, the potential of newly evolved wheat genotypes were evaluated under water stress conditions. It is observed that the irrigation during tillering (after 22 days of sowing) is critical to get more yields from wheat. Greater yields were achieved from newly developed genotypes as compared to the check varieties with single irrigation and two irrigations. The 4 genotypes MSH-22, BWS-77, 8/7 and 28/4 produced higher grain yield than the check variety Margalla-99; 16 than Sarsabz; 20 than Chakwal-86 and all genotypes were high yielding than Thori (awnless). The higher yields obtained with single irrigation could be due to the application of irrigation at most crucial vegetative growth stage, i.e., at tillering. Similarly, comparatively better yields were obtained with the application of two irrigations, i.e., at tillering and preanthesis stages. Most of the test entries showed more effecient performance as compared to drought tolerant check varieties. Grain yield ranged from 1744 to 4025 kg/ha. High yielding genotypes were 10/8, 28/4, 25/1, ESW-9525, 8/7, SI-9590 and MSH-17. The high yielding genotype 8/7 showed less reduction in 1000-grain weight (48.6g) and ranked first among all the entries. This genotype also showed more grain weight with the single irrigation experiment as well; hence possesses more drought tolerance than all other entries. Other genotypes viz., BWM-3, BWM-47, 37/6, BWQ-4 and BWS-78 had more 1000-grain weight. The results achieved study in the present will be helpful in the selection of high yielding wheat genotypes with greater tolerance to water stress conditions.

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التحسين الوراثي لقمح الخبز لاحتياجات الماء المنخفضة من خلال التربيه التقليدية والطفرات

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تم استخدام ٢١ جينوتيب لتجارب التهجين والطفرات في المعهد النووي الزراعي- تاندو جام-باكستان لتقيمها تحت ظروف إجهاد مائي في وجود أربعة أصناف عادية أختبرت معا. وقد تم تنفيذ أربعة تجارب في نظام بلوكات عشوائيا مع ثلاثة مكررات لكل مستوي ماء مختلف. وقد كان الإجهاد المائي مصاحبا لكل مراحل النمو المختلفة. وتم تقدير تأثير الإجهاد المائي علي مستوي الفينولوجيه والمتمثله في الأيام لتكوين السنبلة والأيام للنضج وإمتلاء الحبوب وعلي المستوي المورفولوجي والمتمثل في إرتفاع النبات- وزن ١٠٠٠ حبه- محصول الحبوب وأيضا علي مستوي نتائج الظروف المناخية مثل درجات الحرارة الصغري والعظمي اليومية خلال فصل النمو. وقد لوحظ تأثير معنوي للإجهاد المائي علي إختلاف المحصول ومكونات

المحصول. وبالنسبة للجينوتيبز ال ٢١ الجديدة فقد أظهرت تحمل أعلي للإجهاد المائي وأنتجت محصول حبوب اكثر من تلك الأصناف الأربعة العادية. وعلي مستوي الري المنفرد فقد وصل محصول الحبوب الي معدل تراوح ما بين ١٨٠٥ الي ٣٧٣٠ كليوجرام/هكتار. أربعة من الجينوتيبز MSH-22, BWS-77, 8/7,28/4 أنتجت معنوية بدرجة حريه اكبر من ٠,٠١ أعلي في محصول الحبوب اعلي من الصنف مارجيلا-٩٩ المتحمل للجفاف وكذلك الصنف ١٦ اكبر من سارسابز والصنف ٢٠ أكبر من الصنف شوكال-٨٦ وكلهم أنتجوا محصول أعلي من صنف ثوري. وبالتشابه فإن محصول أحسن قد تم الحصول عليهم عند تطبيق عدد ٢ ريه. معظم الأصناف المختبرة أظهرت إنجاز أعلي عند مقارنتها بالأصناف المتحملة والمستخدمه. وقد تراوح محصول لحبوب من ١٧٤٤ الي ٤٠٢٥ كليوجرام/هكتار. وعلي مستوي وزن الـ ١٠٠٠ حبه فقد تراوح ما بين ٣٥,٢ الي ٤٨,٦ جرام للريتان. وعلي الجانب الآخر فإن الجينوتيب ٧/٨ العالي المحصول قد أظهر إنخفاض في وزن الألف حبه وقييم رقم ١ علي مستوي الأصناف الأخري. وهذا الجينوتيب قد أظهر وزن حبوب عند الرية الواحد، بدرجة جيدة وقدرة علي تحمل الجفاف مقارنة بالأصنلف الأخري.