Arab Gulf J. Scient. Res., Agric. Biol. Sci., B7 (1), pp. 15-25 (1989)

Response of Durum Wheat (*Triticum turgidum* L., var. durum) Varieties to Moisture Stress under Arid Conditions

Ghandorah, M.O.

Plant Production Department, College of Agriculture, King Saud University, P.O. Box 2460 Riyadh 11451, Saudi Arabia

ABSTRACT. Drought tolerance of twenty two durum wehat varieties were determined under field condition at the Agricultural Experiment Station of King Saud University, near Riyadh, Saudi Arabia. The varieties were grown under three water regimes. These regimes were achieved by irrigating the soil at 80, 60, and 40% of the available moisture.

Increasing the available moisture percent increased grain yield, days to heading and the grain filling rate. However, the grain filling period was not affected. The interactions between water regimes and varieties were significant for grain yield and grain filling rate in the first season only. Significant differences were detected among varieties for all the studied characters. Relative drought susceptibility coefficient was calculated with varieties No. 20 and 22 being identified as having tolerance and higher grain yield.

Availability of irrigation water is the most critical factor influences total wheat production in Saudi Arabia. With the spectacular increase in wheat acreage in the last few years, irrigation water became one of the main limiting factors for further increase in wheat acreage. Accordingly, decreasing water requirement for wheat without reducing its grain yield would have a priority in the wheat breeding program.

Moreover, increasing crop productivity under moisture stress conditions is an essential strategy in arid and semi-arid regions as in Saudi Arabia (Anonymous, 1986 and Ghandorah *et al.* 1987). It is important to improve plant water use efficiency by improving crop tolerance to drought stress conditions via breeding methods.

Several studies were initiated at the King Saud University Agricultural Experiment Station to identify drought tolerant cereal crop varieties. Ghandorah

(1985) evaluated 19 barley, two wheat and two triticale varieties under three water regimes (85, 55 and 35% of field capacity). The interaction showed that the varieties reacted similarly to changes in soil moisture. There was a linear decrease in grain yield with soil moisture stress. Therefore, it was concluded that none of the tested varieties were tolerant to moisture stress.

Ghandorah (1987) also screened 12 bread wheat and three triticale varieties under the same three water regimes. Drought susceptibility coefficients were calculated for each variety by regressing the variety grain yield on percent of available soil moisture. The interaction between varieties and water regimes was significant and only the cultivar, West Bred, was consistently non-responsive to the increase in soil moisture percent, indicating its tolerance to drought.

The objective of this investigation was to evaluate possible drought tolerance in 22 genetically diverse durum wheat varieties grown under three water regimes.

Materials ad Methods

Two field experiments were conducted at the Agricultural Experiment Station of King Saud University at Deirab near Riyadh (24° 42′ N, 46° 44′ E, Alt. 600 m) during the winter seasons of 1981-82 and 1982-83. Twenty-two durum wheat varieties were selected from the Regional Durum Wheat Yield Trial distributed by ICARDA, Aleppo, Syria (Table 1). The soil is a highly calcareous, non-saline sandy clay loam. Varieties were grown under three water regimes. Such regimes were achieved by flood irrigating the soil when it reached 80, 60 and 40% of available soil moisture. Soil moisture percent was measured by gypsum blocks installed at a depth of 15-20 cm in the soil in each plot and calibrated with a Bouyoucos moisture meter. A 5-cm depth of irrigation water was applied for each scheduled irrigation throughout the growing season. The source of water was Riyadh municipal waste water.

A split plot design was used with three replications. The water regimes were assigned to the main plots while the 22 wheat varieties were randomly allocated to the sub-plots. Each sub-plot consisted of 5 rows, 5 m long and 0.2 m apart. Plots were planted on November 21st, 1981, and November 26th, 1982, at a rate of 120 kg/ha.

All plots were fertilized at the rates of 120 kg N/ha (in form of urea) and 70 kg P_2O_5/ha. (in form of triple super phosphate). The phosphorus fertilizer was added before seeding, while the N fertilizer was divided into three equal parts and added at sowing and one and two months after sowing.

Data were collected for number of days from planting to 50% heading and

Table 1. Pedigress and origin of the 22 durum wheat genotypes tested in 1981/82 and 1982/83 seasons

Variety No.	Pedigree	Origin
1	Jori	Mexico
2	CM 18882-2Y-OY	Mexico
3	CD 10433-4M-1M-OM	Mexico
4	CD 4775-M-9Y-CM-CY-OKE	Mexico
5	L 74119-2L-OAP	Lebanon/Syria
6	SO 3329-W-229A-OAP	Egypt/Syria
7	CD 1894-1Y-OY	Mexico
8	L 7462-2L-2AP-OAP	Lebanon/Syria
9	L 7476-2AP-OAP	Egypt/Syria
10	L 74113-2L-1AP-OAP	Mexico/Syria
11	CD 15703-65-1AP-OAP	Mexico/Syria
12	Waha	Mexico/Lebanon
13	V 776	Italy
14	L 63-2AP-1AP-OAP	Lebanon/Syria
15	L 603-5L-1AP-OAP	Lebanon/Syria
16	CD 21727-2A-OAP	Mexico/Syria
17	L 126-2AP-OAP	Lebanon/Syria
18	L 598-1AP-OAP	Lebanon/Syria
19	CD 3568-8Y-1M-3Y-OM	Mexico
20	L 436-3L-1AP-OAP	Lebanon/Syria
21	9564-105-2KE-1AP-OAP	Mexico/Syria
22	CD 10535-D-1M-1Y-4M-OY	Mexico

number of days to 75% maturity. Grain yield was determined from a representative random sample of one meter, taken from the three center rows of each sub-plot. Grain filling period was calculated by substracting the number of days to heading from those to maturity. Grain filling rate was determined by dividing the grain yield (g/m) by the grain filling period.

Statistical analysis was performed for each year as suggested by Steel and Torrie (1980). Both the water regimes and varieties were considered fixed. Due to the heterogeneity of error variances for both years, a combined analysis was not calculated.

The overall means of the three water regimes were subjected to orthogonal-polynomial of second degree and the best fitted regression model was calculated according to the significance of linear and quadratic components.

A linear regression equation of grain yield means on the percent of soil moisture for the three regimes was calculated for each variety in each of the two seasons.

Results and Discussion

A summary of the analysis of variance of the two years is given in Table 2. Comparing the individual means for each year, using the t-test with unequal variance (Steel and Torrie, 1980) the 1981/1982 was higher in yield, fewer in days to heading, a longer grain filling period and a decreased grain filling rate (Table 2).

The heterogeneity of the error variance for the two years especially for grain yield, suggested the invalidity of the combined analysis for varieties and water regimes over the two years. Therefore, the results from each year will be discussed separately.

Table 2. Significance levels from the analysis of variance for different characters and their means for the two seasons

Source of variation	Grain yield g/m		Days to heading		Grain filling period		Filling rate g/m /day	
	81/82	82/83	81/82	82/83	81/82	82/83	81/82	82/83
Water regimes (W)	**	**	*	**	ns	ns	**	**
Varieties (V)	**	**	**	**	**	*	**	**
W × V	**	ns	ns	ns	ns	ns	**	ns
Error b (MS)	8285	24444	6.94	8.74	3.22	0.58	4.31	23.58
Mean	305[a]	257[b]	90.0[b]	98.0[a]	45.9[a]	32.3[b]	6.6[b]	8.0[a]
CV%	30.1	58.6	2.9	3.0	3.9	2.4	31.4	58.6

ns, *, ** indicate no significance and significance at the .05 and .01 levels of probability, respectively.
For different characters, seasonal means followed by different letters are significant at the .05 level of probability.

Water regimes:

Means of the three water regimes were significant for grain yield, days to heading and filling rate, in both years. The water regime did not affect the grain filling period (Table 2).

The interaction between water regimes and varieties was significant for grain yield and filling rate in the 1981/82 season only. The response of the different traits to water regimes was partitioned to linear and quadratic effects and the best fitted equation was calculated (Fig. 1).

For grain yield, the response curves for the two years were dissimilar. For 1981/82 season, the relationship was quadratic, however, the difference was small between the dry (40%) and the wet (80%) regimes and it amounted only to 60 g/m (Fig. 1). This would indicate that the dry regime as not a water stress condition. Therefore, it might be concluded that the 1981/82 season was not an optimum season to screen wheat varieties for drought tolerance.

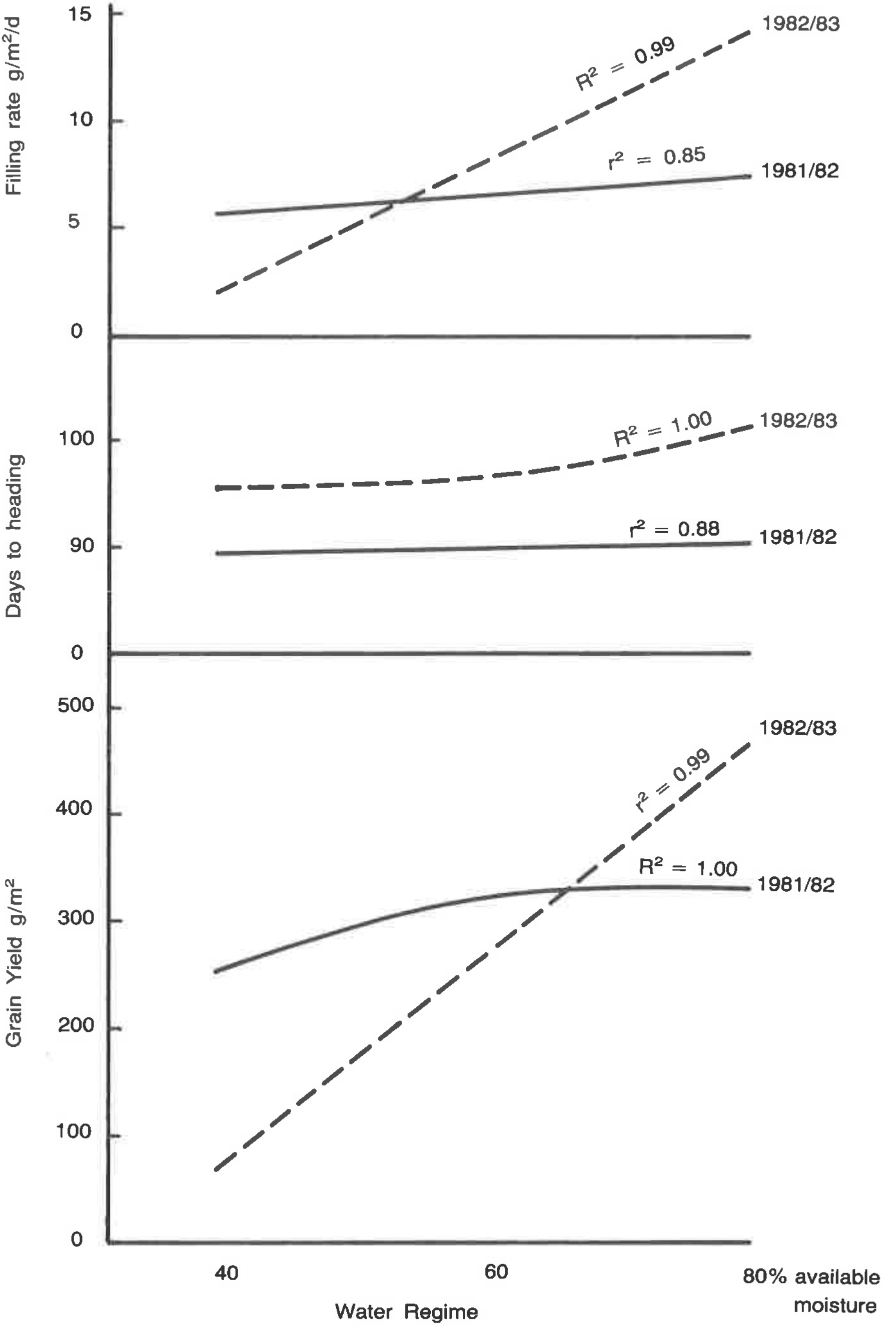

Fig. 1. Response of grain yield, days to heading and grain filling rate to soil moisture content averaged over 22 varieties

The differences between the three water regimes in 1982/83 were more pronounced and the response was linear (Fig. 1). The grain yield difference between the wet and dry regimes was 400 g/m, indicating that the dry regime was a stress environment, while the wet regime was optimum. Therefore, the 1982/83 season was a more ideal season to screen for drought tolerance.

The response of days to heading to changes in soil moisture was linear and quadratic for the 1981/82 and 1982/83 seasons, respectively. The rate of response was smaller in 1981/82 (Fig. 1).

Grain filling rate showed a linear response in both seasons, however, the slope was higher in 1982/83 than in 1981/82 (Fig. 1). It was 0.058 g/m/day for the first season, while it reached 0.288 g/m/day in the second season. These results were similar to those reported by Asana and Saini (1958, 1962), Aspinall *et al.* (1964), Innes and Blackwell (1981) and Ghandorah (1985, 1987).

A summary of the weather conditions in the two seasons is summarized in Table 3. Average monthly temperature was similar in the two seasons. The difference in relative humidity between the two seasons was high during November and December, but was reduced to only 5-6% for the rest of the season (Table 3). The total rain in 1981/1982 was 76.5 mm compared to 142.6 in 1982/83. Distribution of rain was also different in the two seasons and might had an effect on the differences between the three water regimes (Table 3). For example, in 1981/82 and 1982/83, the amount of rain during February was 16.3 and 0.5 mm, respectively. The dry spell in January and February of 1982/83 increased the stress condition for the dry regime just before anthesis. Drought during anthesis reduced the number of kernels per spike and, consequently, the grain yield (Fischer and Maurer, 1978). Also, a delay in planting date of the second season (5 days) and the longer vegetative period resulted in a 14-day delay in anthesis. This limited the grain filling period of the second season to only 32.3 days in comparison with 45.9 days for the first season. Therefore, the grain filling period for the second season was exposed to more heat stress than that for 1981/82 season. This stress was mainly reflected on the mean grain of the dry regime (40%), as shown in Fig. 1.

Varieties:

Differences among varieties were significant for all the traits studied (Table 2). Although the mean grain yield of 1981/82 was higher than that of 1982/83, however, under the optimum water regime, the reverse was true (Fig. 1). Because of heterogeneity of the error variance, variety means of grain yield was calculated for each season. The high yielding varieties, which exceeded the season mean by two standard errors were identified and are presented in Table 4. Six varieties were identified in each season with four varieties common in the two seasons. Varieties No. 19, 20, 21 and 22 were consistently the top yielding varieties for both years. This would indicate that the variety by year interaction did not seriously affecte the rank of the high yielding varieties. These varieties are recommended for further testing.

Table 3. Average monthly temperature, relative humidity and total amount of rainfall at Deirab for the two growing seasons of 1981/82 and 1982/83

Month	Temperature °C		Relative humidity %		Total rainfall mm	
	81/82	82/83	81/82	82/83	81/82	82/83
November	19.5	16.7	38.6	55.4	0.2	27.3
December	15.9	11.5	47.0	60.2	0.6	40.4
January	15.2	12.0	49.2	55.6	13.9	1.2
February	14.0	14.0	46.3	52.9	16.3	0.5
March	19.9	16.8	47.5	52.0	22.6	34.0
April	24.3	23.8	44.0	49.6	17.6	33.6
May	29.7	30.8	37.1	38.7	5.7	5.6

Table 4. Means of the different characters for the highest yielding varieties in 1981/82 and 1982/83 averaged over the three water regimes

Variety No.	Grain yield g/m	Days to heading	Grain filling period	Grain filling rate g/m /day
		– 1981/1982 –		
V 22	416	91.7	45.9	9.1
V 1	408	87.7	46.7	8.8
V 18	398	92.2	45.3	8.8
V 20	394	91.0	46.1	8.6
V 19	394	91.3	46.2	8.5
V 21	372	92.8	45.9	8.1
LSD .05	85	2.5	1.7	1.9
		– 1982/1983 –		
V 20	519	100.7	32.0	16.2
V 21	457	99.0	32.3	14.3
V 19	383	99.4	32.1	12.0
V 22	380	101.0	32.0	11.9
V 16	365	94.7	32.6	11.4
V 8	336	94.0	32.8	10.3
LSD .05	146	2.8	0.7	4.5

The main objective of the present study was to identify the drought tolerant durum varieties. Several criteria have been employed to measure drought tolerance. Fischer and Maurer (1978) suggested the use of drought susceptibility index, where the relative yield was regressed upon a relative environmental condition. This index is independent from the variety mean. Ghandorah (1987) suggested the use of the linear regression coefficient (drought susceptibility coefficient) of grain yield on the percent of available moisture instead of the stability index suggested by Eberhart and Russell (1966). This latter coefficient is more appropriate in drought studies, where the percent of soil moisture is monitored. However, this coefficient is highly correlated with the variety mean. In other words, the high yielding cultivar would have a higher drought susceptibility coefficient (b) than the low yielding cultivar. Therefore, a relative drought suceptibility coefficient (C) was calculated by dividing the drought susceptibility coefficient by the variety mean yield.

The relative drought susceptibility coefficient (C) for the different varieties in the two years is given in Table 5. As indicated before, the 1981/82 season was not an appropriate season for screening for drought tolerance, with only six varieties reflecting a significant reduction in grain yield when the available soil moisture decreased. In the 1982/83 season, 18 varieties showed significant drought susceptibility coefficients (b). The correlation between the drought susceptibility coefficient (b) and variety mean yield was highly significant ($r = 0.88$).

Therefore, the relative drought susceptibility coefficient (C) would be more appropriate for screening than its absolute value. This coefficient would indicate the percent reduction of mean yield upon decreasing the available soil moisture content by 1%. The (C) values for the 1982/83 were higher than those for 1981/82 (Table 5), indicating that the 1982/83 season was a more appropriate environment to identify the drought tolerant varieties. The mean of (C) values for the 1982/83 season was 1.97 ± 0.45. Varieties No. 3, 20 and 22 had the lowest (C) values. Therefore, these varieties would be considered as drought tolerant and their respective (C) values were 1.0, 1.2 and 1.1. Both varieties No. 20 and 22 were among the top yielding varieties, while the mean grain yield of variety No. 3 was low.

Therefore, varieties No. 20 and 22 might be recommended as drought tolerant high yielding varieties. Also, these varieties were consistent in their yielding ability over the two seasons (Table 4).

Table 5. Mean grain yield (y), drought susceptibility coefficient (b) and relative drought susceptibility coefficient (C) for the 22 varieties in 1981/82 and 1982/83 seasons

Variety	1982/1982			1982/1983		
No.	y	b	C	y	b	C
1	408	−3.2**	−0.8	210	3.5*	1.7
2	239	1.0	0.4	113	2.2	1.9
3	275	1.5	0.5	162	1.6	1.0
4	169	0.9	0.5	153	3.4*	2.2
5	257	1.8	0.7	202	3.8*	1.9
6	352	1.0	0.3	313	6.5**	2.1
7	263	−0.5	−0.2	198	4.2**	2.1
8	232	1.1	0.5	336	7.2**	2.1
9	273	0.7	0.3	292	5.8**	2.0
10	306	0.7	0.2	211	5.4**	2.6
11	234	1.0	0.4	169	3.6*	2.1
12	228	2.2**	1.0	237	6.5**	2.7
13	267	0.1	0.0	77	1.5	1.9
14	261	0.1	0.0	200	5.1**	2.6
15	305	2.8	0.9	261	6.1**	2.3
16	340	0.8	0.2	365	8.1**	2.2
17	316	2.8**	0.9	124	2.1	1.7
18	398	0.6	0.2	300	7.1**	2.4
19	394	0.9	0.2	383	7.1**	1.9
20	394	2.9**	0.7	519	6.1**	1.2
21	372	2.2**	0.6	457	7.8**	1.7
22	416	1.4**	0.3	380	4.1**	1.1

* ** indicates significance at the .05 and .01 levels of probability, respectively.

References

Anonymous. (1986) Principles of Plant Production. King Saud Univ. Presses, Riyadh, Saudi Arabia (In Arabic).

Asana, R.D., and **Saini, A.D.** (1958) Studies in physiological analysis of yield. IV. The inlfuence of soil drought on grain development, photosynthetic surface and water content of wheat, *Physiol. Planetarium II,* 666.

Asana, R.D., and **Saini, A.D.** (1962) Studies on physiological analysis of yield. V. Grain development in yield in relation to temperature, soil moisture and changes with age in the sugar content of the stem and in the photosynthetic surface. *Indian J. Plant Physiol.* **5:** 128.

Aspinall, D., Nicholls, P.B., and **May, L.H.** (1964) The effect of soil moisture stress on the growth of barley. I. Vegetative development and grain yield. *Aust. J. Agric. Res.* **15:** 729.

Eberhart, S.A., and **Russell, W.A.** (1966) Stability parameters for comparing varieties. *Crop. Sci.* **6:** 36-40.

Fischer, R.A., and **Maurer, R.** (1978) Drought resistance in spring wheat cultivars. I. Grain yield responses. *Aust. J. Agric. Res.* **29:** 897-912.

Ghandorah, M.O. (1985) Genotypic response of twenty-one cultivars of barley (*Hordeum vulgare* L.) to water stress. *J. Coll. Agric.*, King Saud Univ. **7:** 135-145.

Ghandorah, M.O. (1987) Response of wheat and triticale cultivars to water stress. *J. Coll. Agric.*, King Saud Univ. **9:** 135-145.

Ghandorah, M.O., Sayed, H.I., and **Gadallah, A.M.** (1987) Implications of genotype-environment interaction in genotype stability and testing of wheat genotypes. *J. Coll. Agric.*, King Saud Univ. **9:** 255-266.

Innes, P., and **Blackwell, R.D.** (1981) The effect of drought on the water use and yield of two spring wheat genotypes. *J. Agric. Sci. Camb.* **96:** 603-610.

Steel, R.G.D., and **Torrie, J.H.** (1980) Principles and Procedures of Statistics. 2nd ed., McGraw Hill Co., N.Y., U.S.A.

(Received 02/03/1988;
in revised form 15/11/1988)

استجابة أصناف من اقماح المكرونة لـلاجهاد الـرطوبي تحت ظروف المملكة العربية السعودية

محمد عمر غندورة

قسم الإنتاج النباتي ـ كلية الزراعة ـ جامعة الملك سعود ـ ص.ب ٢٤٦٠ الرياض ١١٤٥١
المملكة العربية السعودية

أجريت تجربتين حقليتين في محطة الأبحاث الزراعية التابعة لجامعة الملك سعود (ديراب) قرب مدينة الرياض في عامي ١٩٨١/١٩٨٢ و ١٩٨٢/١٩٨٣ لاختبار عدد إثنين وعشرون صنفاً من أقماح المكرونة لتحمل الجفاف ـ وقد زرعت هذه الأصناف تحت ثلاثة مستويات من الرطوبة، حيث تروي النباتات عندما تصل نسبة الماء الميسر في التربة إلى ٨٠، ٦٠، ٤٠ .

ولقد أوضحت النتائج أنه بزيادة نسبة الماء الميسر للنباتات تزداد كمية المحصول، عدد الأيام للتزهير ومعدل امتلاء الحبوب، بينما لا تتأثر صفة فترة امتلاء الحبوب، وكان التفاعل بين معاملات الري والأصناف مؤكداً احصائياً لكمية المحصول، ومعدل امتلاء الحبوب في الموسم الأول فقط.

كما أوضحت النتائج أن هناك فروقاً معنوية إحصائياً بين الأصناف في جميع الصفات التي درست ـ وقد حسب معامل المقاومة النسبي للجفاف لكل صنف ووجد أن الصنفين رقم ٢٠ ، ٢٢ تعتبر أصناف متحملة للجفاف وعالية الإنتاج.