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Evaluation of Physiological Indices for Drought Tolerance in Wheat Genotypes in Saudi Arabia

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ABSTRACT. Five promising wheat strains (*Triticum aestivum*) were subjected to different water stress conditions to evaluate their drought tolerance mechanisms. A number of physiological parameters, namely transpiration, diffusive resistance, water potential and temperature differential were measured to determine if these could be used as indices of drought tolerance. Results showed correlations between the above parameters and the water stress levels as well as with the wheat strains. Rate of transpiration and diffusive resistance showed positive relationship with water regimes.

Wheat producing area in Saudi Arabia has increased almost ten-fold during the last decade. Last year, production exceeded the self-sufficiency level. Most of the wheat producing area is characterized by high temperatures, low rainfall and relatively high salt contents in the soil and irrigation water. Water is one of the most important limiting factors for crop production. Efforts are underway for the conservation and use of this important resource more efficiently by growing crops and their improved cultivars that are tolerant to salinity and drought and at the same time are efficient water utilizers. A number of procedures and tests have been used to evaluate the physiological basis of drought and salinity tolerance in field crops. However, there is no single method to produce reliable results. A combination of various methods such as the chlorophyll fluorescence test (Havaux and Lammoye 1985), water retention of leaves (Salim *et al.* 1969), rate of photosynthesis (Berry 1975, PHAM THI *et al.* 1982), stomatal conductance and rate of transpiration (Johnson *et al.* 1984, Quarrie and Jones 1979, Turner & Singh 1984, Adjei & Kirkham 1980;, have been studied in various crops.

To measure the above processes, a number of different types of instruments have been used, namely pressure bomb, air flow porometer and transient or steady state porometer (Kanemasu & Tanner 1969, Fischer *et al.* 1977, Shimshi & Ephrat 1975, Adjei & Kirkham 1980).

This study was undertaken (1) to evaluate a number of technique suitable for measuring the above stated parameters under Saudi Arabian climatic conditions and (2) to screen promising wheat cultivars for drought under various water stress conditions.

Methods and Materials

This study was conducted at the King Saud University Experimental Research site located about 26 km to the south of the city of Riyadh. The soil at this site is highly calcarious and non-saline-sandy-clay loam. Seeds of five strains of wheat (*Triticum aestivum*) namely, R_1-3922, F10/17, R_1-3741, JEC-71 and R_1-3952 (Table 1) were planted during the month of October 1984 at the rate of 120 Kg/ha in rows 20 cm apart. The design was of a split plot with a sub-plot measuring 10.00 m^2 with four replicates in each treatment area. Three moisture regimes were maintained by irrigating the plots whenever the available soil moisture reached 90% - 80% (wet regime), 60% - 50% (medium regime) and 40% - 30% (dry regime) of field capacity. Available soil moisture was measured by installing gypsum blocks at a depth of 15-20 cm in each treatment area and monitored by using a precalibrated Bouyoucos moisture meter. Phosphorus fertilizer was incorporated into the soil before sowing at the rate of 35 Kg/ha and nitrogen fertilizer was applied at sowing and at 6-week and 10-week intervals following sowing in three equal dressings amounting to a total of 120 Kg N/ha.

Measurement of the physiological parameters were made at monthly intervals at about 1000 hours. Water potential of plants was measured on at least five tillers from each strain in each treatment using the pressure bomb technique. Rate of transpiration and stomatal conductance was measured on several leaves using a LI-COR steady state porometer Model LI-1600. Leaf area was measured using a LI-COR portable leaf area meter, Model LI 3000. Temperature differential of the canopy was measured using a Telatemp infrared thermometer, Model Ag-42 at an angle of approximately 45° to the plane of the canopy surface.

Results and Discussion

Photosynthically active radiation (PAR) incident upon the canopy was used as a reference point to the light intensity intercepted by various strains. PAR increased from 1266 $\mu En^{-2}s^{-1}$ in January to $\mu En^{-2}s^{-1}$ in April, an increase of about 50% (Fig. 1). A significant portion of the light was intercepted at half height of the canopy under all the treatments. However, the amount of light transmitted through the canopy under the wet regime was significantly lower than that of the medium or dry regimes, which was mainly due to more tillers per plant and thus more biomass per covered area. Similarly, PAR transmitted through the canopy during January was significantly higher than April values due to greater biomass accumulation in April. Apparently the decreasing amounts of intercepted light by the interior of the canopy during the anthesis and grain filling periods (during April) had no adverse effect on grain yield (Table 1) as most of the spike-bearing

Table 1. Yield determining components of wheat strains at different water stress conditions during ripening stage

Treatments	Strains	# of Tillers/m²	Biomass (g/m²)	Grain Yield (g/m²)
Wet	R_1-3922	707	1633	394.5
	F10/17	561	2622	382.5
	R_1-3741	679	1972	683.0
	JEC-71	707	1972	628.8
	R_1-3952	523	1833	348.8
LSD 0.05		140.94	658.86	267.15
Medium Wet	R_1-3922	683	1571	488.5
	F10/17	572	2539	599.8
	R_1-3741	694	1999	500.5
	JEC-71	711	1827	655.5
	R_1-3952	425	1705	613.8
LSD 0.05		160.5	508.45	195.35
Dry	R_1-3922	567	1372	377.3
	F10/17	445	2471	714.0
	R_1-3741	670	1866	588.2
	JEC-71	663	2000	749.5
	R_1-3952	483	1933	605.5
LSD 0.05		130.58	564.63	261.42

tillers were exposed to the incident light intensity. Wheat is a C_3 plant which utilizes low levels of light intensity efficiently. The flag leaf at this stage is a more efficient source of photosynthate supply to the developing grains than the leaves.

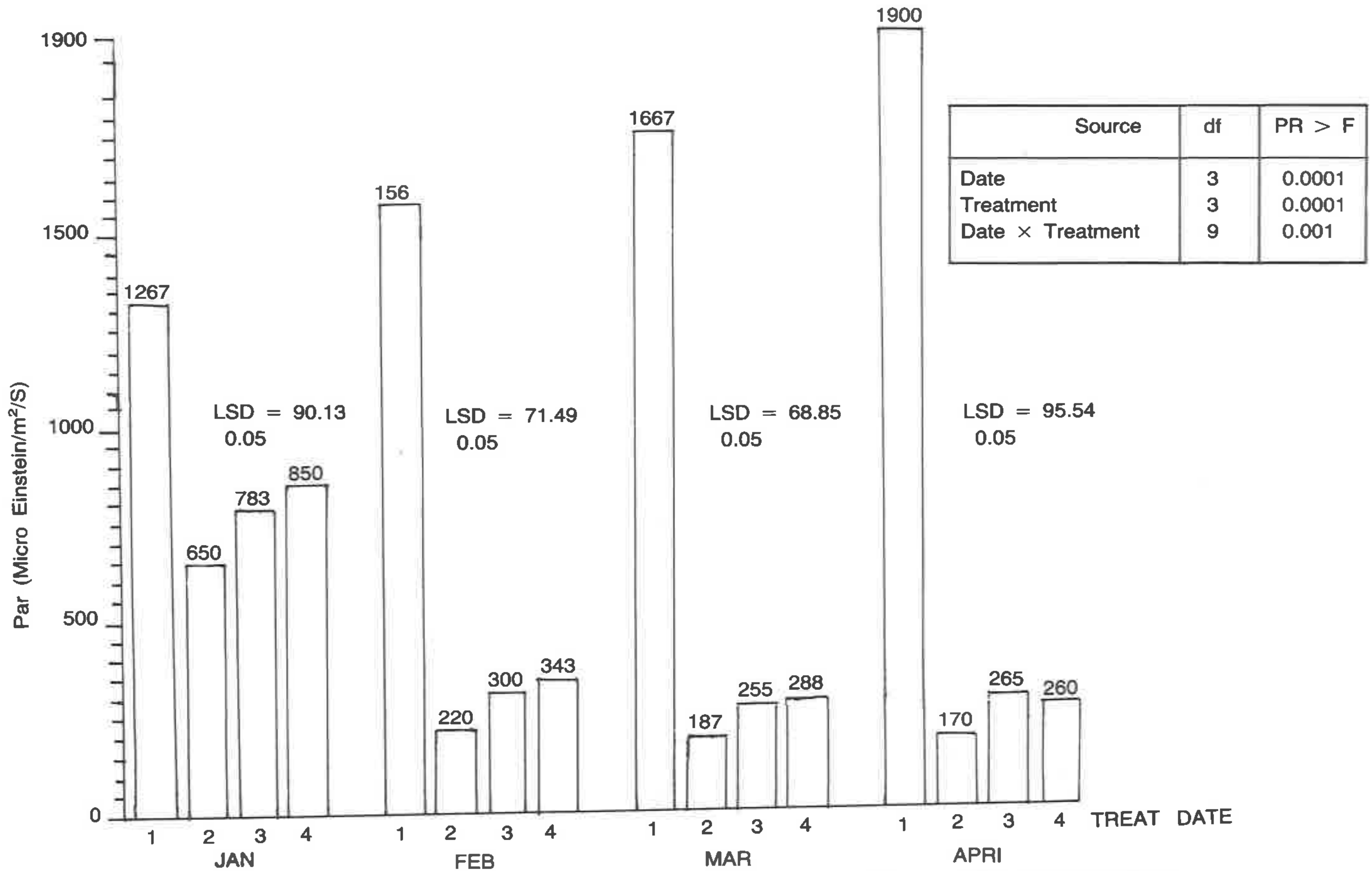
The data in Table 1, substantiates the above findings. Plants under the wet regime produced more tillers and more biomass than the dry regime which is also reflected in greater grain yield from the wet treatments. The strains under medium wet treatment also produced more tillers and greater biomass than the dry treatment except R_1-3952 which had more tillers and greater biomass under dry treatment than under medium wet treatment. However, it was not reflected in greater grain yiẹld in the same strain under the dry treatment. The strain JEC-71 produced more tiller and less biomass under medium wet than under dry treatment, but had greater grain yield under dry treatment. Both R_1-3952 and JEC-71 produced more yield under medium wet and dry treatment than under wet treatment.

All the strains developed larger flag leaf area under the wet regime than under the medium or dry regime (Fig. 2). However, flag leaf area of strains F10/17 and R-3741 was significantly greater than the other strains under similar treatments. Flag leaf plays a very important role during the grain filling period as a source of photosynthate to developing spikes. Strains of wheat with larger flag leaf area have been reported to have larger size grains and higher yields than those with small flag leaf area (Simpson 1968, Monyo & Whittington 1973). Although other leaves supply photosynthate to the developing grains, the flag leaf is a more efficient source due to its proximity to the sink, *i.e.*, the spikes and the spiklets (Austin *et al.* 1982, Carr & Wardlaw 1965).

Water potential of all the strains was lower (more negative) during April than during January under all the treatments (Table 2), due to more evaporative demand during April. The strains under the dry regime maintained a higher water potential compared to the wet and medium regimes which indicates that these strains are capable of adjusting to reduced water supply during the hotter parts of the growing season.

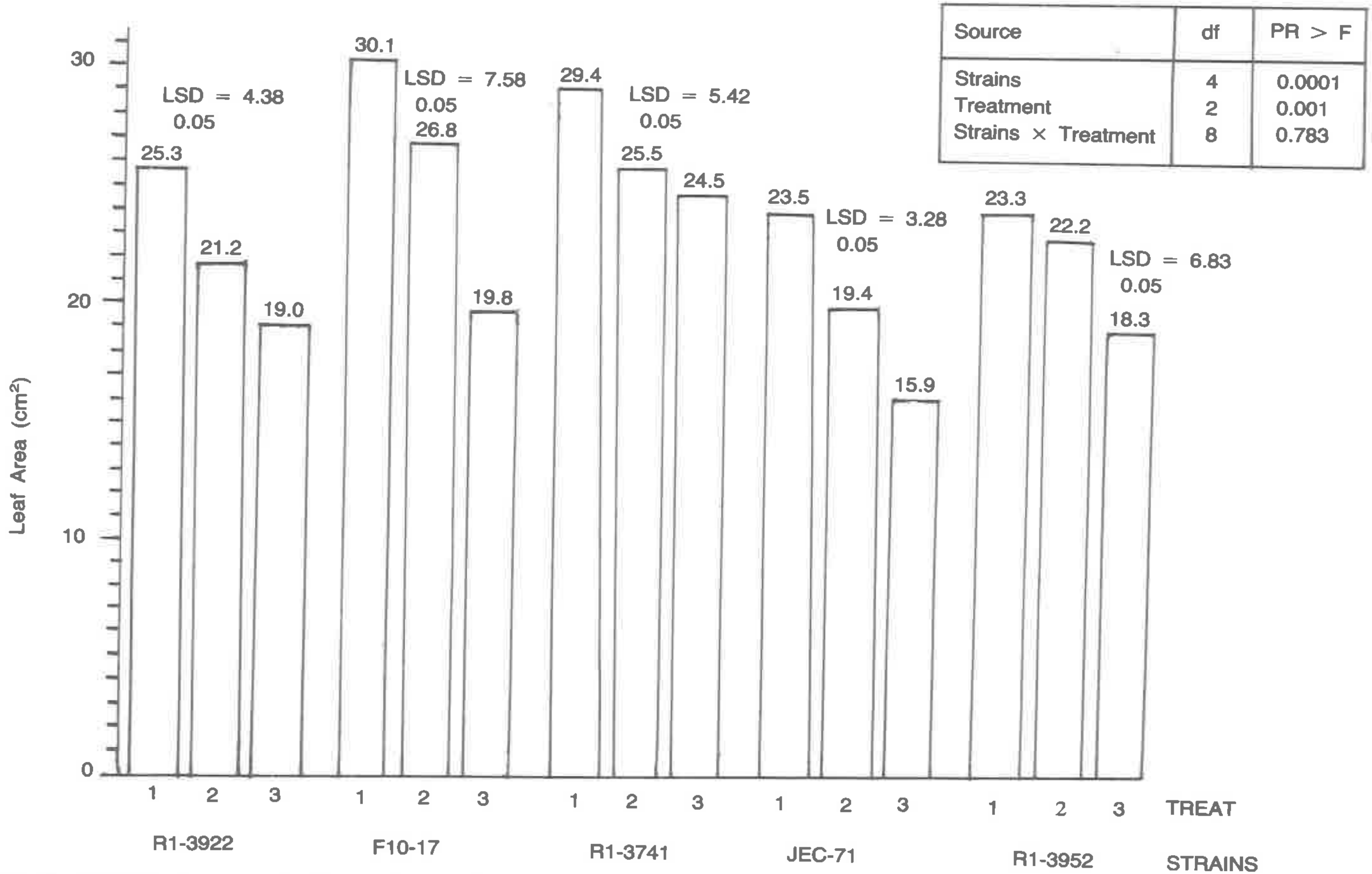
The strains, F10/17 and JEC-17 maintained relatively lower water potential than the other strains under all the treatments which indicates that these two strains may not be capable of adapting to drought conditions.

Diffusive resistance of all strains was higher during January than April under all treatments (Table 3). Under the dry regime it was relatively higher than under the wet or medium regime. The atmospheric evaporative demand is much higher during April and plants are usually losing more water through transpiration (Table 4) during this time than during January.



Source	df	PR > F
Date	3	0.0001
Treatment	3	0.0001
Date × Treatment	9	0.001

Fig. 1. Photosynthetically Active Radiation transmitted through wheat conopy subjected to different water stressed conditions. (1 = reference point above the canopy, 2 = wet regime, 3 = medium regime, 4 = dry regime)



Source	df	PR > F
Strains	4	0.0001
Treatment	2	0.001
Strains × Treatment	8	0.783

Fig. 2: Leaf area of flag leaf of different wheat strains subjected to different water stressed conditions. (1 = wet regime, 2 = medium regime, 3 = dry regime)

The diffusive resistance values are much higher than studies conducted elsewhere (Blum *et al.* 1983, Morgan 1977) thus indicating that these strains are more efficient in conserving water during harsh climatic conditions. The strains, R_1-3922 and F10/17 maintained relatively high diffusive resistance which is also evident from the lower rate of transpiration (Table 4) in the same strains.

Table 2. Water potential (−bar) of wheat strains at different developmental stages subjected to various water stressed conditions

Date	Strains	H_2O Treatments			
		Wet	Medium	Dry	LSD 0.05
January, 1985	R_1-3922	2.1	2.0	1.7	0.68
	F10/17	3.1	2.3	2.5	0.76
	R_1-3741	2.1	1.6	2.0	0.55
	JEC-71	3.8	2.7	3.0	1.08
	R_1-3952	2.2	2.0	2.1	0.91
LSD 0.05		0.66	0.90	0.72	
February, 1985	R_1-3922	2.1	2.0	2.0	0.78
	F10/17	3.8	2.6	3.0	1.06
	R_1-3741	1.0	1.8	2.4	0.53
	JEC-71	4.0	3.0	3.5	1.23
	R_1-3952	2.2	2.2	2.6	1.06
LSD 0.05		0.77	1.08	0.85	
March, 1985	R_1-3922	2.8	2.2	2.3	0.77
	F10/17	3.0	2.8	3.0	0.93
	R_1-3741	1.8	2.6	2.8	0.40
	JEC-71	3.3	3.2	3.4	0.66
	R_1-3952	2.3	2.7	2.7	0.62
LSD 0.05		0.66	0.73	0.57	
April, 1985	R_1-3922	3.8	3.3	3.4	0.61
	F10/17	3.8	4.4	4.6	0.53
	R_1-3741	2.6	4.5	4.7	0.30
	JEC-71	4.0	4.7	4.8	0.27
	R_1-3952	2.7	3.5	4.0	0.37
LSD 0.05		0.37	0.50	0.36	

The rate of transpiration in all strains followed almost the opposite trend to that of diffusive resistance, namely the lower the diffusive resistance, the higher the rate of transpiration. The strains R_1-3741, JEC-71 and R_1-3952 seemed to be somewhat less efficient utilizers of water than R_1-3922 and F10/17.

Table 3. Diffusive resistance (cm/s) of wheat strains at different developmental stages subjected to various water stressed conditions

Date	Strains	H_2O Treatments			
		Wet	Medium	Dry	LSD 0.05
January, 1985	R_1-3922	4.47	3.88	4.26	1.30
	F10/17	3.43	3.7	4.60	1.13
	R_1-3741	3.78	4.91	4.15	1.44
	JEC-71	4.83	4.19	4.06	1.27
	R_1-3952	3.63	3.47	3.82	1.06
LSD 0.05		1.45	0.75	1.21	
February, 1985	R_1-3922	3.95	3.55	3.77	1.01
	F10/17	3.02	3.54	4.06	1.00
	R_1-3741	3.58	4.41	3.63	1.18
	JEC-71	4.11	3.73	3.55	1.17
	R_1-3952	3.11	2.99	3.29	0.85
LSD 0.05		1.20	0.66	1.03	
March, 1985	R_1-3922	3.70	3.13	3.31	0.93
	F10/17	2.79	3.25	3.45	1.03
	R_1-3741	2.81	3.30	3.19	1.28
	JEC-71	3.82	3.10	3.12	0.89
	R_1-3952	2.72	2.70	2.82	0.87
LSD 0.05		1.09	0.76	0.98	
April, 1985	R_1-3922	3.24	2.73	3.00	0.96
	F10/17	2.49	2.84	3.02	0.97
	R_1-3741	2.51	2.98	2.75	1.14
	JEC-71	3.40	2.61	2.62	0.97
	R_1-3952	2.34	2.30	2.43	0.87
LSD 0.05		1.01	0.78	0.98	

Although the strains R_1-3741, JEC-71 and R_1-3952 maintained high water potential under the dry regime inspite of lower diffusive resistance and a higher rate of transpiration, they may be doing so by depleting the available moisture in the soil faster than the other strains.

Table 4. Transpiration (μg/cm²/s) of wheat strains at different developmental stages subjected to various water stressed conditions

Date	Strains	H_2O Treatments			
		Wet	Medium	Dry	LSD 0.05
January, 1985	R_1-3922	5.0	5.8	5.0	1.43
	F10/17	6.3	5.0	5.0	1.32
	R_1-3741	6.2	4.5	5.4	1.57
	JEC-71	6.3	4.2	7.0	2.11
	R_1-3952	6.6	4.6	6.1	0.25
LSD 0.05		0.89	1.41	1.81	
February, 1985	R_1-3922	5.6	6.0	5.5	1.38
	F10/17	6.5	5.6	5.7	0.94
	R_1-3741	6.5	5.4	5.7	1.17
	JEC-71	5.4	4.7	7.0	1.68
	R_1-3952	6.9	5.2	6.6	0.66
LSD 0.05		0.68	1.08	1.52	
March, 1985	R_1-3922	6.3	6.8	6.0	1.19
	F10/17	7.0	6.2	6.1	0.98
	R_1-3741	7.0	5.7	6.3	1.27
	JEC-71	6.0	5.2	7.1	1.06
	R_1-3952	7.4	5.7	7.0	0.68
LSD 0.05		0.76	0.95	1.22	
April, 1985	R_1-3922	6.6	7.2	6.4	1.08
	F10/17	7.5	6.5	6.6	0.91
	R_1-3741	7.5	6.3	7.5	1.26
	JEC-71	6.5	5.7	7.4	0.89
	R_1-3952	8.0	6.3	7.7	0.77
LSD 0.05		0.70	0.91	1.15	

The Tc-Ta values (Table 5) for these three strains were also relatively lower (more negative) than the other strains creating more stressful conditions.

No clear relationship existed between water potential and rate of transpiration or between water potential and diffusive resistance at least in the strains in

Table 5. Temperature differential (C°) of wheat strains at different developmental stages subjected to various water stressed conditions

Date	Strains	H_2O Treatments			
		Wet	Medium	Dry	LSD 0.05
January, 1985	R_1-3922	2.62	2.30	1.45	0.51
	F10/17	2.42	1.85	1.57	0.37
	R_1-3741	2.57	1.90	1.57	0.34
	JEC-71	2.55	1.80	1.57	0.25
	R_1-3952	2.62	1.80	1.35	0.30
LSD 0.05		0.30	0.44	0.26	
February, 1985	R_1-3922	2.70	2.17	1.55	0.16
	F10/17	2.65	1.85	1.50	0.33
	R_1-3741	2.62	1.85	1.45	0.24
	JEC-71	2.65	2.07	1.70	0.43
	R_1-3952	2.57	1.67	1.45	0.26
LSD 0.05		0.27	0.36	0.18	
March, 1985	R_1-3922	3.05	2.45	1.72	0.37
	F10/17	3.10	2.22	1.70	0.26
	R_1-3741	2.92	1.95	1.52	0.30
	JEC-71	3.55	2.70	1.67	0.29
	R_1-3952	3.12	2.72	1.72	0.26
LSD 0.05		0.36	0.28	0.16	
April, 1985	R_1-3922	2.92	1.97	1.65	0.24
	F10/17	3.12	2.17	1.45	0.40
	R_1-3741	3.07	1.97	1.60	0.45
	JEC-71	3.50	2.65	1.90	0.34
	R_1-3952	3.00	2.10	1.80	0.37
LSD 0.05		0.37	0.34	0.33	

this study. However, the rate of transpiration and diffusive resistance indicated close interdependancy. The lower the diffusive resistance, the higher the rate of transpiration. On the other hand, the higher transpiration rate or lower diffusive resistance, did not indicate any positive correlation with water potential.

High water potential as exhibited by some strains during the hotter part of the season had no effect on reducing the rate of transpiration or increasing the diffusive resistance.

Although the parameters studied as an indices of water stressed conditions did not show any clear relationships with respect to each other under different treatments, nevertheless, the physiological indices did show adjustment with advancing maturity. Since, the rate of transpiration and diffusive resistance showed a positive relationship, these two parameters could be used as indices for screening strains of wheat for drought resistance.

Table 6. Summary of significance levels from ANOVA for four treatments

Source	d.f.	T.D.	W.P.	T.	D.R.
Date	3	**	**	**	**
Strain	4	**	**	**	**
Water regime	2	**	*	**	NS
Date & strain	12	**	*	NS	NS
Date & water regime	6	**	**	NS	NS
Strain & water regime	8	NS	**	**	**
Date & strain & water regime	24	*	NS	NS	NS

* and ** Significant at 0.05 and 0.01 levels respectively. NS: non significant.

T.D. = Temperature differential = Tc − Ta when Tc = temperature of canopy, and Ta = temperature of ambient air.

W.P. = Water potential (−bars), T = Transpiration (μg/cm/s), and D.R. = diffusive resistance (cm/s).

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تقييم أصناف من القمح مقاومه للجفاف تحت ظروف المملكة

عناب بخاري[١] و محمد غندوره[٢] و حسن إبراهيم سيد[٢] و فيصل اليعيش[١] و محمود النوري[١]

[١]المركز الاقليمي لابحاث الزراعه والمياه ـ ص. ب: ١٧٢٨٥ الرياض ١١٤٨٤
[٢]وجامعة الملك سعود ـ كلية الزراعة ـ الرياض ـ المملكة العربية السعودية

جربت أصناف مبشره من القمح *(Triticum aestivum)* لثلاث معاملات مائيه لمعرفة مقاومتها لعدة مستويات من المياه لتقييم درجة مقاومتها الميكانيكيه لظروف الجفاف في التربه.

واجرى التحكم لظروف الجهد المائي بواسطة القطع عندما يكون الماء الميسر يصل من ٩٠ ـ ٨٠ ٪ (تحت ظروف رطبه)، ومن ٦٠ ـ ٥٠ ٪ (متوسط الرطوبه)، ومن ٤٠ ـ ٥٠ ٪ (جافه).

العوامل الفسيولوجيه التي درست تشير إلى مدى تحمل الجفاف والبخر نتح وحركة البخار في التربه والمقاومه والجهد المائي ودرجة الحراره في المساحة الخضريه المختلفه ومعدل البخرنتح وإنتشار البخار دلت على علاقه موجبه وتحت ظروف الثلاث معاملات.

إختلاف درجات الحراره والتي هي الفرق بين حراره المسطح الاخضر وحرارة الجو المحيط وجدت أنها تكون أكثر إعتماداً في النباتات تحت ظروف الجهد وهذه الطريقة يمكن إستخدامها كطريقة لتنظيم مواعيد الري ولكن يجب أن تعاير لكل محصول تحت مراحل نمو مختلفة.