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RESPONSE OF INTRODUCED SPRING BREAD WHEAT GENOTYPES TO WATER STRESS

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ABSTRACT

Twenty one bread wheat genotypes introduced from ICARDA along with the Egyptian check (Sakha 61) were evaluated for tolerance to water stress in two sucessive seasons (1999/2000 and 2000/2001). Three moisture levels were used; 100% (control), 70% and 50% of field capacity. Water stress treatments resulted in significant reductions in growth parameters, nutrient uptake, chlorophyll and yield components, while proline content increased for all genotypes. Root length, leaf area, proline, chlorophyll, NPK, sugar and amino acids were good criteria for drought tolerance and they were highly correlated with yield components. Five genotypes exhibited high dry matter accumulation, proline concentration and better yield parameters under water stress conditions and were either equal to or better than the Sakha 61. Two of the source parents (Kauz's' and Vee's') were common in the tolerant genotypes and are potentially a good source for water stress tolerance in wheat breeding programs.

Keywords: wheat, genotypes, drought stress, chemicals, proline, yield.

INTRODUCTION

Drought stress can cause considerable damage to crops of major importance such as wheat, *Triticum aestivum* L., (Blum *et al.,* 1991). Drought stress can also be a primary limiting factor in the distribution and adaptability of cultivated plants. Extending the cultivated area of wheat to newly reclaimed areas which are characterized by more stressful conditions and limited sources of water, should be highly considered.

Plans are made to extend irrigation water through canal such as Tushki to newly reclaimed land in Egypt. However, these sources should be used economically. This demands the introduction of new wheat cultivars that can tolerate such limited moisture and still yield properly. Thus identification of drought-tolerant genotypes for newly reclaimed lands is critical.

Drought stress during vegetative stage can markedly affect spike development and decrease yields of cereal grains (Mass and Grieve, 1990; Blum, *et. al.,* 1991). Blum *et al.*, 1991, also found that stressed as compared with watered plants, resulted in earlier heading, smaller leaf area, less tillers, reduced shoot weight and reduced plant height. Also, drought- stress treatment resulted in significant reduction in grain yield per plant, (Blum *et al.*, 1991).

Sugar and nutrients uptake could be good biochemical markers for drought tolerance (Vieira Da Silva, 1968). Proline accumulation has been noted in most winter cereal species after subjected to abiotic stresses. Proline accumulation under water stress was evident in barley (Singh *et al.*, 1973) as well as in bread and durum wheat (Monneveux and Nemmar, 1986).

Chlorophyll reduction under water stress also has been considered as a good indicator of water stress susceptibility (Gummuluru *et al.*, 1989).

In addition, identification and incorporating specific drought tolerance traits in breeding programs should facilitate more rapid improvement in the drought resistance of wheat and other small-grained cereals (Al-Hakimi and Monneveux, 1993).

The objective of this research was to evaluate a collection of introduced spring bread wheat genotypes for drought tolerance and their yield potentials. To achieve this goal, several criteria; growth parameters, leaf pigments, nutirents uptake, sugars, proline and yield components were examined.

MATERIALS AND METHODS

Genotypes

Twenty one genotypes imported from ICARDA wheat nurseries during 1998, with high potential good productivity, yield stability, and disease resistance were examined. This selection included some ICARDA standard checks (Mexipak 65, Cham-4 and Cham 6). In addition, a widely grown Egyptian cultivar (Sakha 61) was used as a national check. Table (1) lists all the crosses from which the wheat genotypes were selected and their sources.

Experimental design and treatments

Two field experiments were conducted during 1999/2000 and 2000/2001 growing seasons at the Faculty of Agriculture Research Station, Cairo University, Giza (clay loam soil). Experiments were laid out in a split plot design with three replications. Three moisture levels were applied in the main plots. The moisture levels were 100 (control), 70 and 50% of field capacity (F.C.). Field capacity was measured with a moisture meter and the irrigation was applied at the appropriate times.

Wheat genotypes were randomly distributed in the subplots. Water treatments were separated by a one meter border to insure isolation among plots. Each plot consisted of three rows (1.5m long) and five rows (3m long) in the 1st and 2nd seasons, respectively. The rows were 25 cm apart. Single vacant row separated adjacent plots. Recommended practices of fertilization and weed control were applied. Planting dates were on 30th and 27th of November during 1999/2000 and 2000/2001 growing seasons, respectively.

Measurements

- Growth parameters

Growth parameters including plant height, number of leaves/plant, number of tillers/plant, leaf area/plant, fresh and dry weight of root and shoot were measured in two samples collected (after 88 and 125 days from planting). The second sample was taken specifically from flag leaf. Growth parameters were measured only during 1999/2000 season.

Chemical constituents

Determination of chlorophyll a, b and carotenoid concentrations of fresh leaves of all genotypes was measured in two above mentioned samples. Representative samples from the fresh leaves were homogenized in a mortar with 85% aqueous acetone. The homogenate was filtered through sintered glass filter. The optical density of the filterate was determined using a Spectrophotometer at wavelength of 662, 646 and 447 nm for chlorophyll a, b and carotenoids respectively. The pigment concentrations were calculated using the formula adopted by Wettestein (1957).

For measuring free proline, 0.5 g of fresh plant material was homogenized in 10 ml aqueous sulphosalycylic acid and was filtered through a Whatman no. 3 filter paper. Two ml of ninhydrine and 2 ml of glacial acetic acid were added 2 ml of the filterate in a Pyrex test tube. The tube containing the mixture was placed in a water bath at 100 °C for one hour, then cooled directly in an ice bath to stop the reaction. Four ml of toluene were added to the mixture and the tube shaken well for 20 seconds and left to reach room temperature. The supernatant mixture was used for measuring the absorbance at wavelength of 520 nm in a Spectrophotometer (Spectronic 2000) as described by Bates (1973). Free proline content was calculated as follows:

$$\mu \text{ mole proline/g} = \frac{\mu\text{g proline/ml} \times 4 \times 5}{115.5 \times \text{wt .of the sample}}$$

Phosphorus, potassium, sodium, nitrogen, total sugars and total free amino acids concentrations were measured based on dry matter. Phosphorus concentration was estimated colormeterically by using chlorostannous reduced molybdophosphoric blue color method according to Chapman and Parker (1961). Potassium and sodium were determined by using flame photometer as described by (A.O.C.A., 1975). Reducing, non-reducing, total sugars, total free amino acids, and nitrogen were also determined in both samples as mg / g of dry weight of leaves. Hot ethanol extract from leaves was used for determination of total free amino acids using ninhydrine reagent (Moore and Stein, 1954). In addition, hot ethanol extract was used for measuring reducing, non-reducing and total sugars by using the phosphomolybdic acid methods (A.O.A.C, 1975). For determination of total nitrogen and subsequently protein, the modified (Micro-Keldahl) apparatus of Parnas and Wagner as described by Van Shouwenburg and Walinga (1987) was used.

Yield and yield components

At harvest in both seasons, five plants from each replicate were collected to determine yield components; number of spikes/plant, spike length, spike weight, weight of kernels/spike, grain yield/plant, and 1000 grain weight. In the first season, as a result of shortage in seed stock, the yield was determined as yield (g/plant). While in the second season, enough plants allowed measuring yield/m^2.

Data analyses

Data were subjected to statistical analyses of variance by using SAS procedure PROC GLM (SAS Institute, Inc. 1999). Means of moisture treatment, genotypes and treatment X genotypes interactions were separated using Duncan's Multiple Range Test at 0.05 probability level. Correlation and regression analyses among studied traits were also performed.

RESULTS AND DISCUSSION

Genotypes were classified into three groups according to yield/m^2 at 100% F.C in the second season; high, medium and low yielding. Three genotypes were selected to represent each group. The high yielding group included No.1, 9 and 15. The medium group; No.14, 18 and 21. While the low yielding consisted of No. 3, 6 and 20. The Egyptian check (Sakha 61, No. 2) was also included.

Growth parameters

Table (2) shows the effect of three moisture levels on growth parameters in the first vegetative sample during 1999/2000 season. Results show significant differences among treatments, genotypes and in the interaction between treatments and genotypes.

Table (1): Origin and crosses from which genotypes were selected in ICARDA wheat nursery during 1998 season.

Genotype No.	Name or Cross	Origin
1	Tevee's' / KAUZ'S'	Syria
2	Sakha 61 (national check)	Egypt
3	salwa's' // Vee's' / Myna's'	Syria
4	Mexipak 65 (long-term check)	Syria
5	Cham-6(Improved check)	-
6	W3918A / Jup // Vee's' / Snb's'	Syria
7	Ald's' / Hauc's' // CHIL	Syria
8	Mayon's' // Crow's' / Vee's'	Syria
9	KAUZ'S' / 657CI.	Syria
10	Pvn's' / Sprw's'	Mex / Syr
11	Tevee's' // Vee's' / Pvn's'	Syria
12	Tevee's' // Crow's' / Vee's'	Syria
13	Mon's' / Ald's' // Aldans's' / Ias58	Syria
14	Carp / KAUZ'S'	Syria
15	Kauz's' / 3 / Ana / Maya // Tan's'	Mex / Syr
16	Cham-4 (Improved check)	-
17	Vee's'/ Tsi/ 6/ 21931/ 3/ Ch53/ An// Gbs/4 / An64/ 5/Iwp501	Syria
18	Shuha's' // Seri82	Syria
19	Ald's' / Hauc's' // CHIL	Syria
20	CHIL // Vee's' / Tsi	Syria
21	Vee's' // Koel's' / Vee's'	Syria
22	Karawan's' / 3/ Bage / Hork // Aldan	Syria

Source of genotypes is bread wheat observation nursery for semi-arid areas CIMMYT/ICARDA.

Table (2) : Growth parameters in bread wheat genotypes as affected by three moisture levels during 1999/2000 season (1st sample).

Moisture level	Genotype No.	Plant height (cm)	Root length	No. of leaves	No. of tillers	Fresh Wt (g) Shoot	Fresh Wt (g) Root	Dry.Wt (g) Shoot	Dry.Wt (g) Root	leaf area cm^2
100% Field capacity	1	93.5	17.0	7.0	6.0	58.5	9.4	15.1	6.3	298.6
	2	90.0	18.0	7.0	2.0	21.8	2.2	7.1	1.0	322.7
	3	96.0	16.0	7.0	2.5	40.7	2.9	9.0	1.2	348.3
	6	88.0	11.0	7.0	0.0	6.0	0.4	1.3	0.2	327.7
	9	69.0	19.0	7.0	2.0	11.0	1.7	2.0	0.4	235.1
	14	98.0	17.0	7.0	1.0	21.5	2.1	4.1	0.6	275.3
	15	83.0	18.0	7.0	1.0	9.2	1.1	2.3	0.3	377.0
	18	78.0	14.5	7.0	0.5	10.0	1.2	2.2	0.4	290.8
	20	73.0	18.0	7.0	2.0	19.6	1.7	4.0	0.4	396.5
	21	96.0	16.5	7.0	2.5	35.5	2.6	6.6	0.7	475.6
70 % Field capacity	1	85.0	19.0	6.5	4.5	42.0	8.2	10.4	2.9	269.7
	2	74.0	15.0	7.0	3.0	20.0	2.7	3.6	0.3	292.7
	3	92.5	17.0	6.5	2.0	18.9	3.1	3.3	0.9	353.8
	6	75.0	10.0	6.0	1.0	13.5	1.0	2.2	0.2	278.2
	9	85.0	18.0	6.0	2.0	16.5	3.0	3.5	0.6	194.5
	14	93.0	18.0	6.0	4.0	30.5	5.7	3.3	0.8	227.9
	15	89.0	15.0	7.0	2.0	21.8	2.7	3.7	0.7	321.1
	18	71.5	13.5	7.0	2.0	14.1	1.5	2.6	0.4	193.7
	20	65.0	18.0	7.0	3.0	17.0	2.0	[illegible]	[illegible]	180.3
	21	85.5	16.0	7.0	2.5	24.4	2.6	3.5	0.8	471.7
50 % Field capacity	1	79.5	16.5	7.0	1.5	14.5	1.8	3.8	0.5	159.7
	2	71.0	18.0	7.0	1.0	16.9	1.7	4.2	0.8	153.1
	3	81.0	19.5	7.0	1.0	18.5	2.1	4.4	0.7	105.4
	6	55.0	18.0	7.0	0.0	7.3	1.0	1.5	0.4	165.7
	9	80.0	18.0	7.0	2.0	11.5	1.1	2.0	0.3	166.5
	14	53.0	15.0	7.0	2.0	9.7	2.2	2.9	0.4	128.2
	15	86.0	19.0	7.0	0.0	7.8	1.2	1.0	0.3	144.2
	18	60.5	16.5	7.0	1.5	9.1	1.4	2.4	0.3	112.7
	20	74.0	18.0	7.0	2.0	14.5	1.2	2.9	0.2	177.3
	21	79.0	18.0	7.0	1.0	9.4	1.1	2.5	0.6	152.3
LSD (0.05)										
Treatments (T)		3.30	1.37	0.09	0.44	4.08	0.53	0.80	0.21	20.61
Genotypes (G)		9.80	4.10	0.29	1.34	12.27	1.59	2.41	0.63	80.32
T X G		11.80	NS	0.36	1.44	11.04	4.07	2.11	0.57	38.75

Note: All parameters were measured on single plant basis.

At 100 and 70 % F.C., genotype No. 1 scored the highest values for most growth parameters, particularly number of tillers per plant, fresh and dry weight of shoot compared with the other genotypes and the Egyptian check (Sakha 61). Genotype No. 21 exhibited the highest values for leaf area under both 100 and 70% F.C. In addition, at 50 % F.C. genotype No. 3 scored the highest values for root length, and fresh weight of shoot and root.

Moreover, drought stress treatment at 70 % F.C. led to significant reductions in most growth parameters in all genotypes except No. 14, 15, 9, 6 and 18. These genotypes were either unaffected, slightly reduced by 70 % F.C. treatment or contrarily exhibited some insignificant increases. At 50 % F.C., the same trend was observed among genotypes expect in No. 6 and 18 which exhibited tolerance. In this respect, Blum *et al.*, (1991) Asseng *et al.* (1998); and Bajii *et al.*, (2000) reported similar reductions in root growth, leaf area and fresh weight of shoot, respectively, under water deficit.

In the second vegetative sample (Table 3), at 100 % of F.C. genotype No.1 also maintained the highest rank in number of tillers and fresh and dry weight of shoot and root. At 70 % F.C. No. 1 and/or 3 scored the highest values for most growth parameters. However, at 50 % F.C., genotypes No. 9 and18 shared the highest rank in different growth parameters and they were not affected by 70 or 50% F.C. The different response of genotypes under different moisture levels reveals the importance of screening introduced germplasms under more than one level of drought stress. It is also worth mentioning that two of the least affected genotypes in growth parameters (No. 1 and 9) share a common parent (KAUZ, see Table 1).

Table (3) : Growth parameters in bread wheat genotypes under three moisture levels during 1999/2000 season (2nd sample).

Moisture level	Genotype No.	Plant height (cm)	Root Length (cm)	No. of leaves	No. of tillers	Fresh Wt (g)		Dry.Wt (g)		Leaf area cm^2
						Shoot	Root	Shoot	Root	
100% Field capacity	1	92.0	35.0	6.3	3.7	45.7	3.9	15.2	2.2	597.5
	2	113.3	42.0	6.3	2.3	38.2	2.2	9.5	1.1	642.5
	3	115.7	43.0	6.0	1.3	32.9	1.4	6.6	0.5	413.3
	6	126.0	41.7	6.0	2.7	45.9	2.1	11.1	1.2	772.7
	9	95.0	34.7	6.0	0.6	10.9	0.6	2.6	0.4	629.3
	14	121.7	41.3	6.0	1.0	20.1	1.7	4.7	0.8	792.6
	15	112.0	39.7	7.0	0.7	15.7	0.5	4.1	0.2	752.9
	18	100.3	41.3	6.0	2.0	30.4	1.3	7.8	0.6	763.9
	20	98.3	38.0	6.0	1.3	16.2	0.9	5.4	0.5	362.6
	21	119.0	38.0	6.3	0.3	9.7	0.5	3.9	0.2	678.6
70% Field capacity	1	92.3	34.3	7.0	4.0	36.2	3.0	14.0	1.9	572.0
	2	96.0	36.3	6.0	3.3	29.4	2.1	11.0	1.4	526.6
	3	93.3	40.7	6.3	3.0	37.3	4.4	12.4	3.0	522.4
	6	86.0	33.3	6.3	1.7	13.8	1.0	5.3	0.6	527.7
	9	111.0	44.3	6.7	2.0	23.1	1.4	8.2	1.9	308.9
	14	117.7	40.7	6.3	1.7	19.8	1.2	9.7	0.5	571.6
	15	110.0	35.0	6.3	1.0	10.9	0.9	3.8	0.3	445.3
	18	112.7	32.7	7.0	2.3	16.9	2.2	7.3	1.7	335.7
	20	93.3	33.0	6.0	1.0	14.2	1.1	5.3	0.8	372.0
	21	104.3	37.7	[illegible]	1.7	21.6	1.0	8.5	0.7	562.2
50% Field capacity	1	90.0	29.7	7.0	1.3	17.6	2.1	13.4	1.1	225.9
	2	[illegible]	20.7	6.7	0.7	11.9	1.5	5.2	1.0	212.0
	3	100.3	22.7	7.0	1.3	15.8	1.5	5.1	0.8	264.8
	6	98.3	20.3	6.0	1.3	16.1	3.2	7.2	1.4	243.3
	9	108.3	19.0	6.0	1.0	19.2	2.2	9.4	1.3	200.2
	14	92.3	21.0	7.0	1.0	12.7	1.4	5.0	0.6	276.7
	15	86.3	21.0	6.0	1.0	10.0	1.5	3.6	0.6	268.7
	18	84.3	16.0	7.0	2.3	22.0	2.8	6.6	1.0	198.8
	20	97.7	20.0	6.3	1.0	14.5	1.4	5.2	0.6	500.1
	21	101.3	19.0	6.7	1.0	12.9	1.4	5.2	0.6	509.2
LSD (0.05)										
Treatments (T)		2.4	1.1	0.1	0.3	2.5	NS	1.0	0.2	14.2
Genotypes (G)		6.9	3.1	0.4	0.9	7.1	1.1	2.7	0.6	32.8
T X G		11.7	5.3	0.6	1.5	11.3	1.8	4.2	1.0	29.7

Note: All parameters were measured on single plant basis.

Chemical constituents

Table (4) shows the effect of three moisture levels on proline, chlorophyll a, b and carotenoids contents in two leave samples. Analysis of variance for proline and chlorophyll contents showed highly significant differences among treatments (moisture levels), genotypes and treatment X genotypes interactions.

Under 100% F.C., proline content range was narrow among genotypes in both samples. The highest proline contents were observed in genotypes No. 1 at 70% F.C. in both samples and genotypes No. 1 and 15 at 50 % F.C. in the first and second samples, respectively compared to Sakha 61 (No.2). From Table (1) we can notice that genotypes No. 1 and 15, with the highest proline content, share a common parent; Kauz's'. This source parent (Kauz's') was a common factor in genotypes with minimum damage in growth parameters as well (see Tables 2 & 3).

Table (4): Effect of three moisture levels on proline, chlorophyll and carotenoid concentrations among wheat genotypes in two samples (S1 and S2) during 1999/2000 season.

Moisture Level	Genotype No.	Proline content M mole/ g Fr. Wt		Chlorophyl concentration mg/g dry Wt				Carotenoid Concentration	
				(a)		(b)			
		S1	S2	S1	S2	S1	S2	S1	S2
100%	1	10.5	52.4	28.8	39.5	10.5	36.7	9.4	1.9
Field	2	11.0	44.6	21.4	27.4	10.2	9.9	6.3	8.9
capacity	3	12.5	46.4	30.3	39.7	11.5	22.2	9.3	5.6
	6	9.4	43.9	22.5	20.2	9.6	6.8	7.4	6.7
	9	11.8	43.4	29.5	20.9	11.2	5.9	9.1	7.9
	14	8.1	61.0	34.3	40.5	11.9	22.9	10.3	5.7
	15	6.1	61.9	37.8	40.0	14.5	21.4	9.7	6.7
	18	8.1	52.1	31.6	24.0	12.2	9.5	9.3	7.2
	20	9.7	61.3	29.3	33.4	11.1	9.4	9.7	9.3
	21	12.1	56.9	29.6	34.9	11.4	10.7	8.9	9.5
70%	1	39.8	80.2	17.5	17.8	10.3	9.7	7.3	4.7
Field	2	10.9	51.2	24.3	31.2	10.8	[illegible]	7.8	3.7
capacity	3	12.9	46.4	33.0	21.9	12.3	2.5	10.1	6.8
	6	11.8	49.3	18.5	27.3	9.2	7.4	5.4	7.7
	9	7.8	66.7	19.6	40.0	9.6	31.0	5.6	3.9
	14	9.5	58.6	18.4	25.2	9.0	7.1	5.2	7.0
	15	3.8	58.0	15.9	28.4	8.7	13.1	4.1	8.0
	18	4.2	47.4	15.8	34.9	9.0	14.4	4.3	9.2
	20	6.6	55.4	21.5	28.7	10.5	8.3	6.2	7.5
	21	3.6	51.0	28.8	27.7	11.8	6.8	8.6	8.6
50%	1	54.4	41.3	26.8	21.5	10.6	7.6	8.9	5.1
Field	2	24.1	47.3	25.4	6.9	10.5	4.2	8.0	2.3
capacity	3	16.0	40.2	27.5	9.7	12.1	4.7	7.9	2.6
	6	37.5	49.6	23.9	9.5	9.8	4.4	7.2	3.2
	9	37.0	46.7	19.8	20.4	9.2	7.5	6.1	4.8
	14	31.9	44.6	18.2	15.1	9.8	3.6	4.3	4.3
	15	18.1	55.1	29.7	13.3	11.2	5.1	9.4	4.6
	18	27.0	45.4	37.0	22.3	13.0	7.0	10.4	6.5
	20	27.9	42.0	34.0	15.9	12.3	6.3	10.1	4.3
	21	45.6	50.8	28.6	11.9	11.2	4.5	8.5	4.7
LSD (0.05)									
Treatments (T)		0.5	3.4	0.7	1.7	0.3	1.2	0.3	0.3
Genotypes (G)		1.3	3.6	1.9	2.9	0.8	0.7	0.8	0.9
T X G		1.1	4.3	2.3	3.1	1.1	1.5	0.6	0.5

Furthermore, at 70 % F.C. only genotypes 1, 6 exhibited increase in proline content in both samples. At 50 % F.C. all genotypes showed significant increase in proline contents in the first sample, but only genotypes 2, 6 and 9 showed that increase in the second sample. At 50 % F.C., proline content ranged from 18.1 to 54.4 µ mole/ g fresh weight in the first sample and 40.2 to 55.1 4 µ mole/ g fresh weight in the second sample. These results coincide with those found in growth criteria for genotypes No. 6 and 9 which were tolerant in both samples. Also, this finding confirms the relationships previously observed by several authors between drought tolerance and proline accumulation (Singh *et al.,* 1973, Monneveux & Nemmar, 1986 Narayan & Misra, 1989) and Bajii *et al.*, 2000. Also, Ali *et al.*, (1994) found that proline accumulation in stressed plant increased by a factor of 15.7 in relation to the control.

As far as chlorophyll a, b and carotenoid, at 100 % F.C., genotypes exhibited a narrow range of values for all pigments except for chlorophyll b in the second sample where the range was from 5.9 to 36.7mg /g fresh weight of leaves.

At 70% F.C., genotype No. 3 showed the highest values and no decease in chlorophyll in the first sample. While, No. 9 and 18 were the highest in the second sample for chlorophyll a and b and exhibited significant increase in both chlorophyll a and b compared to 100 % F.C. . At 50 % F.C., genotype No. 18 exhibited the highest values in the first sample compared with all other genotypes.

At 50 % F.C., in the first sample, all genotypes exhibited reductions in chlorophyll a & b except genotypes No.18 and 20 which showed no reduction. While in the second sample, all genotypes generally suffered significant reductions in chlorophyll due to drought stress.

The effect of water stress on carotenoid was either in reverse for some genotypes or inconsistent in the others. Rashad and Ismail (2000), found similar effects for heat stress on the carotenoid.

Correlation analyses among growth parameter and pigments as well as proline in the second leave sample revealed several significant relations. There were positive correlations between leaf area and the following:root length (r=0.678**), fresh weight of shoot (r=0.307**) and chlorophyll a (r= 0.271*). Shoot fresh weight was positively correlated with chlorophyll a, carotenoid (r=0.231* and 0.347**, respectively). On the other hand, chlorophyll a, carotenoid and dry weight of shoot were positively correlated with proline (r= 0.579** and r= 0.711**, r = 0.225* respectively). It seems that that the increase in leaf area and fresh weight of shoot, as well as root were correlated with photosynthesis activity (chlorophyll a) and metabolism of assimilates (amino acids and sugars).

Zaharieva *et al.*, (2001) suggested that decreased leaf chlorophyll content in wild relatives of wheat (grown in harsh environment) could limit the energy load from strong sunlight. These wild relatives are characterized by the low biomass and low yield. While, other wild relatives of wheat grown under mild Mediterranean environments had high chlorophyll concentration, biomass and yield. Thus, their thermal regulation of the leaf may rather depend on regulating transpiration. In our study we found a strong correlation between shoot fresh weight (biomass) and chlorophyll a (r=0.231*) and thus we think that reduced chlorophyll concentration is not the mechanism of drought tolerance in our selection of genotypes.

On the other hand, Gummmurlu *et al.*, 1989 considered chlorophyll loss as good indicator of water stress susceptibility. Two genotypes (No. 9 and 18) which had the least effect, or contrarily showed an increase, in chlorophyll concentration at 70% F.C. Therefore, they can be considered relatively tolerant to water stress. The common parent (Kauz's') also exited in genotype No. 9, referring to the high potential of this parent as a source for drought stress tolerance.

Data obtained in Table (5) show the effects of three moisture levels on K, N sugars and amino acids in shoot and root among wheat genotypes in 1999/2000 season in the first sample. There were highly significant effects of treatments (moisture levels), genotypes and treatment X genotypes interactions for most studied nutrients.

Table (5): Effect of three moisture levels on K, N, sugars and amino acids concentrations (mg/g D.W) among wheat genotypes during 1999/2000 season.

Moisture Level	Genotype No.	Potassium		Nitrogen		Sugar in the shoot		Total free Amino acids in shoot
		Shoot	Root	Shoot	Root	Reduced	Total	
100% Field capacity	1	5.00	3.03	18.00	11.25	14.09	21.76	0.30
	2	5.76	3.10	18.25	10.50	13.50	19.90	0.38
	3	6.15	2.97	17.50	11.50	15.98	22.93	0.81
	6	6.85	3.10	16.50	10.25	11.77	18.14	0.48
	9	5.69	2.93	17.50	9.75	20.76	25.98	0.63
	14	5.38	2.10	14.75	7.50	21.65	26.72	0.42
	15	5.31	3.00	17.25	11.25	19.31	25.60	0.44
	18	5.38	3.03	18.50	11.50	19.52	25.70	0.35
	20	6.98	2.73	19.00	10.75	11.23	16.00	0.42
	21	5.76	3.00	16.25	10.25	12.23	19.20	0.48
70% Field capacity	1	5.76	2.43	14.50	11.25	21.38	26.72	0.75
	2	5.15	2.87	13.25	9.00	20.68	27.71	0.73
	3	5.73	2.50	14.75	11.00	21.68	28.70	0.70
	6	6.29	2.90	14.75	10.75	15.53	18.94	0.56
	9	3.57	0.09	13.25	7.25	21.20	25.60	0.40
	14	4.35	0.51	14.00	10.00	12.29	18.02	0.52
	15	3.81	0.22	17.00	10.00	11.75	16.90	0.50
	18	4.14	0.28	14.75	9.75	16.79	22.40	0.37
	20	5.38	0.39	14.50	7.50	9.50	14.53	0.34
	21	3.87	5.76	13.00	6.25	12.39	16.53	0.37
50% Field capacity	1	4.62	2.24	11.25	9.25	9.05	15.90	0.55
	2	4.45	2.77	11.50	7.25	9.97	15.65	0.55
	3	4.14	2.37	10.75	6.25	10.02	16.00	0.81
	6	6.08	2.37	9.50	8.25	10.77	15.94	0.92
	9	4.42	2.73	12.50	9.75	15.55	22.11	0.64
	14	4.38	2.37	10.75	9.00	15.90	22.08	0.73
	15	3.84	1.97	12.25	7.50	15.17	19.17	0.70
	18	3.91	2.33	12.00	7.25	13.18	18.50	0.55
	20	4.25	2.67	13.25	8.25	14.85	20.90	0.40
	21	4.04	2.60	11.25	7.25	14.63	20.74	0.42
LSD (0.05)								
Treatment (T)		0.39	0.29	0.49	0.46	0.39	1.05	0.06
Genotypes (G)		1.11	0.83	1.39	1.30	1.11	2.80	NS
T X G		NS	0.77	0.95	0.86	0.68	1.23	0.09

The highest values for K, N and total sugar concentrations in the shoot at 100 % F.C. were associated with genotypes No. 20, 18 and 14, respectively, compared to Sakha 61. Generally, at 70 %, F.C., sugars concentration in the shoot tended to increase, while K and N tended to decrease. However, at 70 % F.C. genotypes No. 6, 15 and 3 exhibited the highest value for K, N and total sugars in the shoot. While, genotypes No. 21 and 1 showed the highest values for K and N in the roots respectively.

At 50 % F.C, generally, K, N and total sugars in the shoot and the roots tended to decrease. However, genotypes No. 9 showed the highest values in N concentration in the shoot and the root as well as total sugar concentration in the shoots compared with the Egyptian check. While, genotypes No. 6 and 2 had the highest value in K concentration in the shoot and the roots, respectively. Generally in the second vegetative sample, there was no significant difference among genotypes in chemical constituents and no significant genotype X treatment interaction was found. Only significant reduction due to moisture treatment was found in most chemical constituents, where both 70% and 50% F.C. treatments were equally and significantly reduced by drought in most chemical constituents.

Chemical components of shoots and roots exhibited a strong positive association with different elements. For example, total sugars of shoot exhibited strong positive association (r= 0.613**, 0.777** and 0.791**) with K, N and P concentrations in shoots, respectively. Also, total sugars of roots showed similar correlation trends for K (r=0.474**), N (r=0.463**) and P (r=0.334**). Data also showed that total free amino acid concentrations showed positive correlation with K (r=0.705**), N (r= .693**) and P (r=0.753**). This reveals the importance of NPK in the synthesis of total sugar and amino acid. It also confirms the relationship between sugar translocation from shoot to root and K level.

Both Na and N were positively correlated with total free amino acids in the roots (r= 0.425**, 0.666**., respectively). Both Na and total free amino acids in the roots could be osmoprotectant mechanism. Also, leaf area exhibited a positive correlation with N uptake (r=0.615**). This correlation confirms that N is an essential element for biosynthesis of phytohormons, which regulate cell elongation and division. The correlations between root length and K, N, P and amino acids in the shoots were positive (r= 0.525**, r=, 0.779**, r=0.540**, r=0.587**, respectively). Therefore, NPK and amino acids concentrations were considered good indicators for vegetative growth.

This correlation also indicates that root growth depends on nutrient uptake as well as protein synthesis. The strong root system development will allow reaching deeper water and subsequently tolerance to water stress.

Yield and its components

Combined ANOVA indicated significant (P<0.01) interaction between genotypes yield parameters and growth seasons. Therefore means of yield and yield components were presented separately for both seasons.

Table (6) shows the effect of three moisture levels on yield and its components of 10 genotypes in two growing seasons. The results of analysis of variance for grain yield and /or its components were highly significant for the effects of genotypes, moisture levels and their interactions. The tested bread wheat genotypes represented a wide range of reactions whether under normal or stressed moisture conditions.

In the first season, at 100 % F.C. genotypes No. 20 and 21 exhibited the highest values for most yield components. While in the second season, genotype No. 15 was superior in all yield components, except for weight of 1000 grains (where No. 2, i.e Sakha 61 was the highest, 58.7 g) and weight of grain/ 1 m^2 (where No. 18 was the highest, 750 g/m^2).

Table (6): Effect of three moisture levels on yield and its components among bread wheat genotypes during 1999/2000 and 200/2001 seasons.

		No.SPKPL		SPKLNTH (cm)		SPKWTPL (g)		KRLWTSPK (g)		GRNYLDPL (g)		WT1000 (g)		Wt g/m2
Year Moisture level	Genotype No.	99	00	99	00	99	00	99	00	99	00	99	00	00
100% Field capacity	1	3.0	4.7	9.0	10.8	11.4	8.9	2.9	1.4	7.9	6.3	38.8	39.4	462.2
	2	3.0	4.0	9.5	9.3	10.9	5.2	2.8	0.8	8.3	5.3	39.0	58.7	293.6
	3	3.0	3.0	9.7	8.0	10.6	4.5	2.7	1.1	8.0	5.2	45.0	42.8	230.4
	6	3.0	3.7	8.2	8.3	6.0	7.1	1.5	1.4	4.4	5.2	32.1	34.3	362.8
	9	3.0	3.7	8.6	9.2	10.6	7.6	2.6	1.7	7.7	6.2	53.8	39.5	550.0
	14	3.0	3.3	9.4	10.3	9.5	7.0	2.6	1.7	7.1	5.4	39.3	48.5	330.8
	15	3.0	3.7	8.7	12.2	9.7	11.5	2.2	2.1	6.6	7.6	48.8	40.1	312.2
	18	3.0	4.0	8.8	10.3	8.9	9.3	2.3	1.8	7.0	7.0	45.3	39.0	750.0
	20	3.0	3.0	9.8	8.8	11.5	9.2	3.0	2.2	9.0	6.6	52.6	39.8	168.0
	21	3.0	4.0	9.5	8.5	12.4	5.5	3.0	1.0	8.9	6.4	45.9	41.8	400.0
70% Field capacity	1	3.0	3.0	11.4	9.7	11.3	5.1	2.7	1.3	8.0	5.9	38.8	38.9	400.0
	2	3.8	3.3	11.1	8.3	11.6	6.6	2.0	1.6	7.6	5.4	43.4	46.0	178.8
	3	3.3	3.0	12.3	12.2	10.5	7.0	2.1	1.7	7.0	5.0	40.9	46.1	218.6
	6	3.4	3.0	9.9	8.8	8.6	5.8	1.9	1.6	6.4	4.9	38.6	37.9	335.0
	9	2.8	2.3	9.5	12.8	6.8	5.7	1.7	1.7	4.6	3.7	41.5	45.2	218.4
	14	2.8	3.0	10.6	7.3	5.9	5.7	1.6	1.5	4.3	4.4	38.9	57.9	248.4
	15	2.6	3.0	10.4	13.3	7.3	8.8	1.9	2.1	4.8	6.3	55.6	39.3	282.0
	18	3.0	3.0	10.4	8.3	9.0	5.5	1.9	1.4	5.8	4.1	40.4	38.0	318.0
	20	2.6	3.0	12.8	12.7	7.7	11.1	2.2	2.9	5.8	8.6	40.8	34.2	104.4
	21	3.0	3.0	11.4	9.3	9.1	7.8	2.0	2.1	5.9	6.2	40.2	41.2	260.3
50% Field Capacity	1	3.0	3.0	11.0	9.8	11.8	6.7	2.8	1.9	8.3	5.7	46.5	33.7	360.0
	2	3.0	3.3	11.0	9.8	7.1	8.5	1.5	2.2	4.6	7.3	36.5	44.7	214.7
	3	3.3	3.3	10.9	9.8	8.3	9.6	1.9	2.5	6.1	8.4	54.0	33.4	205.4
	6	3.6	3.0	10.6	8.3	8.0	3.9	1.3	1.0	4.5	3.1	36.1	43.5	272.9
	9	3.4	3.0	10.4	9.3	7.8	5.1	1.3	1.5	4.2	4.4	35.7	43.2	200.9
	14	3.2	3.0	10.4	9.3	8.9	6.8	2.1	1.9	6.5	5.8	44.3	52.1	185.2
	15	2.6	3.0	10.6	6.3	5.9	3.7	1.7	0.8	4.5	2.5	44.7	45.0	275.2
	18	2.4	3.0	10.5	9.0	6.5	4.7	1.8	1.4	4.4	4.3	41.2	34.5	307.6
	20	3.4	3.3	9.5	9.8	7.0	5.9	1.7	1.5	5.6	4.9	43.5	41.2	103.3
	21	2.6	3.0	10.0	9.0	6.8	5.4	2.0	1.4	5.0	4.2	44.2	48.5	228.0
LSD (0.05)														
Treatments (T)		NS	0.3	0.2	1.0	0.5	1.2	0.1	0.4	0.4	1.1	1.7	4.8	17.1
Genotypes (G)		0.4	0.1	0.6	0.3	1.4	0.4	0.3	NS	1.1	0.4	4.7	1.7	6.0
TX G		0.7	0.5	1.0	1.7	0.4	2.1	0.6	0.6	1.9	1.9	8.3	4.4	33.4

No.SPKPL = number of spikes per plant, SPKLNTH= spike length (cm), KRLWTSP= kernel weight per spike, GRNYLDP = grain yield per plant (g), WT1000 = weight of 1000 grains (g), WT g/m2 = weight of grain from one square meter.

At 70 % F.C., genotype No. 1 was superior in the first season, while No. 20 was superior in second season. At 50 % F.C., genotype No.1 was still superior in most yield components in the first season and No. 3 in the second season. Genotype No. 14 scored the highest values for weight of 1000 grain in the second season at both 70 and 50% F.C.

Moreover, in the first season, at 70% F.C., moisture levels did not significantly affect number of spikes per plant. Spike length was increased, while kernel weight per spike was reduced in all genotypes. Grain yield per plant was reduced in all genotypes except for 1 and 6. Weight of 1000 grains was also reduced in all genotypes except 2, 6 and 15. At 50% F.C. yield parameters were generally reduced for most genotypes except for number of spikes in genotypes No. 6 ,9, 14 and 20; spike weight in No. 1; grain yield per plant in No. 1 and 6 and weight of 1000 grain in No. 1, 3, 6 and 9. Contrarily, spike length increased in all genotypes except in No. 20.

In the second season, at both 70 % and 50 % F.C., yield parameters were generally reduced for all genotypes except for number of spikes in genotypes No. 3 and 20, spike length in genotypes No. 3,6,9, 20 and 21, spike weight per plant and kernel weight per spike in genotypes No. 2, 3, grain yield per plant in genotypes No. 2 (Sakha 61) and 3, weight of 1000 grain in genotypes No. 6, 9 and 14. Grain yield per m^2 was decreased for all genotypes.

It may be concluded that genotypes No. 6 in the first season and 3, 6 and 9 in the second season showed the least effect of drought at 70 % F.C. in their yield components. While at 50 % F.C. genotypes 1,6, and 9 in the first season and 3 and 9 in the second season showed the least effect of drought at 50 % F.C. in their yield components. This result could be a strong evidence for superiority of genotypes No. 3, 6, 9 under high stress (50 % F.C.) and its considered a good translation of growth and yield. It is worth noting that genotypes number 3 and 6 (which exhibited better yielding ability over the two seasons, share a common parent (Vee's', see Table 1).

Correlation analyses between yield components and growth parameters, proline, pigments as well as chemical constituents are presented in table (7). Spike weight/plant, kernel weight per spike and 1000 grain weight were positively correlated with K, N, P, total sugars and amino acids.

A highly significant positive correlation ($P<0.001$) was found between root length and leaf area in second sample and almost all yield component during 1999/2000 season (Table 7). Contrary to this, a highly significant negative correlation was found between spike length and the same yield components. Multiple regression analysis over the drought treatments showed that shoot fresh and dry weight were the only significant factors that affected grain yield per plant.

Correlation results showed that there were significant positive correlations between proline in the second sample and kernel weight per spike, grain yield per plant and 1000 grain weight (Table 7). Similar results were found by Singh *et. al.* 1973, Monneveux & Nemmar, (1986), Narayan & Misra, 1989, Ali *et al.*, (1994). These authors found that proline is implicated not only in the effects of drought on vegetative growth but also on its effect on reproductive phase (formation of the spike and grain filling). These authors presented evidences for a relation between drought tolerance for grain yield and proline accumulation capacity in the flag leaf at the beginning of the grain-filling period (which was taken in the second sample in our study).

Table (7): Correlation analysis between yield components, growth parameters and chemical constituents in the second sample during 1999/2000 season among wheat genotypes as affected by three moisture levels.

	Spike weight (g)/plant		Kernel weight/ spike		1000 kernel weight (g)		Grain yield/ plant ((g)	
Spike length	-0.279	**	-0.347	**	-0.214	NS	-0.346	**
Root length	0.464	**	0.447	**	0.112	NS	0.469	**
leaf area/pl	0.301	**	0.393	**	0.146	NS	0.353	**
Proline	0.190	NS	0.275	*	0.361	**	0.25	*
K- Shoot	0.711	**	0.688	**	0.332	**	0.765	**
N- Shoot	0.667	**	0.573	**	0.139	NS	0.683	**
P- Shoot	0.632	**	0.653	**	0.234	*	0.731	**
Total sugars in shoot	0.579	**	0.531	**	0.196	NS	0.648	**
TFAA in shoot	0.474	**	0.483	**	0.344	**	0.576	**

[a] **TFAA : Total free amino acids.**
*** Correlation coefficient is significant on 0.05 probability level.**
**** Correlation coefficient is significant on 0.01 probability level.**
NS Correlation coefficient is not significant.

CONCLUSION

Incorporating the drought-tolerant varieties is the Egyptian agriculture is becoming more and more a necessity as long as we extend the borders of our cultivated land into new environments that characterized by stressful conditions. Five genotypes No. 1, 3, 6, 9, and 18 were promising compared to the national check (Sakha 61) and can be recommended after further testing and detailed studies. Although, most genotypes responded differently at the two moisture stress levels (70 and 50% F.C.), the above genotypes generally showed the least effect of drought stress on their most growth parameters, nutrient uptake and yield and its components. Two of the source parents (Kauz's' and Vee's') were common in the tolerant genotypes and we think they have a potential as a good source for water stress tolerance in wheat breeding programs. Correlation results confirmed the role of NPK in the synthesis of total sugar and in amino acid. It also confirmed the relationship between sugar translocation from shoot to root and K level. Root length, leaf area, proline, chlorophyll, NPK, sugar and amino acids were potential criteria for assessment of drought tolerance and they were highly correlated with yield components.

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استجابة سلالات قمح الخبز الربيعية المستجلبة للاجهاد المائى

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تم تقييم واحد وعشرون سلالة من قمح الخبز المستجلبة من الايكاردا مع الصنف المصرى سخا ٦١ لدرجة تحملهم للاجهاد المائى فى موسميين متتاليين (١٩٩٩/٢٠٠٠ و ٢٠٠٠/٢٠٠١). استخدمت ثلاثة مستويات من الرطوبة وهى ١٠٠ (كونترول) ، ٧٠ و ٥٠ % من السعة الحقلية. أدت معاملات الاجهاد المائى الى نقص معنوى فى كل من قياسات النمو و تركيز العناصر المعدنية و الكلورفيل و المحصول ومكوناته بينما ارتفع محتوى البرولين للسلالات المختلفة. كانت صفات طول الجذر ومساحة الاوراق و محتوى البرولين والكلورفيل وعناصر النيتروجين و الفوسفور والبوتاسيوم بالاضافة الى السكريات و الاحماض الامينية من المعايير الجيدة لتحديد درجة التحمل للجفاف حيث ارتبطت كلها بصفات المحصول ارتباطا وثيقا. اظهرت خمس من السلالات تفوقا فى محتوى المادة الجافة و البرولين وكذلك صفات المحصول تحت ظروف الجفاف. وكانت هذه السلالات اما مساوية او متفوقة على الصنف المصرى (سخا ٦١). وقد وجد ان اثنينصدرا جيدا لتحمل الجفاف فىبرامج تربية القمح.