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Response of Twenty Wheat Varieties to Drought Stress Based on Some Agronomic Traits and Molecular Analysis

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ABSTRACT
The electrophoretic patterns of leaf water soluble proteins for 20 wheat varieties showed 17 bands. A new band of 60 kDa appeared in the patterns of the varieties Namangan and Kirsehir under drought stress. The protein bands of 23, 20 and 10 kDa were only presented in the pattern under drought stress for Xinjiang Uygur variety. The peroxidase isozymes showed four clear bands at loci of RF 0.075, 0.165, 0.25 and 0.75 which most of the varieties manifested more band intensities in the drought stress patterns than non-stressed plants. The superoxide dismutase showed three clear isozyme bands at loci of RF 0.28, 0.49 and 0.72. Out of the 20 varieties, 13 varieties manifested more band intensities in the drought patterns than the control and 4 varieties manifested the same band intensities under both conditions. The mean performance of agronomic traits for the varieties Sfaqis, Sids8, Giza164 and Trabulus gave high mean values for plant height, leaf area, number of spikes per plant and 100 grain weight, respectively under both conditions and showed high band intensities in the superoxide dismutase patterns under drought stress.

Key words: Wheat, genetic diversity, drought stress, biochemical markers

INTRODUCTION

In plants, environmental conditions and some pathogens can cause oxidative stress damage by overproduction of toxic oxygen species (Bowler *et al*., 1992; Bowler and Fluhr, 2000) which can damage cellular components such as lipids, proteins, carbohydrates and nucleic acids (Monk *et al*., 1989). The SOD is the first enzyme in the detoxifying process, converts O_2 radicals to H_2O_2. The enzymes CAT and SOD are principle enzymes which scavenge active oxygen species and avoid lipid per-oxidation, cell membranes damage and chlorophyll degradation (Smirnoff, 1993; Foyer *et al*., 1994).

Drought is one of the most frequent abiotic stresses for wheat. Drought tolerance is multigenic trait that is manifested at different levels of organization and different stages of development. Selection for drought tolerance, therefore, must involve molecular, biological, biochemical and physiological approaches using provocative induction treatments. Certain types of stressful environmental conditions can activate stress genes to produce stress proteins that enable organisms to tolerate such stresses. Molecular markers have been used to estimate the level of genetic variability in plant populations (Melchinger *et al*., 1992). Marcinska *et al*. (2013) subjected seedlings of two wheat cultivars, drought tolerance Chinese Spring (CS) and drought-susceptible (SQ1), to osmotic stress in order to assess the differences in response to drought stress between tolerant and susceptible genotypes. They measured chlorophyll content, height of seedlings, length of root, leaf osmotic potential and lipid peroxidation. The results highlighted statistically significant differences in most traits and emphasized that these conditions were optimum for expressing differences in the responses to osmotic stress between SQ1 and CS wheat genotypes.

The amount of soluble protein increases in desiccation-hardened plants and undergo changes in electrophoretic mobility (Faw and Jung, 1972). Cloutier (1983) detected quantitative changes in the electrophoretic patterns of the soluble proteins of different cultivars grown in different environments. Siosemardeh *et al.* (2004) studied water relations and soluble protein content of 11 wheat cultivars. They divided the cultivars into tolerant, semi tolerant and sensitive. Under water stressed conditions, soluble proteins concentration decreased. Significant positive correlations were obtained for relative water content and protein concentrations. Badiani *et al*. (1990) subjected 12-d-old seedlings of wheat cv. "Orso" to water deficit. They found that protein contents progressively declined with increasing water deficit whereas peroxidase (PX) was maintained or increased under the same conditions. They suggested that the enzyme activities were increased in plant tissues as a defensive response to water stress-dependent formation of H_2O_2 and in some species of superoxide dismutase.

Hashad *et al*. (2005) used the enzymes and protein patterns to determine the genetic differences between eight wheat accessions which were characterized by drought stress tolerance. They observed quantitative variations in the protein patterns. Two protein bands of 98 and 54 kDa were specific for the drought tolerant accessions. Abou-Deif (2006) used two wheat varieties "Giza168" and "Sonalika" to study the changes in seedling leaf soluble proteins and PX isozymes under drought conditions. The two varieties manifested four new bands in their protein electrophoretic patterns under drought stress. The PX isozyme bands gave a clear variation between the control and drought patterns. One new band was present in "Giza168" while two new bands appeared in "Sonalika" under drought conditions.

Plants as well as other aerobic organisms, are continuously subjected to potentially destructive Reactive Oxygen Species (ROS). A number of environmental stresses can lead to enhanced production of superoxide within plant tissues and plants are believed to rely on the enzyme superoxide dismutase (SOD) to detoxify this reactive oxygen species (Kliebenstein *et al*., 1998). The generation and elimination of ROS in plants are in dynamic balance which is systematically coordinated by the reaction among SOD, peroxide (POD) and catalase (CAT). Therefore, the balance of ROS was reflected by the activity changes of anti-oxidative enzymes. Superoxide dismutase plays a great role in the development and stress tolerance in plants (Gupta and Datta, 2003). Feng *et al*. (2004) analyzed antioxidant defenses in 2 wheat cultivars differing in sensitivity to dehydration. They showed that wheat leaves had two isoforms of MN-SOD, two isoforms of Cu/Zn-SOD and one of Fe-SOD. The activities of SOD isoforms increased in the 2 cultivars under water deficit and PX isoforms increased significantly during the whole dehydration-re-hydration period.

The objectives of this study were to analyze the genetic diversity among wheat genotypes through protein and oxidative enzymes patterns and detecting their relationships with drought stress as biochemical markers for drought tolerance.

MATERIALS AND METHODS

Materials: Sixteen hexaploid (*Triticum aestivum* L.), two tetraploid (*Triticum monococcum*) and 2 diploid (*Triticum urartu*) wheat varieties from different genetic background were used in this study (Table 1). The first eight wheat varieties (1-8) were furnished by the Wheat Research Section, Agricultural Research Center, Ministry of Agriculture, Giza, Egypt. The other 12 varieties (9-20) were from ICARDA, Alepo, Syria. The names and sources of these genotypes are shown in Table 1.

Methods

Response to drought stress based on yield related traits: The 20 wheat varieties represented in Table 1 were evaluated in 2010/2011 season in the green-house in National Research Centre, Dokki, Giza. The experiment was conducted

Table 1: Twenty wheat varieties used in the study and their origins

No.	Variety	Latin name	Origin
1	Giza157	*Triticum aestivum*	Egypt
2	Giza164	*Triticum aestivum*	Egypt
3	Gemaiza5	*Triticum aestivum*	Egypt
4	Sakha60	*Triticum aestivum*	Egypt
5	Sakha93	*Triticum aestivum*	Egypt
6	Sids8	*Triticum aestivum*	Egypt
7	Sahel1	*Triticum aestivum*	Egypt
8	Bacora	*Triticum aestivum*	Egypt
9	Xinjiang Uygur	*Triticum aestivum*	China
10	Khorasan	*Triticum aestivum*	Iran
11	Diyala	*Triticum aestivum*	Iraq
12	Trabulus	*Triticum aestivum*	Libya
13	Baluchistan	*Triticum aestivum*	Pakistan
14	Raqqa	*Triticum aestivum*	Syria
15	Sfaqis [Sfax]	*Triticum aestivum*	Tunisia
16	Namangan	*Triticum aestivum*	Uzbakistan
17	East Azarbaijan	*Triticum monococcum*	Iran
18	Kirsehir	*Triticum monococcum*	Turkey
19	At Tafilah	*Triticum urartu*	Jordon
20	Baalbek	*Triticum urartu*	Lebanon

in a randomized complete block design with three replications, each blot consisted of 40 pots in which each 2 pots out of the 40 was planted by one variety for control and water deficit. Plants were subjected to drought stress after 30 days from planting and the control was irrigated every 10 days while the stressed plants were irrigated every 20 days. The two agronomic traits, plant height and leaf area, were measured after the first 20 days of drought. Six grain yield traits; number of spikes/plant, spike length (cm), number of spikelets/spike, number of kernels/spike, 100 grains weight (g) and grain yield/plant (g) were recorded on 10 individual plants/variety in each replication. The data were subjected to statistical analysis (Snedecore and Cochran, 1969). The L.S.D. test was used for comparison between mean values (Waller and Duncan, 1969).

Protein and enzymes electrophoresis: Samples of 1 g from leaves exposed to drought stress besides control were used for protein and enzymes analyses. Sodium Dodesil Sulfate-Polyacrylamide Gel Electrophoresis (SDS-PAGE) was performed for protein analysis according to Laemmli (1970). Sample preparation and extraction of water-soluble proteins were performed according to Stegmann (1979). Gels were photographed and scanned by Gel Doc Bio-Rad System (Gel-Pro analyzer V. 3). Native-polyacrylamide gel electrophoresis was used to study the enzymes of peroxidase and superoxide dismutase. Enzyme electrophoresis was performed according to Stegemann *et al*. (1980). Methods of enzyme extraction and electrophoretic running buffers were performed according to Wendel and Weeden (1990). Isozymes staining were made according to Graham *et al*. (1965) for PX and Larsen and Benson (1970) for SOD.

RESULTS

The analysis of variance for plant height, leaf area, yield and its components showed highly significant differences among genotypes for most of the studied traits under drought conditions comparing to the control. This indicated that there are genetic differences between the studied varieties and the drought affected ones.

Mean agronomic and yield performance: Mean values of the two agronomic traits, plant height and leaf area for the 20 wheat varieties under normal and drought conditions are illustrated in Table 2. The mean values manifested that the variety Sfaqis gave the highest values for plant height under control (50.27 cm) and drought (45.27 cm) conditions. The 2 varieties Trabulus and Khorasan gave plant height values in the drought condition more than those of normal condition by 1.0 (2.3%) and 0.60 (1.5%) cm, respectively. The variety Sids8 showed the highest values for leaf area under normal (33.01 cm^2) and drought (27.85 cm^2) conditions. The variety Xinjiang Uygur gave leaf area under drought conditions more than that of normal condition by 0.16 cm^2 (0.8%).

Mean performance values of grain yield and its components for 15 wheat varieties under normal and drought stress conditions are illustrated in Table 3, where five varieties did not grow until mature plants. The variety Bacora gave the highest value for two characters, length of spike (9.58 cm) and number of spikelets per spike (18.50) under normal condition and high values (7.50 cm) and (13.75) under drought conditions with decreasing 18 and 30%, respectively. The variety Sakha93 showed the highest number of grains per spike (33.17) under normal conditions while under drought

Table 2: Means of plant height and leaf area for drought stress and control values for 20 wheat varieties

	Plant height (cm)		Leaf area (cm^2)	
Varieties	Control	Drought stress	Control	Drought stress
Giza157	41.12	31.28	32.14	18.77
Giza164	43.13	37.33	28.91	22.61
Gemaiza5	45.28	39.00	32.29	22.05
Sakha60	41.41	32.60	32.82	18.45
Sakha93	43.00	36.53	32.37	24.42
Sids8	44.13	40.80	33.01	27.85
Sahel1	41.07	35.00	29.17	19.49
Bacora	38.33	35.40	27.57	21.42
Xinjiang Uygur	37.33	35.33	19.91	20.07
Khorasan	41.07	41.67	26.47	21.83
Diyala	44.47	38.53	30.38	21.73
Trabulus	43.27	44.27	27.64	27.40
Baluchistan	47.00	39.00	26.64	19.21
Raqqa	47.20	43.33	22.77	19.67
Sfaqis	50.27	45.27	32.52	26.60
Namangan	43.07	32.57	25.55	15.57
East Azarbaijan	19.67	19.27	6.67	06.15
Kirsehir	21.33	20.20	5.51	05.15
At Tafilah	28.58	24.93	14.20	08.36
Baalbek	21.87	20.00	5.32	06.42
L.S.D 5%	7.67		7.35	
L.S.D 1%	10.18		9.75	

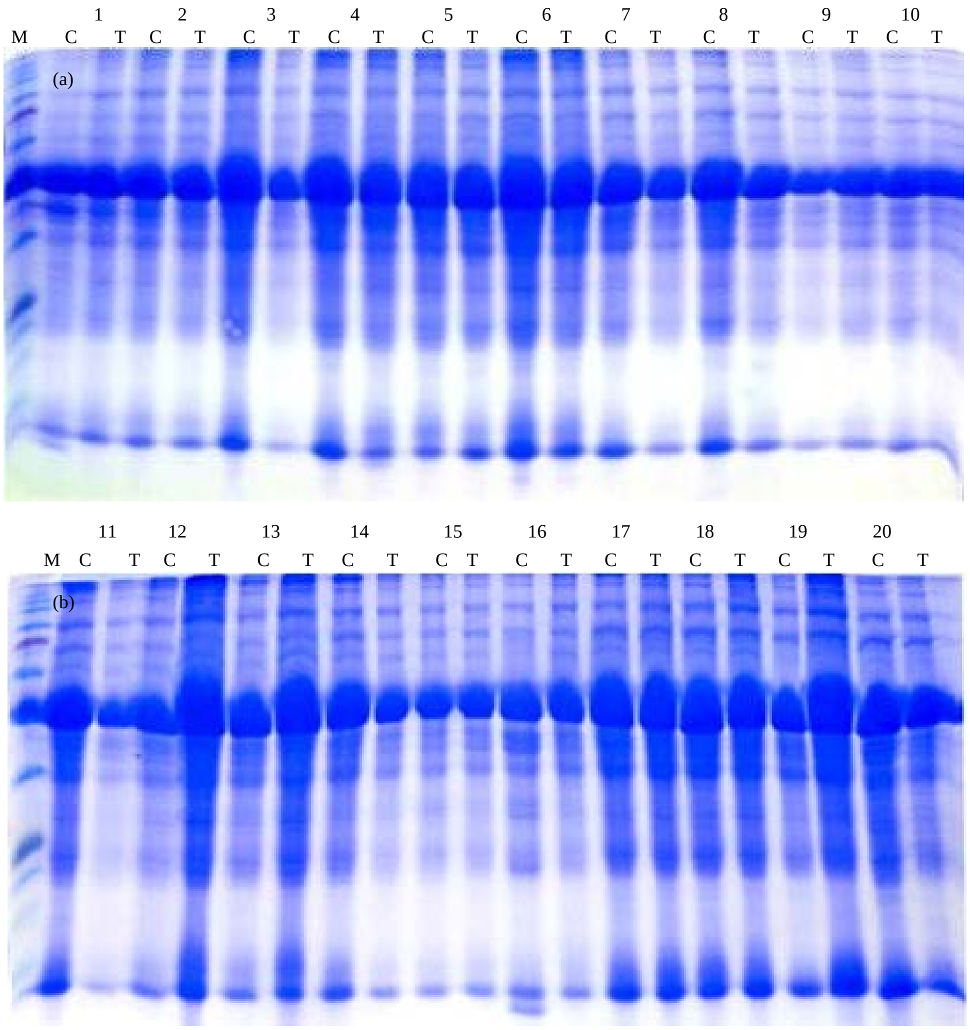

Fig. 1(a-b): Electrophoretic patterns of 20 wheat varieties for leaf water soluble proteins. M: Protein marker. The names of varieties are listed in Table 1

Table 3: Mean of yield and its components for 15 wheat varieties under control and water deficit treatments

	No. spikes/plant		Spike length (cm)		No. of spikelets/spike		No. of grains/spike		100 grain weight (g)		Grain yield/plant (g)	
Varieties	C	T	C	T	C	T	C	T	C	T	C	T
Giza157	3.56	2.00	8.72	6.25	16.44	13.50	23.83	17.75	2.99	3.75	2.03	1.15
Giza164	4.00	4.38	9.00	6.50	18.33	13.75	26.75	13.88	3.52	2.71	2.86	0.68
Gemaiza5	3.83	3.44	7.67	5.22	17.00	10.00	29.58	12.56	3.77	3.12	6.35	0.63
Sakha60	3.28	3.08	9.57	5.25	18.45	11.83	30.37	7.42	3.81	3.21	2.54	0.44
Sakha93	4.13	3.83	9.08	4.67	17.83	10.00	33.17	7.50	4.60	3.03	4.90	0.47
Sids8	3.75	3.17	8.92	5.56	18.50	10.11	27.67	7.78	4.73	3.21	3.13	0.39
Sahel1	4.25	3.75	8.33	6.36	17.33	12.67	22.00	11.33	3.59	3.12	2.14	0.70
Bacora	3.92	3.00	9.58	7.50	18.50	13.75	22.42	20.25	4.04	3.90	2.07	0.86
Xinjiang uygur	3.81	2.89	8.67	7.50	14.11	12.33	17.47	23.08	2.42	1.62	0.88	0.68
Khorasan	3.83	3.33	8.42	5.00	15.58	10.00	11.33	5.50	4.61	2.67	1.27	0.21
Diyala	3.04	2.00	8.00	6.50	17.08	12.00	26.50	11.00	2.38	1.46	1.10	0.24
Trabulus	3.50	3.17	8.00	7.75	14.00	13.83	18.00	15.50	5.69	3.95	2.20	1.24
Baluchistan	4.33	3.80	7.67	6.00	14.67	11.80	18.83	11.40	4.07	3.17	1.88	0.72
Raqqa	3.50	3.00	8.00	6.33	15.75	14.00	12.63	10.33	1.44	1.26	0.54	0.35
Sfaqis	4.25	2.42	8.00	5.50	14.92	10.33	16.92	12.75	4.73	2.98	2.83	0.74
L.S.D (5%)	1.21		1.97		3.74		12.36		1.18		2.58	
L.S.D (1%)	1.61		2.63		4.97		16.43		1.57		3.43	

C: Control, T: Treatment

conditions the variety Xinjiang Uygur was the best (23.08) which increased above the control by 33%. The variety Trabulus gave the highest weight of 100 grains under normal (5.69 g) and drought (3.95 g) conditions (6.359) with decreasing 28%. The variety Gemaiza5 gave the highest weight of grain yield per plant under normal conditions while under drought conditions the variety Trabulus was the heaviest (1.24 g). Therefore, the mean performance for agronomic traits revealed that the varieties Sfaqis, Sids8, Giza164 and Trabulus gave high values for plant height, leaf area, number of spikes per plant and 100 grain weight, respectively under both conditions. Meanwhile, the variety Bacora was the best one for the two traits of spike length and number of spikelets per spike under normal and drought conditions. For grain yield per plant, the variety Gemaiza5 gave the highest value under normal conditions while the variety Trabulus gave the highest value under drought conditions. Generally, the varieties Sakha 93 and Trabulus showed good performance in most of studied traits under normal and drought conditions, respectively.

Protein electrophoresis: The electrophoretic patterns of 20 wheat varieties for leaf water soluble proteins (Fig. 1 and Table 4) showed 17 bands, eleven bands were monomorphic and six were polymorphic. The 8 varieties Giza157, Gemaiza5, Sahel1, Xinjiang Uygur, Diyala, Raqqa, Namangan and Kirsehir exhibited polymorphic bands in different loci. The diploid varieties At Tafilah and Baalbek gave number of bands (14 bands) at the same loci in their protein patterns, indicating similar genetic background. A protein band of MW 30 kDa was presented only in the control plant pattern while disappeared in the drought stressed plant pattern of Namangan variety. One band of MW 23 kDa was absent in the pattern of Gemaiza5 under drought stress and two bands of MW 20 and 23 kDa were not presented in pattern of drought stress of Diyala. Also a band of MW 10 kDa was absent in protein patterns of Gemaiza5, Sahal1, Diyala and Raqqa varieties under drought stress and a band of 6 kDa was not shown in the patterns of Giza 157 and Namangan under drought stress conditions.

Relation between drought stress and protein patterns: The protein bands of 23, 20 and 10 kDa were presented in the pattern of drought stress for Xinjiang Uygur and absent in the control. This variety gave leaf area (20.07 cm^2) in the drought stressed plants more than that of the control plants (19.91 cm^2) as shown in Table 2, indicating tolerance to drought. On the other hand, the varieties Giza157, Gemaiza5, Sahel1, Diyala, Raqqa and Namangan lacked protein bands in their electrophoretic patterns under drought conditions. They also gave lower values under drought stress comparing with the control for plant height by 23.93, 13.87, 14.78, 13.33, 8.20 and 24.38% and for leaf area by 41.60, 31.71, 33.18, 28.47, 13.61 and 39.02%, respectively (Table 2). The varieties Giza157, Gemaiza5, Sahel1, Diyala and Raqqa showed low band numbers in the patterns of water stressed plants (Fig. 1 and Table 4) and gave low values under drought conditions comparing with the control for grain yield by 43.35, 90.08, 67.29, 78.18 and 35.19%, respectively (Table 3).

Relation between drought tolerance and peroxidase patterns: The peroxidase enzyme extracted from leaves of the 20 wheat varieties as control and drought stressed plants showed four clear isozyme bands in its electrophoretic patterns at loci of RF 0.075, 0.165, 0.25 and 0.75 as shown in Fig. 2 and Table 5. Band No. 1 of RF 0.075 appeared only in the tetraploid wheat varieties East Azarbaijan and Kirsehir and the diploid varieties At Tafilah and Baalbek while band No. 3 of RF 0.25 was not exhibited in these 4 varieties. Most of the varieties manifested higher band intensity in the drought stress patterns than non-stressed plants which may indicate tolerance against drought stress. Six varieties out of the 20 (Giza157, Giza164, Sahel1, Bacora, Namangan and Kirsehir) showed lower intensity in some bands in the drought stress patterns than the control which may indicate sensitivity against drought.

Variety Xinjiang Uygur showed more intensity bands in its peroxidase pattern under drought stress than non-stresses plants. This variety gave mean leaf area (20.07 cm^2) in the drought stressed plants than the control (19.91 cm^2) as shown in Fig. 2, Table 2 and 5 and also showed the highest mean value for number of grains per spike (23.08) under drought stress which increased above the control by 33% (Fig. 2, Table 3 and 5), indicating tolerance to drought. Variety Sfaqis gave the highest mean value for plant height (50.27 and 45.27 cm) under control and drought conditions, respectively. Variety Sids8 showed the highest values for leaf area in the control (33.01 cm^2) and drought (27.85 cm^2) conditions. The two varieties Sfaqis and Sids8 also manifested high density peroxidase bands in the patterns of both conditions.

Relation between drought tolerance and superoxide dismutase patterns: The superoxide dismutase enzyme extracted from leaves of the 20 wheat varieties as control and drought stressed plants showed three clear isozyme bands in their electrophoretic patterns at loci of RF 0.28, 0.49 and 0.72 except the variety Giza157 which gave two bands only in its pattern of control as shown in Fig. 3 and Table 6. Thirteen varieties manifested more band intensity in the drought stress patterns than the control and four varieties manifested the same band intensity under both conditions. This may indicate tolerance against drought stress comparing to the other three studied varieties Sahel1, Kirsehir and At Tafila that showed low intensity in some bands under drought conditions which may indicate sensitivity against drought stress.

The 2 varieties Khorasan and Trabulus showed higher band intensity in their SOD patterns under drought conditions than the control. They also gave mean values for plant height under drought stress (41.67 and 44.27 cm) more than the control (41.07 and 43. 27 cm), respectively (Fig. 3, Table 2 and 6). The variety Giza164 gave more intensity in all bands

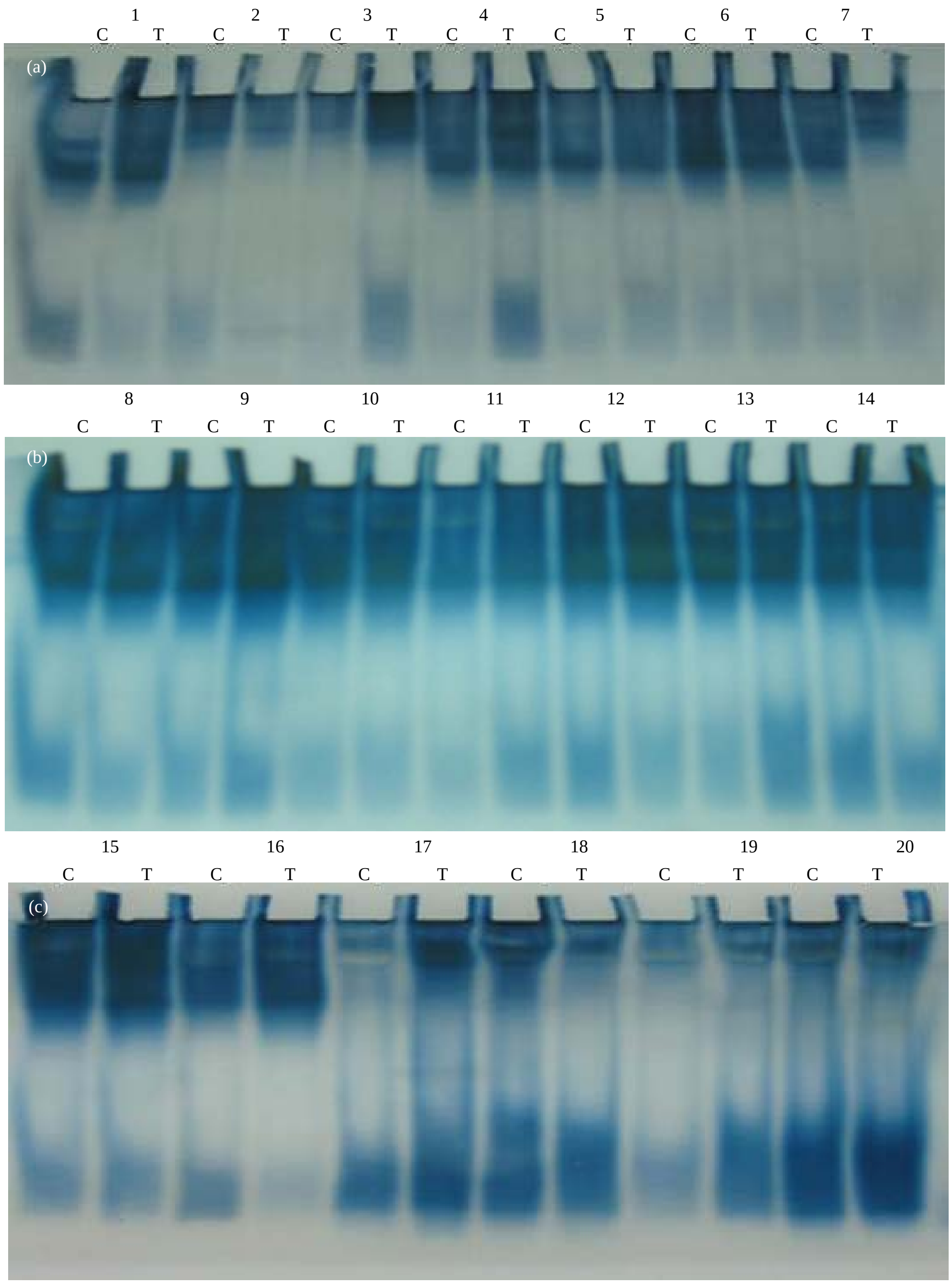

Fig. 2(a-c): Electrophoretic patterns of peroxidase isozymes for 20 wheat varieties exposed to drought stress, (a) Varieties 1-7, (b) Varieties 8-14 and (c) Varieties 15-20. C: Control and T: Treatment of drought. The names of varieties are listed in Table 1

in SOD pattern under stress and also gave the highest mean number of spikes per plant under drought stress more than the control as revealed in Fig. 3, Table 6 and 3. The variety Trabulus gave the highest mean value for spike length (7.75 cm), 100 grain weight (3.95 g) and grain yield per plant (1.24 g) under drought conditions, it also manifested higher intensity in the SOD bands under drought conditions than normal conditions (Fig. 3, Table 3 and 6).

The mean performance of agronomic traits revealed that the varieties Sfaqis, Sids 8, Giza 164 and Trabulus gave high mean values for plant height, leaf area, number of spikes per plant and 100 grain weight, respectively under both conditions. These varieties also showed high band intensity in their SOD patterns under drought stress and higher than those of non-stressed plants (Fig. 3, Table 2, 3 and 6).

Table 4: Densitometric analysis represents leaf water soluble protein electrophoretic patterns for 20 wheat varieties under normal and drought conditions

			Varieties																			
			Giza157		Giza164		Gemaiza5		Sakha60		Sakha93		Sids8		Sahel1		Bacora		Xinjiang Uygur		Khorasan	
Band No.	MW	RF	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T
1	374	0.027	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2	309	0.045	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
3	277	0.054	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
4	123	0.104	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
5	87	0.153	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
6	60	0.223	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
7	45	0.324	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
8	38	0.379	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
9	36	0.412	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
10	35	0.446	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
11	32	0.516	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
12	30	0.550	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	23	0.628	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	-	+	+	+
14	20	0.662	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	-	+	+	+
15	10	0.870	+	+	+	+	+	-	+	+	+	+	+	+	+	-	+	+	-	+	+	+
16	8	0.908	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
17	6	0.955	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

			Varieties																			
			Diyala		Trabulus		Baluchistan		Raqqa		Sfaqis		Namangan		East Azarbaijan		Kirsehir		At Tafilah		Baalbek	
Band No.	MW	RF	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T
1	374	0.027	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2	309	0.045	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
3	277	0.054	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
4	123	0.104	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
5	87	0.153	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
6	60	0.223	+	+	+	+	+	+	+	+	+	+	-	+	+	+	-	+	-	-	-	-
7	45	0.324	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
8	38	0.379	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
9	36	0.412	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
10	35	0.446	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
11	32	0.516	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
12	30	0.550	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
13	23	0.628	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
14	20	0.662	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
15	10	0.870	+	-	+	+	+	+	+	-	-	-	-	-	+	+	+	+	+	+	+	+
16	8	0.908	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
17	6	0.955	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-

MW: Molecular weight, RF: Relative front, C: Control, T: Treatment of drought stress, +: Presence of band, -: Absence of band

DISCUSSION

Protein, peroxidase and superoxide dismutase patterns and their relations with drought stress: Some protein bands were present in the electrophoretic patterns of non-stressed plants while disappeared in the drought stressed plant patterns and vise versa. These results are in agreement with those of Siosemardeh *et al*. (2004) who found that soluble protein concentrations decreased under water stressed conditions. Also, Badiani *et al*. (1990) found that protein contents progressively declined with increasing water deficit. On the other hand, a band of 60 kDa appeared in the patterns of Namangan and Kirsehir only under drought stress and another three bands of 23, 20 and 10 kDa appeared in the pattern of variety Xinjiang Uygur under drought stress. These results coincides with that of Abou-Deif (2006) who found that 2 wheat varieties Giza168 and Sonalika manifested four new bands in their protein electrophoretic patterns under drought conditions comparing with the control. One variety "Xinjiang Uygur" gave more protein bands in the drought patterns and showed high values in some agronomic traits under drought conditions comparing with the control, indicating tolerance to drought. On the other hand, other varieties such as Gemaiza5 and Diyala showed low band numbers and low values for grain yield under drought conditions comparing with the control.

Most of the varieties manifested higher band intensity in the drought stress patterns of PX isozymes and some of them gave high mean values for some agronomic traits in drought stress than non-stress conditions which may indicate tolerance against drought stress. The results indicated that peroxidase patterns were effective in distinguishing between drought tolerant and sensitive plants for the twenty studied varieties. These results are in agreement with those obtained by Abou-Deif (2006) who found that the peroxidase isozyme bands gave a clear variation between the control and

Table 5: Densitometric analysis of peroxidase profiles from leaves of the 20 wheat varieties under control and drought conditions

		Varieties																			
		Giza157		Giza164		Gemaiza5		Sakha60		Sakha93		Sids8		Sahel1		Bacora		Xinjiang Uygur		Khorasan	
Band No.	RF	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T
1	0.075	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	0.165	+++	++++	++++	+++	+++	++++	+++	++++	+++	++++	++++	++++	+++	+++	+++	++++	+++	++++	+++	+++
3	0.250	++++	++++	-	-	-	-	+++	+++	+++	++	+++	+++	+++	+	++++	++++	++++	++++	+++	+++
4	0.750	+++	+	++	+	+	+++	+	+++	+	++	+	+	+	+	+++	++	++	+++	++	++

		Varieties																			
		Diyala		Trabulus		Baluchistan		Raqqa		Sfaqis		Namangan		East Azarbaijan		Kirsehir		At Tafilah		Baalbek	
Band No.	RF	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T
1	0.075	-	-	-	-	-	-	-	-	-	-	-	-	++	++++	++++	+++	++	+++	+++	++++
2	0.165	+++	++++	++++	++++	++++	++++	++++	++++	++++	++++	+++	++++	++	+++	+++	++	++	+++	++++	++++
3	0.250	+++	+++	+++	++++	++++	++++	++++	++++	++++	++++	+++	++++	-	-	-	-	-	-	-	-
4	0.750	++	+++	+++	++	++	+++	+++	++	++	++	++	+	+++	++++	++++	++++	++	+++	++++	++++

RF: Relative front, +: Presence of band, -: Absence of band, +: Faint band, ++: Dark band, +++: Very dark band, ++++: V. Very dark band

Table 6: Densitometric analysis of SOD profiles from leaves of the 20 wheat varieties under control and drought stress conditions

		Varieties																			
		Giza157		Giza164		Gemaiza5		Sakha60		Sakha93		Sids8		Sahel1		Bacora		Xinjiang Uygur		Khorasan	
Band No.	RF	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T
1	0.28	+	+++	+++	++++	+++	++++	++++	++++	++++	++++	++	++++	++++	+++	++	++++	++++	++++	++++	++++
2	0.49	-	+++	+++	++++	+++	+++	+++	+++	++++	++++	++	++++	++	++	+	++	++	++	++	+++
3	0.72	++	++++	+++	++++	+++	++++	++++	++++	++++	++++	+++	++++	++++	++++	+++	++++	++++	++++	++++	++++

		Varieties																			
		Diyala		Trabulus		Baluchistan		Raqqa		Sfaqis		Namangan		East Azarbaijan		Kirsehir		At Tafilah		Baalbek	
Band No.	RF	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T
1	0.28	+	++	++	++++	+++	++++	+++	++++	++++	++++	++++	++++	+++	++++	++++	+++	++++	++++	++++	++++
2	0.49	+	++	+	+++	++	+++	+	+++	++	++	+	+	+	+++	+++	+++	++	+	+	+
3	0.72	+++	+++	+++	++++	+++	++++	+++	++++	+++	++++	+++	++++	++++	++++	++++	++++	+++	++++	++++	++++

RF: Relative front, +: Presence of band, -: Absence of band, +: Faint band, ++: Dark band, +++: Very dark band, ++++: V. Very dark band

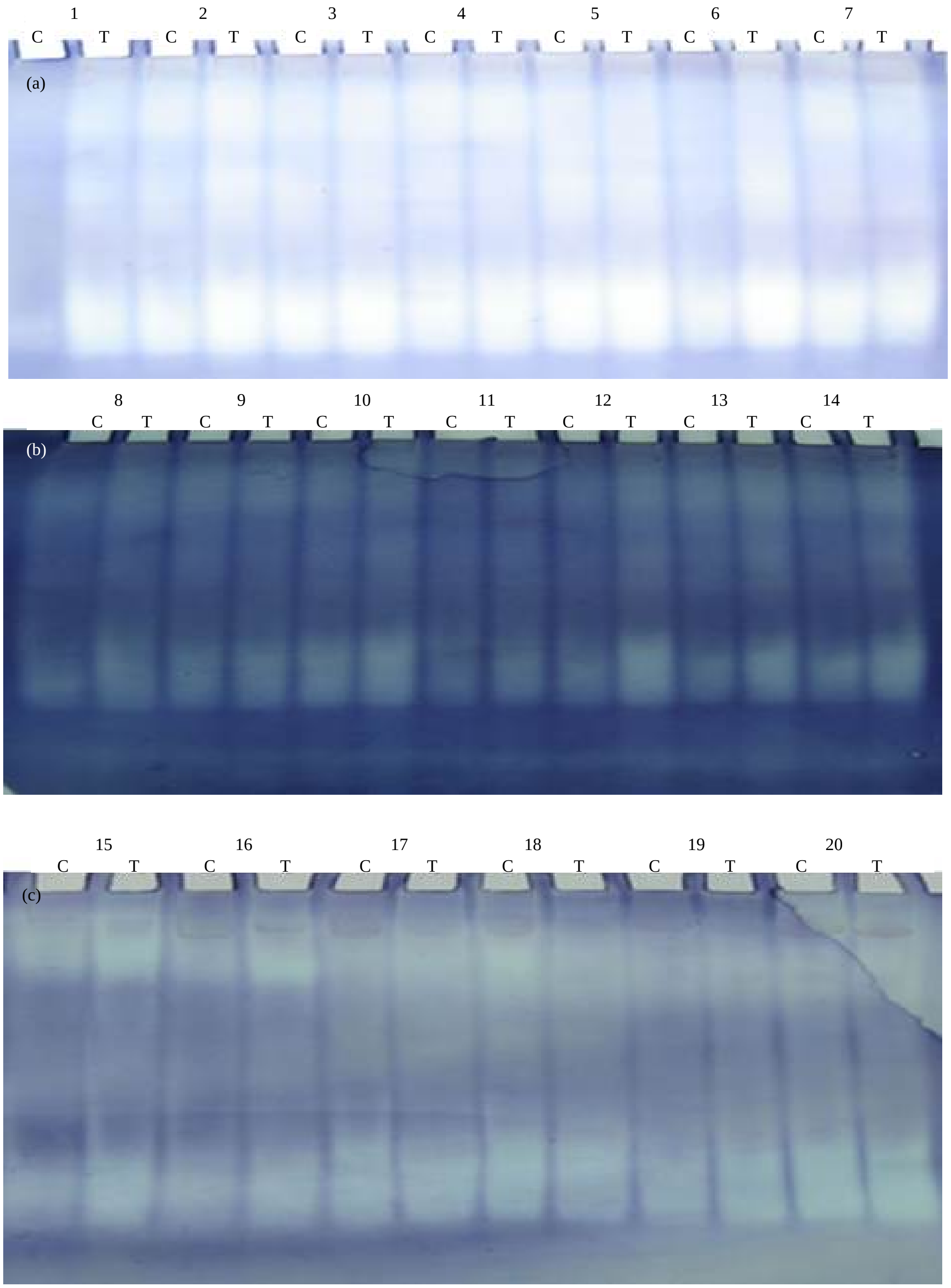

Fig. 3(a-c): Electrophoretic patterns of SOD isozymes for 20 wheat varieties exposed to drought stress, (a) Varieties 1-7, (b) Varieties 8-14 and (c) Varieties 15-20. C: Control and T: Treatment of drought. The names of varieties are listed in Table 1

drought stress and one new band was present in the drought pattern of Giza168 variety while variety Sonalika produced two bands in the electrophoretic pattern under drought conditions more than the control. The results are also in agreement with those of Badiani *et al*. (1990) who found, in wheat, that peroxidase was maintained or increased under water deficit and also Feng *et al*. (2004) who reported that peroxidase isoformes were significantly increased during dehydration period. They suggested that the enzyme activities are increased in plant tissues as a defensive response to water stress.

Out of the 20 varieties, 13 varieties manifested more band intensity in the drought stress patterns of SOD than the control and 4 varieties manifested the same band intensity under both conditions. Most of these varieties gave high mean values for some agronomic traits. This may indicate tolerance against drought stress comparing to the other 3 studied varieties that showed low intensity in some bands under drought conditions which may indicate sensitivity against drought stress. These results indicated that SOD pattern is effective in distinguishing between drought stressed and non-stressed plants and as biochemical marker for drought tolerance trait. These results agreed with those of Feng *et al*. (2004) who analyzed antioxidant defenses in 2 wheat cultivars differing in sensitivity to dehydration. They showed that wheat leaves had two isoforms of MN-superoxide dismutase (SOD), two isoforms of Cu/Zn-SOD and one of Fe-SOD. The activities of SOD isoforms were increased in 2 studied cultivars under water deficit.

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