

<http://www.pjbs.org>

**PJBS**

ISSN 1028-8880

**Pakistan  
Journal of Biological Sciences**

**ANSI***net*

Asian Network for Scientific Information  
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

## Response of Two Differentially Drought Tolerant Varieties of Maize to Drought Stress

Ibrahim, M. Zeid and Nermin, A. El-Semary

Botany Dept. Faculty of Science, Helwan Univ., Ain Helwan, Cairo, Egypt

**Abstract:** The grains of two differentially drought tolerant varieties of maize, Giza 2 and Single Cross Hybrid 155 (SCH 155), were planted under different levels of drought stress induced by polythene glycol (PEG 4000) to study their response to drought stress in absence or presence of the growth regulators cycocel (CCC) or gibberellic acid ( $GA_3$ ). Giza 2 was more tolerant than SCH 155, since 50 % of its grains have germinated at the water potential  $-0.8$  MPa, while the germination percentage of SCH 155 grains was reduced to 30% at the soil water potential  $-0.6$  MPa, and 100% inhibited at  $-0.8$  MPa treatment. However, the application of growth regulators (CCC and  $GA_3$ ) induced germination of SCH 155 grains under severe osmotic potential ( $-0.8$  MPa) to become 30%. The photosynthetic efficiency of Giza 2 leaves was higher than SCH 155 variety at all levels of soil water potentials. Growth regulators treated plants had higher protein, total nitrogen, sugars, and mineral ions than untreated plants.

**Key words:** Amino acids, germination, Giza 2, growth regulators, photosynthesis, polythene glycol, SCH 155.

### Introduction

Water is the important limiting factor for the crop production in arid and semiarid areas of the world. If sufficient water is not available, application of fertilizers and high yielding crop varieties are useless. Drought stress, in general, reduces nutrient uptake by roots and transport from roots to shoots, because of restricted transpiration rates and impaired active transport and membrane permeability resulting in a reduced root-absorbing power of crop plants (Erlandsson, 1975). Plants may increase its drought tolerance by decreasing osmotic potential by accumulation of solutes, which allows cell enlargement, plant growth and keeps stomata open and  $CO_2$  assimilation under drought conditions. Many solutes may be used in osmotic adjustment including inorganic ions, such as  $Na^+$ ,  $K^+$  and  $Cl^-$  (Ford and Wilson, 1981; Wyn Jones and Gorhan, 1983) and organic solutes such as sugars and amino acids, especially proline (Navari-Izso *et al.*, 1990). Polyethylene glycol (PEG) is a neutral polymer available in a range of molecular weights, highly soluble in water with toxicity to mammals. PEG is widely used to induce drought stress under laboratory conditions. Wu (1987) reported that the tomato seed germination percentage decreased with decreasing water potential from 0 to  $-4$  bar using PEG 6000. Presoaking in water, salt solutions and phytohormones and drying the seeds before planting is one of the techniques applied to enhance the germination and also to increase drought or salt tolerance of seeds (Shannon and Francois, 1977).  $GA_3$  application had an enhancing effect on germination of seeds under drought stress (Beak *et al.*, 1993) and salt stress conditions (Dhankhar and Singh, 1996). The promoting effect of  $GA_3$  on seed germination might be attributed to an increase in  $\alpha$ -amylase activity, thus increasing soluble sugars and this may enable the embryo to germinate and accelerate the mobilization of reserves from endosperm (Martin, 1975). Application of CCC also had appreciable effect on seed germination e.g., cucumber (Kazim and Khalil, 1983), and fenugreek (Ambika *et al.*, 1995). Ambika *et al.*, (1995) found that the protein and amino acid contents were higher in seedlings of CCC-treated seeds than those of untreated ones.

The present study was conducted to test the hypothesis that the plant uses the inorganic or organic solutes for cellular osmoregulation in response to drought stress conditions, with special reference to the variations in the free amino acid pool

in leaves of two differentially drought tolerant varieties of maize. Plant hormones were also applied to test their effect on seed germination and the metabolic activity of the two varieties.

### Materials and Methods

A preliminary experiment using seven genotypes of *Zea mays* [Single Cross Hybrids (SCH) 10, 122, 123, 129, 155; three ways-cross hybrid TCH 320; open-pollinated variety Giza 2] indicated that the osmotic value of  $-1.0$  MPa totally inhibited seed germination of the seven genotypes. Giza 2 exhibited higher germination percentage and best growth than other genotypes at  $-0.8$  MPa treatment, while SCH 155 seeds were totally inhibited at this osmotic value. Giza 2 and SCH 155 were considered as a drought tolerant and a drought sensitive varieties, respectively. Another preliminary experiment was carried out using a series of concentrations of the growth regulators, indole acetic acid (IAA), gibberellic acid ( $GA_3$ ), and chlorocholine chloride (CCC), to improve germination and early growth of Giza 2 and SCH 155 varieties under drought stress conditions.  $GA_3$  at concentration of  $100$  mg  $L^{-1}$  and CCC at concentration of  $1000$  mg  $L^{-1}$  resulted in a maximum germination percentage, best growth of seedlings, and highest relative water content of leaves.

Germination percentage was expressed as:

$$\text{Germination Stress Index (GSI)} = \frac{\text{Germination of stressed seeds}}{\text{Germination of control seeds}} \times 100$$

The present experiment was carried out using two maize genotypes, Giza 2 (drought-tolerant) and SCH 155 (drought-sensitive), which were germinated in pure sand culture in plastic pots (25 cm diameter, 20 cm depth). Each pot contained 25 grains and irrigated with Hoagland's nutrient solution under natural conditions. The temperature ranged between 28 to 35°C. After full germination (one week after sowing), the pots of each variety were divided into three groups, and each group was divided into five sets. Each set consisted of four replicates. The first five sets were subjected to the water potential values 0,  $-0.2$ ,  $-0.4$ ,  $-0.6$ , and  $-0.8$  MPa. The second five sets were subjected to the same osmotic values and treated with  $100$  mg  $L^{-1}$   $GA_3$  in the nutrient solution. While the third five sets were subjected to the same osmotic values and treated with  $100$  mg  $L^{-1}$  CCC.

## Zeid and El-Semary: Response of two maize varieties to drought stress

After 12 days from sowing, the plant samples were prepared for analysis. Borate buffer (pH 8) extract of dried plant material was used for estimation of soluble nitrogenous compounds (Naguib, 1969). The total-N content was estimated in the acid digested samples (50% sulphuric acid and 35% perchloric acid) as free ammonia using Borthelol reaction, according to the procedures mentioned by Fawcett and Scott (1960), and Chaney and Marbach (1962). Nitrate-N was measured according to Paech and Tracey (1956). Amino-N was determined according to Russel (1944). The procedure of Lowry *et al.* (1951) was followed for measuring the peptide-N content. Free amino acids were assayed on Eppendorff Biotronk Amino Acid Analyzer model 3000, in the Regional Center for Mycology and Biochemistry, Nasr city, Cairo. Photosynthetic efficiency was measured as the rate of CO<sub>2</sub> consumption during photosynthesis by using Licor-6200 instrument (in the Agricultural Research Center, Giza, Egypt). The leaf content of carbohydrates was determined using anthrone reagent as described by Umbriet *et al.* (1959). The mineral ions content was analyzed (in the Agricultural Research Center, Giza, Egypt), in acid digested samples. Na, K, and Ca content were determined photometrically using a

Corning-400 flame photometer. Mg, Fe, P, and Mn content was determined using atomic absorption spectrophotometer (Perkin Elmer 2380).

Statistical analysis was carried out according to Snedecor and Cochran (1980) using analysis of variance (Completely Randomized three-factor Design) and the significance was determined using LSD values at 0.05 and 0.01 levels.

### Results

Germination percentage under drought stress conditions was expressed as germination stress index (GSI) and represented in Table 1. The results indicated that the germination of Giza 2 grains was reduced to 60% at -0.6 MPa and 50% at -0.8 MPa treatment, while the reduction in germination of the drought-sensitive genotype SCH 155 started at -0.2 MPa (80%) and decreased progressively and recorded zero% at -0.8 MPa. However, the application of CCC and GA<sub>3</sub> markedly stimulated the germination of SCH 155 grains by 30% at severe osmotic stress value (-0.8 MPa).

Variations in nitrogen metabolism in response to drought stress and treatment with CCC and GA<sub>3</sub> are presented in Table 1. Amount of ammonia increased and accumulated with the

Table 1: Effect of PEG-induced drought stress and growth regulators on seed germination and nitrogenous components [mg g<sup>-1</sup> (d.m.)] of maize leaves (n= 4)

Variety	Treatments			Ammonia-N	Nitrate-N	Amino acid N	Peptide N	Total soluble N	Insoluble N	Total-N	
	Growth regulators	Water Potential (Mpa)	Germination stress index (GSI)								
Giza 2	0	control (0)	100	0.035	0.32	1.45	19.71	27.32	45.96	73.28	
		-0.2	100	0.053	0.45	1.64	20.80	28.78	36.64	65.42	
		-0.4	100	0.093	0.47	1.84	26.47	30.84	28.16	59.00	
		-0.6	60	0.1451	0.56	2.07	27.52	32.80	23.08	55.88	
		-0.8	50	0.193	0.70	2.08	28.31	35.56	14.18	49.74	
	CCC	0	100	0.111	0.25	1.42	19.90	24.89	75.68	100.57	
		-0.2	100	0.134	0.38	1.65	21.26	26.96	71.16	98.12	
		-0.4	100	0.177	0.43	1.90	23.80	29.83	63.36	93.19	
		-0.6	65	0.206	0.47	2.11	26.39	30.62	42.77	73.39	
		-0.8	50	0.237	0.66	2.71	27.11	34.15	32.84	66.99	
	GA <sub>3</sub>	0	100	0.076	0.38	1.47	18.76	28.34	68.21	96.55	
		-0.2	100	0.077	0.44	1.57	20.11	31.35	53.89	85.24	
		-0.4	100	0.141	0.47	1.73	21.36	33.24	48.33	81.57	
		-0.6	70	0.171	0.69	2.09	22.84	34.72	40.27	74.99	
		-0.8	60	0.200	0.80	2.11	23.85	36.98	32.94	69.92	
	SCH 155	0	control (0)	100	0.021	0.35	2.06	19.60	22.72	45.02	67.74
			-0.2	80	0.062	0.48	2.09	21.51	25.57	36.90	62.47
			-0.4	60	0.063	0.51	2.19	23.72	28.05	28.71	56.76
-0.6			30	0.065	0.61	2.21	27.21	31.64	16.02	47.66	
-0.8			0	0.077	0.70	2.30	29.45	34.22	9.25	43.47	
CCC		0	100	0.104	0.27	2.14	19.24	22.60	69.96	92.56	
		-0.2	90	0.105	0.42	2.21	19.55	23.14	54.39	77.53	
		-0.4	80	0.123	0.48	2.47	21.80	25.42	50.06	75.48	
		-0.6	60	0.270	0.51	2.46	23.10	29.20	45.25	74.45	
		-0.8	30	0.270	0.69	2.51	24.64	30.98	35.58	66.56	
GA <sub>3</sub>		0	100	0.037	0.39	2.13	19.16	22.88	61.43	84.31	
		-0.2	100	0.040	0.47	2.15	20.46	26.10	49.31	75.41	
		-0.4	85	0.100	0.58	2.24	22.60	27.67	46.69	74.36	
		-0.6	65	0.150	0.70	2.27	24.24	29.58	38.38	67.96	
		-0.8	30	0.170	0.80	2.40	25.71	30.54	33.39	63.93	
LSD		at 0.05	2.6	0.017	0.15	0.04	0.4	3.4	4.3	4.3	
LSD		at 0.01	3.4	0.022	0.20	0.06	0.6	4.5	5.8	5.8	

**Zeid and El- Semaary: Response of two maize varieties to drought stress**

**Table 2:** Effect of PEG-induced drought stress and growth regulators on the carbohydrate content [ $\text{mg g}^{-1}$  (d.m.)], and photosynthetic efficiency ( $\mu\text{mol. M}^{-2} \text{s}^{-1}$ ) of maize leaves (n= 4)

Variety	Treatments		Total sugars	Starch	Total Carbohydrate	Photosynthetic efficiency	
	Growth regulators	Water potential (Mpa)					
Giza 2	control	(0)	36.96	94.59	131.55	37.26	
	0	-0.2	37.67	88.98	126.65	24.73	
		-0.4	41.38	80.32	121.70	10.85	
		-0.6	41.47	71.43	112.90	3.18	
		-0.8	42.80	60.40	103.20	1.74	
	0	0	42.90	86.10	129.00	44.73	
		-0.2	47.56	74.39	121.95	32.24	
		-0.4	50.79	71.06	121.85	22.28	
		-0.6	51.79	57.06	108.85	12.2	
	CCC	0	59.31	43.84	103.15	4.93	
		-0.2	49.56	70.19	119.75	70.31	
		-0.4	49.71	65.79	115.50	26.78	
		-0.6	50.05	58.45	108.50	9.47	
	GA <sub>3</sub>	0	59.46	44.94	104.40	4.62	
		-0.2	63.03	39.22	102.25	1.28	
-0.4							
-0.6							
SCH 155	control	(0)	33.09	95.46	128.55	25.37	
	0	-0.2	40.20	84.25	124.45	20.75	
		-0.4	44.73	66.77	111.50	9.55	
		-0.6	45.31	59.34	104.65	1.22	
		-0.8	45.34	54.41	99.75	1.01	
	0	0	49.42	63.48	112.90	34.84	
		-0.2	53.34	51.36	104.70	24.51	
		-0.4	58.05	46.20	104.25	11.98	
		-0.6	64.22	34.78	99.00	4.84	
	CCC	-0.8	71.68	25.07	96.75	1.29	
		0	51.96	56.64	108.60	29.26	
		-0.2	55.56	48.39	103.95	21.67	
		-0.4	59.64	43.06	102.70	10.72	
	GA <sub>3</sub>	-0.6	71.17	27.23	98.40	3.84	
		-0.8	78.74	17.41	96.15	1.27	
		LSD	at 0.05	3.6	3.9	3.9	1.9
		LSD	at 0.01	4.8	5.2	5.2	2.5

**Table 3:** Effect of PEG-induced drought stress on mineral ions content [ $\text{mg g}^{-1}$  (d.m.)] of maize leaves.

Variety	Treatments		Na	K	Ca	Mg	P	Mn	Fe	Total
	Growth regulators	Water potential (Mpa)								
Giza 2	control	(0)	7.84	5.13	0.13	2.62	0.032	0.042	0.31	16.10
	0	-0.2	6.82	4.20	0.15	2.24	0.030	0.044	0.24	14.72
		-0.4	6.25	4.08	0.16	2.61	0.030	0.060	0.28	13.47
		-0.6	6.89	4.20	0.13	2.12	0.024	0.064	0.40	13.83
		-0.8	6.52	4.30	0.07	2.24	0.018	0.060	0.35	13.56
	0	0	7.27	5.23	0.18	2.59	0.024	0.060	0.25	15.60
		-0.2	8.07	5.57	0.18	2.84	0.022	0.062	0.28	17.02
		-0.4	7.16	5.80	0.16	2.08	0.020	0.066	0.42	15.71
		-0.6	8.18	6.02	0.17	2.29	0.024	0.058	0.40	17.14
	CCC	-0.8	8.18	6.13	0.13	2.14	0.022	0.065	0.27	16.93
		0	6.70	5.57	0.18	2.11	0.020	0.044	0.17	14.79
		-0.2	6.30	6.14	0.18	2.17	0.020	0.056	0.15	15.02
		-0.4	5.68	5.45	0.22	2.55	0.020	0.044	0.18	14.14
	GA <sub>3</sub>	-0.6	4.70	5.45	0.22	2.51	0.024	0.054	0.20	13.16
		-0.8	4.70	5.45	0.20	2.26	0.024	0.042	0.19	12.87
control		(0)	3.14	4.31	0.14	2.89	0.026	0.054	0.26	10.82
SCH 155		0	-0.2	2.57	4.77	0.14	2.24	0.026	0.078	0.33
	-0.4	2.57	4.54	0.14	2.48	0.020	0.062	0.23	10.04	
	-0.6	2.23	4.43	0.13	2.57	0.028	0.062	0.24	9.69	
	-0.8	2.18	3.30	0.12	2.39	0.026	0.074	0.23	8.32	
	0	0	5.14	5.75	0.23	1.40	0.018	0.052	0.23	12.82
		-0.2	5.82	6.36	0.25	1.75	0.028	0.070	0.18	15.56
		-0.4	6.25	6.14	0.24	1.69	0.016	0.050	0.19	14.58
		-0.6	5.57	6.25	0.23	1.40	0.026	0.060	0.21	13.75
	CCC	-0.8	5.68	5.91	0.25	1.26	0.022	0.060	0.20	13.38
		0	6.68	5.91	0.21	1.89	0.016	0.046	0.24	14.99
		-0.2	7.04	5.91	0.19	1.62	0.028	0.044	0.23	15.06
		-0.4	7.38	6.36	0.17	1.45	0.018	0.054	0.39	15.82
	GA <sub>3</sub>	-0.6	5.91	6.13	0.22	1.50	0.028	0.056	0.29	14.13
		-0.8	5.48	6.36	0.24	1.84	0.028	0.058	0.25	14.26

two maize varieties to drought stress

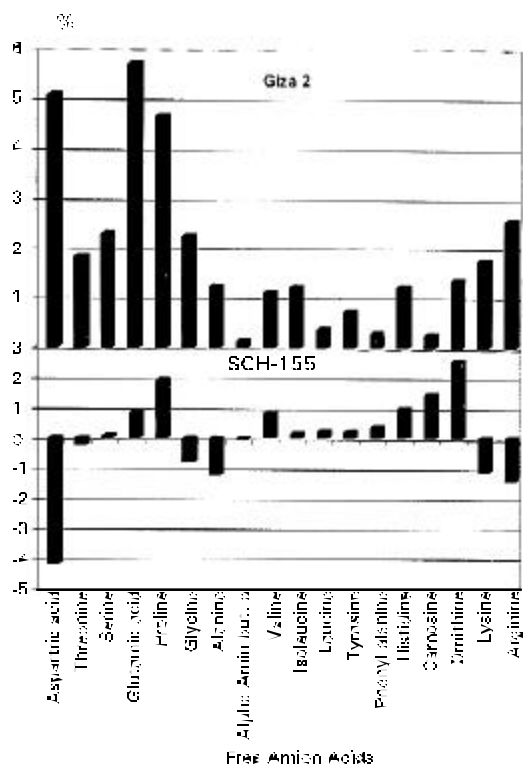


Fig. 1: Variations in the composition of free amino acid pool in leaves of maize seedling subjected to drought stress (-0.8 Mpa) as compared to the control unstressed plants. Data show how each single amino acid increase or decrease its percentage proportion in the free amino acid pool following the treatment.

progressive decrease in soil water potential. Application of CCC and GA<sub>3</sub> significantly increased accumulation of ammonia in drought-stressed and unstressed plants. The nitrate-nitrogen content tended to increase with increasing drought stress. The amino-N content significantly increased with the gradual decrease in soil water potential in growth regulators treated and untreated plants. In general, the amount of amino-N in leaves of SCH 155 variety was more than that of Giza 2. Treatment with CCC and GA<sub>3</sub> significantly increased amino-N content in both varieties. The peptide-N content exhibited a gradual increase with increasing drought stress in untreated and treated plants with growth regulators. Application of CCC and GA<sub>3</sub> reduced the peptide-N content in drought stressed plants compared with untreated plants. The total soluble nitrogenous compounds markedly increased under drought stress conditions, in growth regulators treated and untreated plants. Most of the insoluble nitrogen fraction represents the protein-N content. It was markedly diminished in drought-stressed plants. Treatment with growth regulators considerably increased protein-N content as compared to untreated plants under all levels of water potentials tested. Total-N content significantly decreased with drought stress. Application of CCC or GA<sub>3</sub> has increased the total-N content in drought-stressed and unstressed plants, when compared with the corresponding untreated plants of both varieties. The concentration of total-N in leaves of SCH 155 variety was generally, less than that of Giza 2 at different treatments of drought stress and growth regulators.

Variations in the balance of the free amino acid pool in plants subjected to severe drought stress (-0.8 Mpa), in comparison to control unstressed plants are illustrated in Fig. 1. In Giza 2

leaves, the rearrangement of the amino acid pool involved a strong increase in the amount of glutamate, aspartate and proline 5.67, 5.06 and 4.64%, followed by arginine, serine and glycine 2.52, 2.26, 2.23%, and then threonine, ornithine, alanine, histidine, isoleucine and valine 1.81, 1.33, 1.2, 1.19, 1.18, 1.08%, respectively. A slight increase was observed in tyrosine, leucine, phenylalanine, carnosine and alpha-amino butyric acid 0.71, 0.35, 0.26, 0.24 and 0.12%. In SCH 155 leaves, an increased accumulation of ornithine (2.51%) was observed, followed by proline and carnosine 1.88, 1.43%, and then histidine, glutamate, valine 0.94, 0.81, 0.8%, respectively. A slight increase was observed in phenylalanine, leucine, tyrosine, isoleucine and serine 0.35, 0.22, 0.21, 0.14 and 0.07%, respectively, while the amount of aspartate, arginine, alanine, lysine, glycine, and threonine was reduced by 4.92, 1.41, 1.22, 1.1, 0.8, and 0.25%, respectively less than the control.

Data in Table 2 indicates a highly significant reduction in photosynthetic activity in both varieties. Photosynthetic activity of Giza 2 leaves was higher than SCH 155 under all levels of drought stress. Application of GA<sub>3</sub> did not increase photosynthetic activity. However, the application of CCC markedly activated photosynthesis in unstressed and drought-stressed plants until -0.6 MPa treatment in Giza.2 and -0.4 MPa in SCH 155, while its effect was insignificant at severe drought stress (-0.8 MPa), in comparison with untreated plants.

Decreasing the soil water potential from 0 to -0.8 MPa by PEG remarkably increased the content of soluble sugars which was associated with a marked decline in starch (Table 2). Treatment with growth regulators (CCC and GA<sub>3</sub>) significantly increased the soluble sugars content compared with untreated plants under different osmotic values of the soil solution. The increment was more pronounced in plants treated with GA<sub>3</sub>. The reduced content of starch was more obvious in SCH 155 and GA<sub>3</sub>-treated plants.

The results presented in Table 3 indicate a significant reduction in leaf content of total mineral nutrients (Na, K, Ca, Mg, P, Mn, Fe) with the reduction in the available soil water. Giza 2 variety retained a relatively higher content of mineral nutrients as compared to SCH 155 variety. Application of CCC and GA<sub>3</sub> increased K and Ca content in both varieties. The leaf content of P, Mn, and Fe was low and irregular towards drought stress and growth regulators treatment in both varieties of maize.

## Discussion

Polyethylene glycol (PEG) decreases the available soil water required for seed germination and plant growth. The inhibitory effect of PEG on seed germination of different plants was recorded by many investigators (Stout *et al.*, 1980, Heikal and Shaddad, 1982 on cotton, pea and wheat, Kuhad *et al.*, 1987 on *Pennisetum americanum*). The promoting effect of GA<sub>3</sub> on seed germination, as suggested by Martin (1975) and Bush (1996), might be attributed to an increase  $\alpha$ -amylase activity, thus increasing soluble sugars and this may enable the embryo to germinate and accelerate the mobilization of reserves from endosperm. Many workers reported that treatment with GA<sub>3</sub> may diminish the adverse effects of drought-stress (Beak *et al.*, 1993) and salt-stress (Tipirdamaz *et al.*, 1995) on seed germination. Ambika *et al.* (1995) also reported an appreciable effect of CCC application on seed germination.

The accumulation of ammonia under drought stress conditions supports the postulate that the drought-induced ammonia accumulation may be due to diminution of anabolic processes (protein synthesis and growth), meanwhile, there is a feedback inhibition for N uptake and nitrate reduction (Mifflin and Lea, 1980), leading to subsequent detoxification by sequestering ammonia into nitrogen-containing compounds

(e.g., proline). Reddy *et al.* (1990) suggested that the higher activities of NAD and NADP-dependent glutamate dehydrogenase enzymes may form a mechanism to assimilate excess ammonia under drought stress. The observed accumulation of nitrate-N with increasing water deficit (Table 1) may be explained by the observations of Reddy *et al.* (1990), who recorded a decrease in nitrate reductase activity under drought stress conditions, and Foyer *et al.*, (1998), who found that this reduction was accompanied by a decrease in nitrate reductase transcript. The reduction in peptide-N content in drought stressed plants in response to growth regulators treatment may be due to its incorporation in protein synthesis which significantly increased under all levels of water potentials. The total soluble nitrogenous compounds including amino acids may play an important role in cellular osmotic regulation under drought stress conditions. The reduction in protein-N (or insoluble-N) content in plants grown under water deficit conditions might be attributed to decreased synthesis and increased protease activity as suggested by Rose (1988). The increased level of protein-N in CCC and GA<sub>3</sub> treated plants agree with the observations of Banyal and Rai (1983), who proposed that the recovery of protein level in drought-stressed plants by GA<sub>3</sub> may be related to effects at the ribosomal levels. Drought stress increases monosome content (Hsiao, 1970), while GA<sub>3</sub> treatment promotes the formation of polyribosomes (Evans and Varner, 1972). Ambika *et al.* (1995) also recorded increased content of protein and amino acids in seedlings of CCC-treated seeds than those of untreated ones under water deficit conditions. The present observations are in agreement with those of Khan and Singh (1983), who reported that glutamate may represent a terminal point of biosynthetic pathways and can be regarded as an indication of impaired protein synthesis and increased protein hydrolysis. The accumulation of proline may be attributed to its stimulated synthesis via glutamate pathway (Buhl and Stewart, 1983), or due to the inhibition of proline dehydrogenase proline oxidase under stress conditions (Kumari and Veeranjayulu, 1996). In Giza 2, the increased level of arginine may be attributed to its synthesis from glutamate (as an amine donor) through ornithine (Ranieri *et al.*, 1989). In SCH 155, the increased level of ornithine and the decreased level of arginine may be due to suppression of ornithine conversion to arginine. Photorespiration may rise briefly as stress develops and stomata close (Clarke and Dureley, 1984). This may explain the increase in glycine and serine in Giza 2 and their reduction in SCH 155, which may suggest that the activity of glycolate pathway may play a role in the drought-tolerance mechanism. The observed increase in aspartate and alanine in Giza 2 agree with the observations of Reddy *et al.* (1990) who pointed out that the enhanced activities of aspartate amino-transferase and alanine aminotransferase may suggest the conversion of Keto acids into amino acids in the presence of accumulated ammonia. The increment of soluble sugars which was associated with a decline in starch content may be attributed to the drought-induced activity of amylases (Sheoran, 1980; Dhingra and Varghese, 1986). The increased levels of organic solutes such as soluble sugars and amino acids as a result of increased activity of hydrolytic enzymes (Zayed and Zeid, 1998) is considered as a very important phenomenon for osmotic regulation under water stress conditions, since it increases the capacity of the root to absorb water from the soil solution of high osmotic value. The role of growth regulators is to accumulate the soluble sugars through activation of amylases for osmotic adjustment and improvement of the plant water balance. These results agree with that of Abdalla (1992), and Hamdie and El-Komy (1998). The observed accumulation of sugars in the leaves support the

suggestion of Pelleschi *et al.* (1997), who postulated that the translocation of assimilates may be affected by drought stress, and the resulting assimilate saturation in the leaves may limit photosynthesis. The stimulating effect of CCC on photosynthesis was also recorded by Sairam *et al.* (1991), which may be attributed, to some extent, to the increase in leaf water potential by the influence of CCC treatment. The increased content of K and Ca in both varieties as a result of CCC and GA<sub>3</sub> treatment support the results of Jones and MacMillan (1987), who reported that GA<sub>3</sub> treatment alleviates the reductive effect of drought stress by increasing or promoting the content of K and Ca which governs shoot tissue extensibility by maintaining the turgidity of plant tissue under drought stress conditions.

On the basis of results following conclusions have been made:

- 1 Drought-stressed maize plants tends to accumulate organic solutes e.g., sugars and the soluble nitrogenous compounds including amino acids, for cellular osmoregulation under drought stress conditions, which was associated with a great reduction in starch and protein content. The limited photosynthesis in drought-stressed plants might be attributed to sugar accumulation in the leaves.
- 2 Giza 2 plants had higher photosynthetic activity, the total-N and the total mineral ion content than SCH 155. These results point out that Giza-2 plants had higher metabolic activities than SCH 155. The drought-induced accumulation of certain amino acids e.g., glutamic acid, aspartic acid, arginine, serine, and glycine besides proline in Giza 2 leaves indicates that these amino acids may serve as indicators of the drought-tolerance in maize genotypes.
- 3 Treatment with growth regulators alleviated the drought-induced damage on seed germination, particularly in case of the drought-sensitive variety SCH 155. These observations indicate that the growth regulators-treated plants had higher metabolic activities than untreated plants. The accumulation of sugars, K and amino acids may account for the high osmo-regulation in growth regulators-treated plants under drought stress conditions.

## References

- Ambika, S.R., B.I. Shaheena and S. Bi, 1995. Stress proteins induced by cycocel in fenugreek. - *Flora Fauna* 1: 13- 18.
- Beak, S.B., G.Y. Kim and H.B. Kim, 1993. Accelerated gemination of orchard grass (*ata*) seed under water stress by seed pretreatment. - *J. Korean Soc. Grassl. Sci.*, 13: 31- 37.
- Buhl, M.B. and C.R. Stewart, 1983. Effects of NaCl on proline synthesis and utilization in excised barley leaves. *Pl. Physiol.*, 72: 664- 667.
- Bush, D.S., 1996. Effects of gibberellic acid environmental factors on cytosolic calcium in wheat aleurone cells. - *Planta*, 199: 89- 99.
- Chaney, A.L. and Marbach, 1962. Modified reagents for determination of urea and ammonia. - *J. Clin. Chem.*, 8: 180- 182.
- Clarke, J.M. and R.C. Dureley, 1984. Water stress on plants The response of plants to drought stress. Tata McGraw Hill Press.
- Dhankhar, D.S. and M. Singh, 1996. Seed germination and seedling growth in ammonia (*Phyllanthus emblica*) as influenced by gibberellic acid and thiourea. *Crop Res.*, 12: 363-366.
- Dhingra, H.R. and T.M. Varghese, 1986. Effect of NaCl salinity on the activities of amylase and invertase in *Zea mays L.* - *Pollen. Ann. Bot.*, 57: 101-104.

## Zeid and El-Semary: Response of two maize varieties to drought stress

- Erlandsson, G., 1975. Rapid effects on ion and water uptake induced by changes of water potential in young wheat plants.- *Physiol. Plant*, 35: 256-262.
- Evans, W.H. and J. E. Varner, 1972. Hormonal control of polyribosome formation in barley aleurone layers.- *Plant Physiol.*, 49: 348 – 352.
- Fawcett, J.K. and J.E. Scott, 1960. A rapid and precise method for the determination of urea.- *J. Clin. Pathol.*, 13: 156- 159.
- Ford, C.W. and J.R. Wilson, 1981. Changes in levels of solutes during osmotic adjustment to water stress in leaves of 4 tropical pasture species.- *Aust. J. Plant Physiol.*, 8: 77- 91.
- Foyer, C.H., M.H. Valadier, A. Migge and T.W. Becker, 1998. Drought-induced effects on nitrate reductase activity and mRNA and on the coordination of nitrogen and carbon metabolism in maize leaves.- *Plant Physiol.*, 117: 283-292.
- Hamdie, M.A. and H.M. El-Komy, 1998. Effect of salinity, gibberellic acid and azospirillum inoculation on growth and nitrogen uptake of *Zea mays*. *Biol. Plant.*, 40: 109-120.
- Heikal, M.M.D. and M.A. Shaddad, 1982. Alleviation of osmotic stress on seed germination and seedling growth of cotton, pea and wheat by proline.- *Phytol. (Aust.)* 22: 275-287.
- Hoagland, D.R. and D.I. Arnon, 1950. The water culture method for growing plants without soil.- *Calif. Agric. Exp. Sta. Cir.*, 347.
- Hsiao, T.C., 1970. Rapid changes in levels of polyribosomes in *Zea mays* in response to water stress.- *Plant Physiol.*, 46: 281 – 285.
- Jones, R.L. and J. MacMillan, 1987. Gibberellins: In (ed. Wilkins, M.B.). *Advanced Plant Physiol.* The Bath Press, Avon, pp: 21-52.
- Kazim, A.A. and A. Khaliel, 1983. Effect of saline water and CCC on germination and seedling growth of cucumber (*Cucumis sativus*).- *Punjab Hort. J.*, 23: 95 – 99.
- Khan, A.H. and A. Singh, 1983. Amino acid indicators of water stress condition in a maize cultivar.- *Nat. Acad. Sci. Letter*, 6: 117-119.
- Kuhad, M.S., I.S. Sheoran and S. Kumari, 1987. Alleviation and separation of osmotic and ionic effect during germination and early seedling growth in pearl millet by presoaking the seeds with growth regulators.- *Ind. J. Plant Physiol.*, 30: 139- 143.
- Kumari, B.D.R. and K. Veeranjayulu, 1996. Changes in leaf water potential osmotic adjustment and protein metabolism in mulberry during water stress.- *Tamil Nadu. India*, 103: 1245.
- Lawlor, D.W., 1970. Absorption of polyethylene glycols by plants and their effects on plant growth. – *New Phytol.*, 20: 501- 513.
- Lowry, O.H., J. Rosenbrough, A.C. Fan and R.J. Randal, 1951. Protein measurement with Folin phenol reagent. *J. Biol. Chem.*, 193: 265-275.
- Martin, C.C., 1975. The role of glumes and gibberellic acid in dormancy of *Themda triandra* spikelets.- *Physiol. Plant*, 33: 171-176.
- Mifflin, B. J. and P.J. Lea, 1980. Ammonium assimilation. (ed. Stumpf, P.K. and Conn, E.E.). *The Biochemistry of Plants*.- Academic Press, New York, 5: 169- 202.
- Morgan, J.M., 1984. Osmoregulation and water stress in higher plants.- *Annu. Rev. Plant Physiol.*, 35: 299.
- Naguib, M.I., 1969. Effect of various nitrogen sources and/or colchicine on the colorimetry of nitrogen components of plant tissue.- *Bull. Fac. Sci., Cairo Univ.*, 43: 1-5.
- Navari-Izzo, F., M.F. Quartacci and R. Izzo, 1990. Water stress- induced changes in protein and free amino acids in field grown maize and sunflower.- *Plant Physiol Biochem.*, 28: 531- 537.
- Paech, K. and M.V. Tracey, 1956. *Modern Methods of the Plant Analysis*.- Springer Verlag Berlin.
- Pelleschi, S., J.P. Rocher and J.L. Parioul, 1997. Effect of water restriction on carbohydrate metabolism and photosynthesis in mature maize leaves.- *Plant Cell Environ.*, 20: 493- 503.
- Ranieri, A., R. Bernardi, P. Lanese and G.F. Soldatini, 1989. Changes in free amino acid content and protein pattern of maize seedlings under water stress.- *Env. Exp. Bot.*, 29: 351- 357.
- Reddy, P., C. Sreenivasulu and S. Veeranjayulu, 1990. Water stress induced changes in enzymes of nitrogen metabolism in horsegram seedlings.- *Ind. J. Exp. Biol.*, 28: 273- 276.
- Rose, I.A., 1988. Effect of moisture stress on the oil and protein components of soybean seeds. – *Aust. J. Agric. Res.*, 39: 163- 170.
- Russel, J.A., 1944. Colorimetric detection of amino nitrogen.- *J. Biol. Chem.*, 56: 467.
- Sairam, R.L., P.S. Deshmukh and D.S. Shukula, 1991. Influence of chlormequat chloride on photosynthesis and nitrate assimilation in wheat genotypes under water stress.- *Ind. J. Plant Physiol.*, 34: 222-227.
- Shannon, M.C. and L.E. Francois, 1977. Influence of seed pretreatments on salt tolerance of cotton during germination. *Agron. J.*, 69: 619- 622.
- Sheoran, I.S., 1980. Changes in amylase during germination and early seedling growth of mung bean (*Vigna radiata* L.) Eilczek under different salts.- *Ind. J. Plant Physiol.*, 23: 169.
- Sendecor, G.W. and W.G. Cochran, 1980. *Statistical Methods*. 6<sup>th</sup> Ed., Iowa, State University Press, Ames.
- Tipirdamaz, R., M. Durusoy and S. Bozuck, 1995. Effect of exogenous polyamines on alpha-amylase activity during seed germination under salt stress.- *Turk. J. Bot.*, 19: 411- 416.
- Umbriet, W.W., R.H. Burris, J.F. Stauffer, P.P. Cohen, W. Johnse, W.J. Johanse, G.A. Lee Page, V.R. Potter and W.C. Schneider, 1959. *Manometric technique, a Manual describing method, Applicable to the Study of Describing Metabolism*, Burgess Publishing Company, pp: 239.
- Wu, M.L., 1987. The effects of seed treatments on the germination of tomato seeds under water or salinity stress.- *J. Agric. Assoc. China*, 138: 52- 62.
- Wyn Jones, R.G. and J. Gorhan, 1983. Osmoregulation. In: *Encyclopedia of Plant Physiology*, New Series. Vol. 12 C. (Lange, O.L., Nobel, P.S., Osmond, C.B. Ziegler, H.). *Physiological Plant Ecology*. III. Responses to the Chemical and Biological Environment. p. 35. Springer-Verlag, Berlin – Heidelberg- New York.
- Zayed, M.A. and I.M. Zeid, 1998. Effect of water and salt stress on growth, chlorophyll, mineral ions and organic solutes contents, and enzymes activity in mung bean seedlings. *Biol. Plant*, 40: 351- 356.