

THE ROLE OF PACLOBUTRAZOL ON MAIZE PLANTS AGAINST CERTAIN ENVIRONMENTAL STRESSES.

Fouda, R.A.* and Amany A. Ramadan**

*** Department of Botany, Faculty of Agriculture, Mansoura University.**

**** Department of Botany, National Research Center, Cairo, Egypt.**

ABSTRACT

Two pot experiments were carried out during the summer of the growing season 1999 to study the effects of paclobutrazol (PBZ) on growth, photosynthetic pigment contents, endogenous phytohormone contents and leaf structure of maize plants stressed with NaCl, high temperature and drought condition as well as the effects of PBZ on the alleviation of the adverse effects of these stresses.

Pre-soaking of maize grains in 100 ppm PBZ decreased plant growth expressed by shoot and root lengths, leaf area, endogenous auxins (IAA), gibberellin (GA₃) and abscisic acid (ABA) concentrations. Whereas, the number of roots, photosynthetic pigment contents and endogenous concentration of cytokinins were increased. On the other hand, all stress treatments decreased all the above mentioned parameters, but endogenous concentration of ABA was increased. Exposure to heat stress had more aggressive injury on plant growth than other types of stresses. Treatments with PBZ partially alleviated the adverse effects of stress treatments.

Anatomically, PBZ increased leaf thickness, epidermal cell thickness, mesophyll tissue thickness, the main vascular bundle dimensions and its xylem and phloem thickness, but all the above mentioned parameters were decreased under stress treatments.

Pre-soaking of maize grain in PBZ at 100 ppm is recommended for protection of maize plants from salinity, high temperature and drought conditions.

INTRODUCTION

In recent years, there are an increasing interest to study the effects of various environmental stresses on plant growth and development. Salinity, drought and high temperature are major factors that exert negatively different effects on plant growth and development, hence, crop production.

Increasing salt concentrations in the soil and water of irrigation is considered major problem of great concern to modern Agriculturists especially in developing countries, i.e. Egypt. High temperature and drought also commonly occur during plant growth periods and development as well as causing yield reduction in many crop plants (Stone *et al.*, 1995 and Huang *et al.*, 1998). When maize plants are exposed to high temperature and drought especially during early seedling growth, wilting is considered the most effective factor in all the three types of stresses. In addition, leaf chlorosis and dehydration are associated with a decrease in the photosynthetic pigments and net photosynthetic rate which depress plant growth and yield (Stone *et al.*, 1995; Kraus *et al.*, 1995; Gilley and Fletcher, 1997 and Huang *et al.*, 1998), as well as induce certain modifications in the internal structure of plant leaves (Sakr *et al.*, 1989 and Fouda, 1999).

The reduction in plant growth under several types of stresses is associated with shifting the balance of the important hormones including

gibberellins, cytokinins and ABA (Asare-Boamah *et al.*, 1986; Davis *et al.*, 1988; He and Cramer, 1996 and Nesiem, 1998). In addition, ethylene production in plants was also stimulated by many kinds of stresses (Kimmerer and Kozlowski, 1982). Triazole compounds have been shown to protect plants against various stresses including salinity drought, low and high temperature (Fletcher and Hofstra, 1987 and Kraus *et al.*, 1995). Paclobutrazol as a gibberellin inhibitor has been known as the best triazoles in protecting plants against various stress (Gilley and Fletcher, 1997).

The present investigation was designed to study the effects of salinity, high temperature and drought on growth, photosynthetic pigment contents and endogenous phyto-hormone contents in maize plants as well as leaf anatomical structure. The use of paclobutrazol to minimize the injuries of the above types of stresses is a major part of this investigation.

MATERIALS AND METHODS

Two pot experiments were carried out in the greenhouse and labs. of Agric. Bot. Dept., Fac. of Agric., Mansoura Univ. during May and July 1999.

Maize (*Zea mays*, L. "var. Giza 2") grains were soaked for 18 h in distilled water or in 100 ppm aqueous solution of PBZ (2Rs-3Rs)-1(4-chlorophenyl)-4-4-dimethyl-2-(1-4-, 1-2, 4 triazolyl) (Penta-n-3-01). The grains were left for air drying during 3 days, according to (Gilley and Fletcher, 1997). Two weeks after planting, both non-treated and PBZ-treated plants were divided into four groups to investigate the effects of other stress conditions as follows:

1. The first group of both non-treated and treated plants was left without any stress to compare the effect of PBZ, others were exposed to many kinds of stresses as follows:
2. The second group of both non- and treated plants was irrigated by aqueous solution containing NaCl (200 ppm).
3. The third group of both non- and treated plants was exposed to drought stress by withholding water for 10 days, subsequently, the plants were re-watered up to (50% W.H.C.).
4. The fourth group of plants was exposed to high temperature stress by keeping them in phytotron $45\pm 1^{\circ}\text{C}$ for 2 h. Heat stress was repeated during three successive days. The experiments included 8 treatments as follows:

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|-------------|-----------------|----------------------|----------------------------|
| 1- Control. | 2- PBZ. | 3- Salinity. | 4- PBZ + Salinity. |
| 5- Drought. | 6- PBZ+Drought. | 7- High temperature. | 8- PBZ + high temperature. |

Each treatment consisted of 5 plastic bags contained 3 kg clay/sand soil (1:1, w/w) and arranged in a complete randomized design with three replicates.

At harvesting (45 days after planting), root and shoot lengths, number of adventitious roots, percent of dead plants were recorded. Moreover, leaf area (cm^2) of the third leaf was calculated according to Lal and Subb Rao, 1951).

In addition, photosynthetic pigments were determined in the third leaf (Mackinney, 1941). For anatomical studies, samples were taken from the

middle part of the second leaf. Samples were fixed in FAA, 70% alcohol solution, dehydrated in alcohol series.

Cross sections (15-20 μ m) thick were prepared by a rotary microtome, stained in safranin-light green combination and mounted in canada balsam (Gerlach, 1977). The sections were examined microscopically.

Endogenous IAA, GA₃, cytokinins and ABA were extracted, purified and separated according to the method described by Gazit and Blumenfeled (1970). For bioassay of auxins, the straight-growth test of *Hordeum* coleoptile sections followed Younis and El-Tigani (1970) was used. For measurement of gibberellin-like substances, the lettuce hypocotyl bioassay adapted by Frankland and Wareing (1960) was followed. The technique used to assay the activity of cytokinin was as described by Esashi and Leopold (1969) using sunflower cotyledonary leaf section test. The ABA content was bioassayed by the straight-growth test of *Triticum* coleoptile segments as recommended by Wright (1969).

Data were subjected to statistical analysis of variance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

1. Growth parameters:

Severe reduction in plant growth, chlorosis, wilting, senescence of the leaves and death of the lower leaves were observed in all stressed plants. Moreover, the visual symptoms of heat stress are a flaccid appearance of the leaves and desiccation of leaf tips, dropping of the mature leaves and death of some plants. The results in Table (1) show that the temperature treatment had the highest percent (49%) of dead plants, while treatment with PBZ before salinity had the lowest percent (12%). The plants treated with PBZ were shorter and darker green than those untreated or stressed plants.

The results in the same table indicate that treatment with PBZ decreased plant growth expressed by shoot and root lengths and leaf area during the two experiments. With regard to number of roots, data indicated that treatment with PBZ increased significantly number of roots per plant. Data in the same table indicated that all stress treatments decreased the above mentioned parameters. Exposure to heat stress had more aggressive injury on plant growth than other types of stresses. Treatment with PBZ at 100 ppm partially reduced the injurious effect of various stress conditions. Similar results were previously reported by Gilley and Fletcher (1997) and Kandil *et al.*, (1999).

The retardant effects of PBZ may be attributed to the reduction in internode-length (Lecain *et al.*, 1986), and the inhibition or the interference with biosynthesis of gibberellic acid by blocking the oxidation of kaurene to kaurenoic acid (Hedden and Graebe, 1985). In addition, PBZ tends to reduce the synthesis and action of auxin in plants through enhancing the activity of IAA-oxidase as well as reducing the rate of transformation of tryptophane into IAA and reducing the distribution of IAA in the leaves and roots (Wang *et al.*, 1998). On the other hand, triazoles promoted adventitious root formation

(Grzesik, 1990). It is possible that the improved root formation is related to decreased shoot growth and hence increased partitioning of assimilates from leaves to roots (Davis *et al.*, 1988).

The depressing effect of salinity on plant growth may be due to an inhibition of the shoot apex growth in maize plants (Patel and Vora, 1985). Nieman (1965) attributed the inhibition effects of salinity to its effects on cell division and cell elongation. Also, the deleterious effects of salinity on plant growth may be attributed to the decrease in water absorption, ion imbalance and the excessive accumulation of toxic ions such as Na⁺ in plant cells, or a combination of these factors (Ayala and O'leary, 1995). They added that Na⁺ may have direct toxic effects through interference with the function of potassium as a co-factor in various reaction, as well as its deleterious effects on the structural and functional integrity of membranes (Kurth *et al.*, 1986). El-Banna and Attia (1999) noted that salinity caused disruption in the internal structure of root tip meristematic cells and complete damage of mitochondria and leaf chloroplasts. According to He and Cramer (1993b) the growth reduction by salinity was correlated with decreased photosynthesis and net assimilation rate.

Table (1): Effects of PBZ on plant growth of maize plants stressed with NaCl, high temperature and drought conditions during the two experiments.

Treatments	First experiment					Second experiment				
	Shoot length (cm)	Root length (cm)	No. of roots	Leaf area (cm ²)	% of dead plants	Shoot length (cm)	Root length (cm)	No. of roots	Leaf area (cm ²)	% of dead plants
Control	73.2	17.3	4.6	53.2	00.0	75.8	18.5	5.0	55.0	00.0
PBZ (100 ppm)	40.5	16.3	12.3	40.3	00.0	43.5	17.2	13.9	43.2	00.0
Salinity (200 ppm)	63.6	12.3	6.0	35.8	23.5	65.3	12.7	7.4	39.8	25.0
PBZ + Salinity	48.0	13.2	6.4	38.3	12.0	56.5	13.9	8.2	41.5	15.0
High temperature	43.3	9.5	3.0	31.7	49.0	45.7	10.4	4.1	35.5	52.0
PBZ + High temp.	60.0	10.7	5.5	35.9	20.1	64.2	11.6	6.2	38.4	21.2
Drought (50% W.H.C.)	51.4	10.9	3.7	39.4	35.0	53.1	11.9	3.8	40.9	37.6
PBZ + Drought	45.0	11.2	6.3	42.2	17.3	50.0	11.5	7.1	44.1	19.6
L.S.D. at 0.05	7.2	4.5	1.1	5.9	-	7.9	3.1	0.5	6.6	-

High temperature caused a number of adverse effects including damage to plant cells and cell organelles resulted in the progressive dehydration. This effect may be attributed to a rapid water loss (Stone *et al.*, 1995). Also, it caused denaturation of protein, enzyme inactivation, metabolic rate imbalance and damage of the chloroplasts and mitochondria (Blum, 1988) as well as increased ion leakage due to a loss of membrane integrity and severe membrane damage (Gilley and Fletcher, 1997). In addition, high temperature decreased photosynthetic rate and root growth (Huang *et al.*, 1998). Paulsen (1994) suggested that the production of fine roots or root thinning under high temperatures could be due to limited carbohydrate supply or increased carbohydrate consumption in roots.

The decrease in plant growth under drought condition may be attributed to an inhibition of shoot apex growth (Helaly *et al.*, 1985). Drought

also causes water loss from plant tissues that results in growth inhibition, increases loss of cell membrane integrity, ion leakage and root death as well as reduction of photosynthetic rate (Baruch, 1994; Tourneux and Peltier, 1995 and Huang *et al.*, 1998). Accumulation of ABA has been shown to increase under salinity (He and Cramer, 1996), or high temperature (Talanova *et al.*, 1991) and drought (Asare-Boamah *et al.*, 1986). The ABA decreased plant growth through influencing cell division and elongation of sub-apical meristems in the shoot system (Dicks, 1980).

Triazole compounds have been found to protect several plants from various types of environmental stress, including salinity (Kandil *et al.*, 1999) drought and high temperature (Gilley and Fletcher, 1997). Protection against such stress may be attributed to an increase in the natural anti-oxidants, tocopherol and ascorbate in the leaves; reduction in cell and organelles damage by increased antioxidant enzyme activities, which reduced lipid peroxidation (Sankhla *et al.*, 1992), as well as reduction of water loss by increased stomatal resistance and absorbed reduction by decrease in leaf orientation (Asare-Boamah *et al.*, 1986 and Fletcher and Hofstra, 1987 & 1990). In addition, triazole caused an increase in shoot water potential (Asare-Boamah *et al.*, 1986) through promotion the adventitious root formation (Table 1), as well as reduction in susceptibility to heat injury (Davis *et al.*, 1988).

2. Photosynthetic pigment content:

Data in Table (2) indicate that treatment with PBZ increased the concentration of all photosynthetic pigments, i.e. chl. A, B and total chlorophylls as well as carotenoids in maize leaves. Data in the same table revealed that plant exposure to salinity, high temperature and drought caused a marked reduction in the concentration of the photosynthetic pigments. Exposure to high temperature had more deleterious effect than other types of stress. Treatment with PBZ reduced the adverse effects of all types of stress.

The increment in photosynthetic pigment content due to PBZ application may be attributed to increased chlorophyll synthesis (Fletcher and Arnold, 1986), and increased cytokinin content of treated plants (Izumi *et al.*, 1988). Previous records showed the important role of cytokinins in delaying senescence of leaves by decreasing chlorophyllase enzyme activity (Sabater and Rodriguez, 1978) or increasing prochlorophyllide content and activity of chlorophyll synthesis (Chen, 1990).

Table (2): Effects of PBZ on photosynthetic pigments content (mg/g fresh weight) of maize plants stressed with NaCl, high temperature and drought conditions during the two experiments.

Treatments	First experiment				Second experiment			
	Chl. A	Chl. B	Total chl.	Carotenoids	Chl. A	Chl. B	Total chl.	Carotenoids
Control	0.89	0.77	1.66	0.33	0.94	0.85	1.77	0.37
PBZ (100 ppm)	2.20	1.29	3.49	0.83	2.35	1.37	3.72	0.95
Salinity (200 ppm)	0.81	0.70	1.51	0.15	0.87	0.81	1.68	0.23

PBZ + Salinity	1.59	0.83	2.42	0.32	1.67	0.86	2.53	0.38
High temperature	0.71	0.51	1.22	0.10	0.78	0.67	1.45	0.15
PBZ + High temp.	0.85	0.82	1.67	0.17	1.53	0.95	2.48	0.21
Drought (50% W.H.C.)	0.82	0.56	1.38	0.29	0.85	0.69	1.54	0.37
PB+ Drought	1.33	1.10	2.43	0.36	1.47	1.17	2.64	0.42
L.S.D. at 0.05	0.16	0.14	0.23	0.10	0.11	0.17	0.25	0.80

The decrease in chlorophyll content under salinity may be due to one or more of the following processes: the inhibitory effect of chloride on the activity of Fe-containing enzyme; cytochrome oxidase which, in turn, may decrease the rate of chlorophyll biosynthesis (El-Hadidi *et al.*, 1985a), through an increase in chlorophyllase activity (Svitsev *et al.*, 1973), increased ABA content (He and Cramer, 1996). The ABA is known to accelerate leaf senescence through inhibiting chlorophyll synthesis (Bengtson *et al.*, 1977). Moreover, salinity caused a disruption of chloroplast swelling in grana, intergrana and stroma (El-Banna and Attia, 1999).

The reduction in photosynthetic pigment contents under high temperature may be attributed to an increase in the loss of membrane integrity, loss in the integrity of thylakoid pigment-protein complexes and chlorophyll fluorescence (Booker *et al.*, 1991 and Gilley and Fletcher, 1997). They added that all symptoms of damage were alleviated by triazole treatment. Moreover, high temperature caused more rapid and high photo-inhibition and increased damage of the chloroplasts (Blum, 1988 and Kraus *et al.*, 1995). Treatment with triazole reduced photo-inhibition and hastened the recovery of damaged photosynthetic processes (Kraus *et al.*, 1995). In addition, triazole treatment stimulated an increase in the levels of enzymes that protect chloroplasts from oxidative damage (Sankhla *et al.*, 1992).

The decrease in chlorophyll content under drought conditions may be attributed to the decrease in cytokinin biosynthesis or to abscisic acid activity which increased in stressed plants and this compound is known to accelerate leaf senescence (Helaly *et al.*, 1984). Moreover, leaf dehydration under drought conditions was associated with inhibition of photosynthesis due to a direct inhibition of photosynthetic CO₂-assimilation and inhibition of electron transport due to photo-inhibition of PSII (Kaiser, 1987 and Tourneux and Peltier, 1995).

3. The endogenous phytohormones:

Data in Table (3) indicate that treatment with PBZ increased significantly cytokinin content, while IAA, GA₃ and ABA were decreased. On the other hand, under all stress treatments, IAA, GA₃ and cytokinins tend to decrease, while ABA content was increased. Accumulation of ABA under various types of stress and changing the balance of important hormones were previously reported by Asare-Boamah *et al.* (1986) and Nesiem (1998). The increase in cytokinin contents due to PBZ application was previously reported by Izumi *et al.* (1988) on rice and Zhang *et al.* (1994) on wheat plants. This effect due probably to a stimulation of adventitious root formation (Table 1). Roots are considered to be the predominate site of cytokinin synthesis. The reduction in the endogenous auxins content caused by PBZ application may be due to stimulating the activity of IAA oxidase and

reducing the rate of transformation of tryptophane into IAA (Wang *et al.*, 1998). With regard to GA₃ content, Hedden and Graebe (1985) reported that uniconazole inhibits gibberellin biosynthesis by blocking the oxidation of kaurene to kaurenoic acid. The effect of triazoles on inhibition of ABA biosynthesis has been reported by Norman *et al.* (1986). They concluded that paclobutrazol interfered with the conversion of farnesyl pyrophosphate to the next intermediate in the pathway to ABA.

Table (3): Effects of PBZ on the endogenous hormones (IAA, GA₃, cytokinin and ABA) contents (µg/g fresh weight) of maize plants stressed with NaCl, high temperature and drought conditions during the second experiment.

Treatments	IAA	GA ₃	Cytokinin	ABA
Control	18.46	18.20	14.53	2.49
PBZ (100 ppm)	12.82	12.18	28.80	1.89
Salinity (200 ppm)	9.88	15.81	12.30	3.05
PBZ + Salinity	15.85	14.34	17.97	2.85
High temperature	7.35	9.73	10.58	3.43
PBZ + High temp.	10.95	14.06	17.61	2.96
Drought (50% W.H.C.)	9.81	11.68	11.00	2.74
PBZ + Drought	10.95	15.96	20.06	2.70
L.S.D. at 0.05	0.76	1.11	0.87	0.33

Concerning the effects of other types of stress on the endogenous phytohormones, data revealed that there is a close relationship between the accumulation of ABA and the marked decrease in cytokinins, gibberellin and auxins. This correlation is supported by the results obtained from the plant exposure to stress treatments and the exogenous application of ABA. In this connection, Nesiem (1998) found that application of ABA led to an accumulation of ABA and marked decrease in cytokinins, gibberellins and auxins. Accumulation of ABA under stress treatments was previously reported by Asare-Boamah *et al.* (1986) and Nesiem (1998). He and Cramer (1996) found that salt stress caused an increase of ABA concentrations in plant tissues due to de novo synthesis or transport. Also, Nilson and Orcutt (1996) mentioned that an increase in the concentration of ABA under salinity may be as a result of release from bound forms, an increase in the rate of synthesis or a decrease in the rate of destruction.

The reduction in IAA content by salinity may be attributed to reduction in tryptophane synthase, tryptophane biosynthesis and consequently IAA content was decreased (Stefi, 1988). Shukla and Bajjal (1977) added that salinity increased IAA-oxidase activity. The reduction in cytokinin content may be attributed to an increase of ABA (Table 3).

4. Leaf structure:

The effects of PBZ and stress treatments as well as their combinations on leaf structure of maize plants are shown in Table (4) and Figs. (1-8).

Figure (1) shows that maize leaf blade consists of adaxial and abaxial epidermis, mesophyll parenchymatous tissue as well as large and small vascular bundles.

Data in Table (4) and Fig. (2) show that PBZ increased leaf thickness in the keel region, adaxial and abaxial epidermal cell thickness, mesophyll tissue thickness, the main vascular bundle dimensions, and its xylem and phloem thickness compared with both control and other stress treatments.

Regarding the effects of stress treatments, results in the same table and Figs. (3, 5 and 7) indicate that all the mentioned parameters were decreased. High temperature had more deleterious effect on leaf structure.

Table (4): Effects of PBZ and stress treatments as well as their combinations on leaf structure of maize plants.

Treatments	Leaf thickness (µm)	Adaxial epidermal cells thickness (µm)	Abaxial epidermal cells thickness (µm)	Mesophyll tissue thickness (µm)	No. of mesophyll cell layers	Main V.B. dimensions (µm)		Xylem tissue thickness (µm)	Phloem tissue thickness (µm)
						Length	width		
Control	800.0	15.2	17.5	767.3	8.0	118.0	100.0	67.2	50.8
PBZ (100 ppm)	1050.0	22.6	28.9	998.5	12.2	140.0	111.0	77.5	62.6
Salinity (200 ppm)	750.0	14.7	16.2	709.1	7.5	100.0	70.0	57.3	42.7
PBZ + Salinity	720.0	16.5	18.3	685.2	9.0	120.0	80.0	76.7	43.3
High temperature	600.0	8.3	8.9	582.8	6.1	72.0	56.3	32.5	39.5
PBZ + High temp.	625.0	13.6	15.8	595.6	7.3	94.5	60.0	40.3	44.2
Drought (50% W.H.C.)	620.0	10.3	11.1	598.6	7.0	80.4	67.2	41.0	38.6
PBZ + Drought	815.0	17.4	18.1	779.5	9.5	100.2	73.5	45.0	55.2
L.S.D. at 0.05	22.7	2.5	3.2	15.3	1.1	8.7	9.5	7.2	5.6

Moreover, along with the above mentioned parameters it was observed severe plasmolysis in the mesophyll cells and destruction of adaxial epidermal cells and hypodermal zone of mesophyll tissue. Treatment with PBZ partially alleviated the adverse effects of stress treatments.

The increase in leaf thickness due to PBZ may be attributed to an increase in cell number and size of mesophyll tissue (Fig. 2). Gad *et al.* (1996) noted that PBZ increased leaf thickness of some ornamental plants due to an increase in number of palisade cells and their enlargement.

The decrease in leaf thickness under salinity may be attributed to a decrease in the mesophyll tissue thickness (Table 4). Wignarjah *et al.* (1975a) attributed the decrease in kidney bean leaflet thickness under salinity to an inhibition of cell division and cell expansion as well as a reduction in the palisade parenchymatous layer thickness. Curtis and Läuchli (1987) added that salinity decreased leaf area due to a decrease in the epidermal cell size and number.

With regard to the effect of high temperature can cause severe damage to leaves of plants, disruption of cell metabolism. The later effect may be due to protein denaturation, production of toxic substances or membrane damage (Levitt, 1972). The decrease in leaf thickness under drought stress was reported by Helaly *et al.* (1985) on Petunia and Sakr *et al.* (1989) on garlic plants. They reported that water stress decreased leaf thickness, xylem and phloem thickness. Little (1975) added that water stress

inhibits cambial activity. Moreover, the reduction in leaf thickness under stress treatments, possibly due to an accumulation of both ABA and ethylene. The ABA inhibits cell growth by affecting both cell division (Evans, 1984) and cell expansion (Wakabashi *et al.*, 1989).

Ethylene is a naturally occurring plant hormone, which is responsible for shortening the internode regions by impeding cell elongation and division (Burg *et al.*, 1971) and increasing cellulose activity (Huang *et al.*, 1997). The later effect is associated with degradation of adaxial epidermal cells and hypodermal zone of mesophyll tissue under high temperature.

Figs. (1-4): Cross sections of maize leaf as affected by PBZ and stress treatments as well as their combinations (Obj. 10 x Oc. 10 x).

1- Control. 2- PBZ. 3- Salinity. 4- PBZ + Salinity.
Ad: adaxial epidermis; mes: mesophyll; X: Xylem; ab: abaxial epidermis;
Sc: Scerenchyma; M.V.B. Main vascular bundle

Figs. (5-8): Cross sections of maize leaf as affected by PBZ and stress treatments as well as their combinations (Obj. 10 x Oc. 10 x).

5- High temperature. 6- PBZ+High temperature. 7- Drought. 8- PBZ+Drought.
Ad: adaxial epidermis; mes: mesophyll; X: Xylem; ab: abaxial epidermis; Phloem: Phloem; Sc: Sclerenchyma

It could be concluded that treatment with PBZ plays an important role in the protection of maize plants from salinity, drought and high temperature injuries. These effects may be attributed to one or more of the following processes: 1) reduction in leaf area and transpiration as well as an increase of the root system formation which increase water absorption and avoid drought, 2) an increase in the photosynthetic pigment contents, the higher levels of carotenoids play a role in the protective action of triazoles against various environmental stresses some of which occur by oxidative damage (Senaratna *et al.*, 1988), 3) an increase in leaf thickness and epicuticular wax (a protective waxy layer on the leaf surface) as well as shifting in the balance of important plant hormones including cytokinins (Table 3), which play an important role in plant protection under stress conditions. In addition, Fletcher and Hofstra (1987); Sankhla *et al.* (1992) and Gilley and Fletcher (1997) concluded that triazoles decreased ion leakiness due to a loss of membrane integrity and reduced lipid peroxidation, and increased the natural anti-oxidants, tocopherol and ascorbate (vitamins E and C) in the leaves.

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دور البكلوبترازول في مواجهة بعض الظروف البيئية غير المناسبة لنباتات الذرة
رمضان عبد المنعم فودة* و أماني عبد المحسن رمضان**
* قسم النبات - كلية الزراعة - جامعة المنصورة
** قسم النبات - المركز القومي للبحوث - القاهرة - مصر.

أجريت تجربتي أصص خلال صيف 1999 لدراسة تأثير البكلوبترازول على النمو، محتوى صيغات البناء الضوئي، الهرمونات الداخلية، وكذلك التركيب التشريحي لورقة نباتات الذرة المعرضة

للملوحة بكلوريد الصوديوم ، الحرارة العالية وظروف الجفاف ، وأيضاً دور الباكلوبترازول على تخفيف التأثيرات الضارة لهذه الظروف البيئية غير الملائمة. وأظهرت النتائج المتحصل عليها مايلي:

- أدى نقع حبوب الذرة في محلول الباكلوبترازول بتركيز 100 جزء في المليون إلى نقص نمو النبات معبراً عنه بطول كلاً من المجموع الخضري والمجموع الجذري ومساحة الورقة وكذلك محتوى المجموع الخضري من الأكسينات ، الجبرلينات ، حمض الأبسيسك ، بينما أدى إلى زيادة عدد الجذور وتركيز السيتوكينينات.

- على الجانب الأخر ، أدت كل العوامل البيئية غير الملائمة إلى نقص كل الصفات السابقة إلى أنها أدت إلى زيادة محتوى حمض الأبسيسك. وكان تعرض النباتات للحرارة العالية أشد ضرراً على نمو النبات من العوامل البيئية الأخرى. وأدت المعاملة بالباكلوبترازول إلى تخفيف الأثار الضارة لتلك العوامل البيئية.

- وتشرحياً: أدت المعاملة بالباكلوبترازول إلى زيادة سمك الورقة ، البشرة العليا والسفلى والنسيج المتوسط وأبعاد الحزمة الوعائية الرئيسية وكذلك سمك نسيجى الخشب واللحاء ولكن أدت كل العوامل البيئية إلى نقص كل الصفات السابقة.

ويمكن التوصية بنقع حبوب الذرة في محلول الباكلوبترازول بتركيز 100 جزء في المليون لحماية نباتات الذرة من التأثيرات الضارة للملوحة والحرارة العالية والجفاف.