INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
1560–8530/2004/06–3–499–503
http://www.ijab.org

# Amelioration of Salinity-Induced Metabolic Changes in Soybean by Weed Exudates

H.R. MOUSSA
*Radioisotope Department, Atomic Energy Authority, Egypt*
Corresponding e-mail: helal_moussa@hotmail.com

## ABSTRACT

Root exudates of three weed plants, jungle rice, cocklebur and purslane, were used as foliar spray into NaCl-stressed soybean seedlings to test their possible ameliorative effects on NaCl-induced injury. Exudates of jungle rice roots exhibited highest level of kinetin and gibberellic acid and lowest concentration of indole acetic acid as well as abscisic acid. Cocklebur root exudates contained highest level of IAA or ABA while purslane one showed lowest amount of $GA_3$ or Kinetin. NaCl imposition decreased contents of protein, oil, K, Mg, P, and $NO_3$, whereas increased contents of free proline, alkaloids, Na and Cl. The activity of nitrate reductase was reduced while that of protease was stimulated. Translocation rate of carbon assimilates was also inhibited by salt exposure. The highest contents of protein, oil, nitrate reductase activity, translocation efficiency ($^{14}CO_2$-assimilates), $NO_3$, P, K, and Mg ions and the lowest contents of free proline, total alkaloids, protease activity, Na, and Cl ions in salinized soybean were found as a result of application of root exudates of jungle rice weed plant. This may be due to its highest inclusion of growth regulators that mitigate NaCl deleterious effects. Other possible mechanisms that explain alleviation effects of weed root exudates against NaCl stress are discussed.

**Key Words:** Root exudates; Kinetin; $^{14}CO_2$; Gibberellic acid; Salinity

## INTRODUCTION

Soybean (*Glycine max* L. Merr.) is one of great important leguminous plant. It is also considered as a good source of vegetable protein and oil since it has the highest level of protein in comparison with the other leguminous plants. In Egypt, it is not feasible to expand the area for such valuable crop due to high competition since cotton, rice and maize. Therefore, it is necessary to investigate certain abiotic factors that may limit the soybean yield, for example, drought and salinity. Eisa and Hanna (1997) and Frederick *et al.* (2001) showed that drought stress reduced growth pattern in soybean. Marques (1982) reported that soybean plants are most susceptible to drought stress during the reproductive period particularly pod formation and filling.

NaCl stress negatively influence the protein content and proline oxidase activity while increased protease capacity (Muthukumarasamy *et al.,* 2000). Saker and EL-Ashal (1995) found that salinity stress increased the content of alkaloids. NaCl treatment increased $Na^+$ and $Cl^-$ level whereas decreased $K^+$ and $Mg^{2+}$ level (AL-Wakeel *et al.,* 1995) in fenugreek plants. The present work was undertaken to investigate whether the injurious effects induced by salinity could be mitigated using exudates of certain weed roots as natural tools.

## MATERIALS AND METHODS

**Plant material.** Uniform seeds of soybean (*Glycine max* L. Merr.) cv. Giza 35 were obtained from the Crop Institute, Agricultural Research Center, Giza, Egypt.

The seeds were surface sterilized using 1.0 g $L^{-1}$ $HgCl_2$ for 15 minute and rinsed thoroughly with distilled water. The seeds were then germinated in Petri dishes in the dark at 24°C. The pregerminated seeds were transferred into 25 cm diameter black polyethylene pots containing sand culture. The water holding capacity was 12-15% and the pH of the soil extract was about 7.0. Five seedlings were planted in each pot. The pots were irrigated with 1/4-strength Hoagland's nutrient solution (Hoagland & Arnon, 1950). A 250 mL of the nutrient solution were supplied to each pot twice daily. After 35 days of seedling emergence salt stress treatments were imposed. The seedlings were treated with full Hoagland's solution containing NaCl levels of 1.2, 5.7, 10.3 and 19.4 dS $m^{-1}$ which are equivalent to 0.0, 50, 100 and 200 mM, respectively. The plants were subjected to these salt levels for 90 d. The pots were rinsed with water once a week to avoid salt accumulation.

**Collecting the root exudates.** Sixty uniform plants of the three weeds; jungle rice (*Echinochloa colonum* L.), cocklebur (*Xanthium* sp.) and purslane (*Portulaca oleraceae* L.) were gently pulled with their intact root system in the vegetative stage from the soil of field practices in the Horticultural Research Center, Giza. The plants of each weed were washed carefully with distilled water several times. The weeds were kept inside clean flasks full of 1 L distilled water for 3 days at 22-23°C and light intensity of 1500 Lux. The resulting solution in each flask was filtered and evaporated to 200 mL under vacuum at 25°C. Then, the

insoluble materials were removed by centrifugation at 2000 rpm for 30 min according to the methods of El-Habasha and Behairy (1977). The exudates of the three weeds were collected and divided into two groups. The first (20 mL) was used for determination of growth regulators using HPLC following the procedure of Shindy and Orrin (1975). The second (180 mL) was added to Tween 20 to fix solutions to the plant leaf surface. The solutions were sprayed once into the leaves in the morning at the flowering stage after 45 days using a manual pump. All determinations were carried out at the harvest stage (90-day-old). All treatments were replicated 3 times.

**The translocation efficiency ($^{14}CO_2$-assimilates**). It was assayed according to (Moussa, 2001). A pot from each treatment was placed under Bell-jars, which were used as a photosynthetic chamber. Radioactive $^{14}CO_2$ was generated inside the chamber by a reaction between 10% HCl and 50 µC $NaH^{14}CO_3$ + 100 mg $Na_2CO_3$ as carrier. Then the illumination was afforded by tungsten lamp. After 30 min., which was considered as zero time, the plants were removed from the chamber and left for 2 and 4 h in the normal air to assimilate $CO_2$. After the assigned period had elapsed the leaves were quickly detached from the stem, weighed and frozen for 5 min. to stop the biochemical reactions. Then the leaves were subjected to extractions by 80% hot ethanol. The ethanolic extracts were taken for $^{14}C$ assay in soluble compounds using Bray Cocktail by means of Liquid Scintillation Counter (LSC2-Scaler Ratemeter SR7, Nuclear Enterprises).

**Protein, proline, oil and alkaloids contents**. Protein content was quantified according to (Bradford, 1976). Following the method of A.O.A.C. (1975) percentage of seed crude oil level was estimated. Extraction and determination of alkaloids were carried out following the method of Koul *et al.* (1982). The procedure of Bates *et al.* (1973) was applied to estimate free proline concentration.

**Nitrate reductase and protease activity**. Nitrate reductase activity was assayed according to the method of Ferrario *et al.* (1998). Protease enzyme activity was measured as described by Gallop *et al.* (1957).

**Elemental analysis**. According to the procedure of Cataldo *et al.* (1975), the content of $NO_3$ was calculated. Chloride concentration was determined as described by Lutts *et al.* (1996). The method of Prokopy (1995) was applied for phosphorus estimation. Potassium, sodium and magnesium levels were determined using an AAS-1-N Atomic Absorption Spectrophotometer (Zeiss, Jena, Germany).

## RESULTS AND DISCUSSION

Root exudates of the three examined weeds showed various levels of growth regulating substances (Fig. 1). In this respect, roots of jungle rice exuded the highest amount of cytokinins (kin), and gibberellic acid ($GA_3$) and low levels of auxins (IAA) and abscisic acid (ABA), while exudates of cocklebur roots had the highest levels of auxins (IAA), ABA and moderate level of cytokinins (kin). Purslane roots exuaded the lowest amount of $GA_3$ and kin and moderate levels of IAA or ABA. These results are consistent with those reported by Arshad and Frankenberger (1991), Behairy *et al.* (1998) and Hamed (2000).

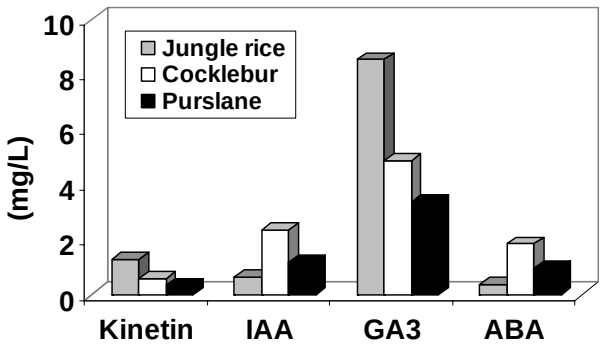
**Protein and oil content.** Soybean plants exposed to 100 and 200 mM NaCl showed significant decrease in their protein content by 20.3% and 41.7% below those of control samples (Table I). Muthukumarasamy *et al.* (2000) reported remarkable decrease in the protein content of salt stressed radish plants. The interactive effect of NaCl (100 & 200 mM) and foliar spray of extracts of (a) jungle rice, (b) cocklebur and (c) purslane into soybean plants, induced marked increases in protein accumulation by: 14.9 and 21.1% for (a), 10.6 and 8.98% for (b) and 2.6 and 14.45% for (c), respectively, as compared with samples received only salt treatments (Table I). These findings were in agreement with those indicated by Datta *et al.* (1997) who reported that damage to the apparatus of protein synthesis by salinity was prevented by kinetin, which led to better plant growth. Stefanov *et al.* (1998) also indicated that application of $GA_3$ and phenylurea increased protein and total nitrogen contents of maize seedlings. Soybean plants treated with 100 or 200 mM NaCl exhibited significant decreases in their oil contents by 45.5 or 81.3%, respectively, when compared with that of untreated samples (Table I). This inhibition in the oil content is similar to that reported by Noureldin *et al.* (2002) who found a reduction in the oil yield of soybean plants under salt stress. Foliar spraying of weed extracts: jungle rice (a), cocklebur (b) and purslane (c) in presence of NaCl 100 and 200 mM substantially increased the oil content by 60.2 and 156.8%

**Table I. Effect of foliar applications of weed extracts on alkaloids (mg $g^{-1}$DW), free proline (µmol $g^{-1}$FW), protein and oil contents of stressed soybean plant after 90 days**

| Weed extract | NaCl (mM) | Free proline | Total alkaloids | Seed % | |
|---|---|---|---|---|---|
| | | | | Protein | Oil |
| 0.0 | 0.0 | 198.5 | 18.5 | 43.9 | 23.5 |
| | 50 | 230.1 | 23.4 | 40.2 | 19.1 |
| | 100 | 258.4** | 30.9** | 35.0** | 12.8** |
| | 200 | 295.6** | 41.6** | 25.6** | 4.4** |
| Jungle rice | 0.0 | 186.8 | 17.1 | 51.6 | 30.1 |
| | 50 | 205.4 | 16.8 | 47.4 | 27.4 |
| | 100 | 235.6** | 24.6** | 40.2** | 20.5** |
| | 200 | 267.5** | 31.5** | 31.0** | 11.3** |
| Cocklebur | 0.0 | 190.1 | 17.5 | 48.8 | 31.0 |
| | 50 | 210.3 | 17.0 | 47.5 | 21.4 |
| | 100 | 227.4** | 21.4** | 38.7* | $14.5^{NS}$ |
| | 200 | 270.2** | 25.8** | 27.9* | 7.0* |
| Purslane | 0.0 | 180.6 | 17.7 | 45.0 | 27.8 |
| | 50 | 221.4 | 14.8 | 42.1 | 22.6 |
| | 100 | 239.2** | 10.5** | $35.9^{NS}$ | 16.4* |
| | 200 | 261.3** | 11.3** | 29.3* | 8.6** |

*Significant; **Highly significant; NS: Non significant. Each value is the mean of three replicates

**Fig. 1. The content of growth regulator in the three weed extracts**




for (a) 13.3 and 59.1% for (b) and 28.13 and 95.45% for (c), respectively, above those of salinized plants (Table I). The increase in oil content may be due to a reduction in lipase activity induced by a hormone presents in the extracts (Sodek & Wright, 1983).

**Proline and alkaloid content.** Stress imposed by 100 and 200 mM NaCl increased the free proline content of soybean plants by 30.18 and 48.92%, respectively, in comparison with control samples (Table I). The increase in proline content could be attributed to a decrease in proline oxidase activity in saline condition as indicated by Muthukumarasamy *et al.* (2000) and Rajesh *et al.* (1999). Proline concentration markedly decreased following treatment soybean seedlings with 100 and 200 mM NaCl and extracts of (a) jungle rice (b) cocklebur and (c) purslane by 8.8 and 9.51% for (a), 11.99 and 8.59% for (b) and 7.4 and 11.6% for (c) as compared with plants received salt alone (Table I). This decrease in proline could be accounted for decreasing ABA level in salinized plants, which sprayed with growth regulators as reported by Hathout (1996). ABA has been shown to increase proline content in salt stressed plants (Younis *et al.,* 1994). NaCl stress caused significant increases in the alkaloid content of soybean plants when compared with control samples (Table I). Spraying the salinized soybean plants with the tested weed extracts significantly decreased their alkaloid contents compared with only NaCl-treated plants (Table I). Salinized Hyoscyamus plants exhibited high level of alkaloid fraction, which may be induced by K deficiency and proline accumulation in saline environment Saker and El-Ashal (1995).

**Table II. Effect of foliar applications of weed extracts on enzyme activities of stressed soybean plant after 90 days**

| Weed extract | NaCl (mM) | Nitrate reductase (U $g^{-1}$FW) | Protease (U $g^{-1}$FW) |
|---|---|---|---|
| 0.0 | 0.0 | 170 | 248 |
| | 50 | 156 | 269 |
| | 100 | 128 | 307 |
| | 200 | 101 | 341 |
| Jungle rice | 0.0 | 178 | 245 |
| | 50 | 170 | 230 |
| | 100 | 158 | 261 |
| | 200 | 132 | 215 |
| Cocklebur | 0.0 | 181 | 243 |
| | 50 | 172 | 239 |
| | 100 | 135 | 258 |
| | 200 | 116 | 219 |
| Purslane | 0.0 | 168 | 246 |
| | 50 | 159 | 221 |
| | 100 | 140 | 243 |
| | 200 | 108 | 226 |
| LSD | 1% | 11.6 | 13.5 |
| | 5% | 7.1 | 8.4 |

**Table III. Effect of foliar applications of weed extracts on ion contents (mg $g^{-1}$DW) of stressed soybean plant after 90 days**

| Weed extract | NaCl (mM) | Na | Cl | $NO_3$ | P | K | Mg |
|---|---|---|---|---|---|---|---|
| 0.0 | 0.0 | 53.5 | 61.4 | 105.6 | 63.2 | 96.8 | 27.4 |
| | 50 | 63.9 | 78.9 | 90.2 | 50.1 | 80.2 | 20.3 |
| | 100 | 79.4 | 92.4 | 77.5 | 43.0 | 65.4 | 13.2 |
| | 200 | 96.8 | 123.6 | 51.4 | 30.2 | 41.6 | 5.0 |
| Jungle rice | 0.0 | 50.0 | 62.4 | 123.5 | 78.9 | 118.6 | 40.2 |
| | 50 | 51.6 | 63.6 | 115.1 | 70.1 | 105.1 | 31.5 |
| | 100 | 60.2 | 50.2 | 98.3 | 62.5 | 90.2 | 25.3 |
| | 200 | 43.8 | 38.1 | 72.4 | 46.4 | 81.1 | 15.7 |
| Cocklebur | 0.0 | 52.1 | 58.9 | 125.6 | 83.4 | 123.6 | 38.5 |
| | 50 | 49.2 | 60.4 | 110.3 | 74.6 | 101.2 | 32.7 |
| | 100 | 47.8 | 51.7 | 102.1 | 61.8 | 97.4 | 21.8 |
| | 200 | 46.3 | 41.2 | 70.1 | 49.2 | 75.3 | 13.2 |
| Purslane | 0.0 | 51.4 | 61.0 | 119.4 | 75.1 | 120.0 | 35.0 |
| | 50 | 50.0 | 65.1 | 106.5 | 68.3 | 90.3 | 25.8 |
| | 100 | 58.2 | 57.3 | 95.1 | 57.1 | 78.6 | 17.4 |
| | 200 | 47.9 | 39.2 | 67.4 | 40.2 | 67.1 | 10.1 |
| LSD | 1% | 3.8 | 2.9 | 8.1 | 4.5 | 10.5 | 5.8 |
| | 5% | 2.4 | 1.7 | 5.0 | 2.7 | 6.7 | 3.7 |

Each value is the mean of three replicates

**Nitrate reductase and protease activity.** NaCl (100 & 200 mM) treated-soybean samples exhibited significant reduction in the activity of nitrate reductase (NR) enzyme by 24.71 and 40.59% and increase in protease capacity by 23.79 and 37.5% in comparison with control plants (Table II). Abd El-Baki *et al.* (2000) reported that application of salinity decreased NR activity in maize. Application of weed extracts to soybean plants increased their NR activity relative to salinized controls (Table II), which could be explained by effect of kinetin and $GA_3$ of weed extracts. Kinetin and $GA_3$ have been reported to increase NR activity in maize leaves (Sinha *et al.,* 1994). Taiz and Zeiger (1998) indicated that cytokinin regulates NR by controlling transcription of NR gene. Consistent with our results is that NaCl increased protease activity in radish plants (Muthukumarsamy *et al.,* 2000) and in *Ceriops roxburghiana* plants (Rajesh *et al.,* 1999). Protease activity decreased in presence of NaCl and foliar spray of soybean

**Table IV. Effect of foliar application of weed extracts on translocation rate (TR) of stressed soybean plant after 90 days**

| Weed extracts | NaCl (mM) | Zero time (30 min) | Translocation rate (2 h) | | Translocation rate (4 h) | |
|---|---|---|---|---|---|---|
| | | Specific activity (*dpm $mg^{-1}$ FW) | Specific activity (dpm $mg^{-1}$ FW) | TR (%) | Specific activity (dpm $mg^{-1}$ FW) | TR (%) |
| 0.0 | 0.0 | 53887 | 38799 | 28 | 24249 | 55 |
| | 50 | 50146 | 37108 | 26 | 25073 | 50 |
| | 100 | 45602 | 35569 | 22 | 25993 | 43 |
| | 200 | 38114 | 32396 | 15 | 25917 | 32 |
| Jungle Rice | 0.0 | 55813 | 35162 | 37 | 16743 | 70 |
| | 50 | 54066 | 35142 | 35 | 20004 | 63 |
| | 100 | 51841 | 35770 | 31 | 23328 | 55 |
| | 200 | 45422 | 34066 | 25 | 25436 | 44 |
| Cocklebur | 0.0 | 52988 | 34442 | 35 | 15366 | 71 |
| | 50 | 48342 | 32872 | 32 | 19336 | 60 |
| | 100 | 42825 | 30834 | 28 | 20556 | 52 |
| | 200 | 33614 | 25882 | 23 | 20168 | 40 |
| Purslane | 0.0 | 54128 | 35724 | 34 | 17320 | 68 |
| | 50 | 52617 | 35253 | 33 | 20521 | 61 |
| | 100 | 48101 | 35594 | 26 | 25493 | 47 |
| | 200 | 40398 | 30702 | 24 | 25855 | 36 |

FW = fresh weight; *Disintegration per minute

plants with weed extracts (Table II). Growth regulators have been reported to reduce protease activity in cotton and wheat (Renu & Goswami, 1995; Hegazi *et al.*, 1995).

**Elemental analysis.** Salinity treatment (100 and 200 mM NaCl) significantly declined the content of $NO_3$, P, K and Mg of soybean plants while increased the content of Na and Cl as compared with control plants (Table III). Other reports indicate that salinity stress increased Na and Cl whereas decreased K, Mg and P in different plant species (Al-Wakeel *et al.*, 1995; Gadallah, 1996; Briendra & Bijandra, 1996). The contents of $NO_3$, P, K and Mg of soybean plants treated with 100 and 200 mM NaCl and sprayed with weed extracts increased the values of these ions than those of salinized plants, meanwhile lower contents of Na and Cl as compared with those receive NaCl alone (Table III).

Salinity adversely affected the $NO_3$ content in soybean plants concomitantly with reduction in NR activity. These results could be interpreted on the basis that decreasing $NO_3$ content inhibits the biosynthesis of NR enzyme. Moreover, it has been demonstrated that nitrate reductase is substrate inducible enzyme and thus its level should be an index of reduced nitrogen available for protein synthesis in plants (Heldt, 1997). These effects of weed extracts through their inclusion of growth regulators are consistent with the data of Niharika *et al.* (1998), Irving *et al.* (1992), Hegazy and Abdel Wahab (1966) who indicated an increase in K, P as a result of kinetin and $GA_3$ treatment. Excess Na might cause problems with membranes, enzyme inhibition, or general metabolic dysfunction (Hopkins, 1995). Photosynthesis, on the other hand, is inhibited when high concentrations of Na and/or Cl accumulate in chloroplasts (Taiz & Zeiger, 1998). Exogenous application of GA increased the growth and yield of salt-stressed plants. GA reduced the net accumulation of Na and Cl and maintained a high level of K in salinized (Prakash & Prathapasenan, 1990). The previous data are agreement with our results presented in Table III.

Salt stressed soybean plant showed inhibitory influence on the translocation rate of labeled soluble compounds by 26, 22 and 15% after two hours and by 50, 43 and 32% after four hours in response to 50, 100 and 200 mM NaCl, respectively as compared with control plants (Table IV). Application of weed extract: (a) jungle rice, (b) Cocklebur and (c) purslane to NaCl (50, 100 and 200 mM) treated soybean plants, considerably increased their translocation rate by 35, 31 and 25% for (a), 32, 28 and 23% for (b) and 33, 26 and 24% for (c), after two hours, respectively, as compared with salinized plants (Table IV). Also, that application of weed extract: (a) jungle rice, (b) Cocklebur and (c) purslane and NaCl (50,100 and 200 mM) to soybean plants, considerably increased their translocation rate by 63, 55 and 44% for (a), 60, 52 and 40% for (b) and 61, 47 and 36% for (c), after four hours, respectively, relative to salinized plants. It seems that weed extracts application might exert some sort of initiating steps to favour the translocation presumably through increasing the contents of either K or P (Mengel & Viro, 1974; Yamada *et al.*, 1997)

## REFERENCES

Abd El-Baki, G.K., Z.F. Siefrt, H.M Man, H. Weiner, R. Kaldenhoff and W.M. Kaiser, 2000. Nitrate reductase in *Zea mays* L. under salinity.

*Cell Envir.,* 23: 515–21

Al-Wakeel, S.A., A.A. Hamed and S.S. Dodoura, 1995. Interactive effects of water stress and gibberellic acid on mineral composition of fenugreek plant. *Egypt J. Physiol. Sci.,* 18: 269–82

A.O.A.C., 1975. *Official Methods of Analysis,* 12th Ed., Assoc. of Official Agric. Chemists, Washington, D.C.

Arshad, M. and J. Frankenberger, 1991. Microbial production of plant hormones. *Beltsville-Symposia Agri. Res.,* 14: 327–34

Bates, L.S., R.P. Waldern and I.D. Teare, 1973. Rapid determination of free proline for water stress studied. *Plant Soil,* 39: 205–7

Behairy, A.G., F.A. Rizk and M.R. Shafeek, 1998. Germination of some vegetable plants as affected by root exudates of three weeds. *Egypt J. Appl. Sci.,* 13: 13–5

Bradford, M.M., 1976. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. *Ann. Biochem.,* 72: 248–54

Briendra, K. and S. Bijendra, 1996. Effect of plant hormones on growth and yield of wheat irrigated with saline water. *Ann. Agric. Res.,* 17: 209–12

Cataldo, D.A., M. Haroon, T.E. Schrader and V.L. Youngs, 1975. Rapid colorimetric determination of nitrate in plants tissue by nitration of salicylic acid. Commun. *Soil. Sci. Plant Ann.,* 6: 71–80

Datta, K.S., S.K.Varma, R. Angrish, B. Kumar and P. Kumari, 1997. Alleviation of salt stress by plant growth regulators in *Triticum aestivum* L. *Biol. Plant,* 40: 269–75

Eisa, M.S. and A.M. Hanna, 1997. Frequency and timing of irrigation effect of yield and its components of two soybean cultivars. *J. Agric. Sci. Mansoura Univ.,* 22: 4105–13

El-Habasha, K.M. and A.G. Behairy, 1977. Influence of root exudates on seed germination and seedlings development of some cultivated plants. *Zeitschrift Far Acker und Pflanzenbau,* 145: 66–74

Ferrario, M.S., M.H. Valadier and C. Foyer, 1998. Overexpression of nitrate reductase in tobacco delays drought induced decreases in nitrate reductase activity and mRNA. *Plant Physiol.,* 117: 293–302

Frederick, J.R., C.R. Camp and P.J. Bauer, 2001. Drought stress effects on branch and mainstern seed yield and yield components of determinate soybean. *Crop Sci.,* 41: 759–63

Gadallah, M.A., 1996. Abscisic acid, temperature and salinity interactions on growth and some mineral elements in carthamus plants. *Pl. Growth Regul.,* 20: 225-36

Gallop, P.M., S. Seifter and E. Meilman, 1957. The partial purification and mode of activation of bacterial collagenases. *J. Biol. Chem.,* 227: 891–906

Hamed, M., 2000. Productivity of some vegtable crops as affected by intercropping system. *Ph.D. Thesis,* Faculty of Agric. Ain Shams Univ. Cairo, Egypt

Hathout, T.A., 1996. Salinity stress and its counteraction by the growth regulator (Brassinolide) in wheat plants (*Triticum aestivum* L. cultivar Giza 157). *Egypt J. Physiol. Sci.,* 20: 127–52

Hegazy, A.H. and M.F. Abdel-Wahab, 1966. Effect of gibberellic acid on the phosphate availability in *Vicia faba* seedlings using $^{32}$P. II Studies on influence of gibberellic acid spray on the absorption of phosphate through root and shoot system. *Isotopenpraxis,* 3: 33–44

Hegazy, A.M., F.A. Ebad, F.M. El-Gaaly and N.M. Noureldin, 1995. Interacting effects of salinity and growth regulators on some chemical composition of wheat plants. *Ann. Agric. Sci. Mosht.,* 33: 659–68

Heldt, H.W., 1997. *Plant Biochemistry and Molecular Biology.* New York. Oxford Univ. Press

Hoagland, D.R. and D.I. Arnon, 1950. The water culture method for growing plants without soil. *California Agri. Expt. Station Circ.,* 347: 32–3

Hopkins, W.G., 1995. *Introduction to Plant Physiology.* John Wiley and Sons. Inc. New York

Irving, H.R., C.A. Gehring and R.W. Parish, 1992. Gibberellic acid induces changes of cytosolic free calcium, pH and elongation in maize coleoptiles. *Physiologists,* 49: 112–7

Koul, S., A. Ahuja and S. Grewal, 1982. Growth and alkaloid production in suspension culture of *Hyoscyamus muticus* as influenced by various cultural parameters. *Planta Medica.,* 47, 11-6

Lutts, S., J.M. Kinet and J. Bouharmont, 1996. Effects of soil stress on growth, mineral nutrition and proline accumulation in relation to osmotic adjustment in rice (*Oryza sativa* L.) cultivars differing in salinity resistance. *Plant Growth Regul.,* 19: 207–18

Marques, J.B.B., 1982. Stages of soybean development most susceptible to drought. *Lavaura Arrazeira,* 35: 38–40

Mengel, K. and M. Viro, 1974. Effect of potassium supply on the transport of photosynthates to the fruits of tomatoes. *Physiol. Plant.,* 30: 295–300

Moussa, H.R., 2001. Physiological and biochemical studies on the herbicide (Dual) by using radiolabelled technique. *Ph.D. Thesis.* Fac. of Sci. Ain-Shams Univ.

Muthukumarasamy, M., S. Dutta Gupta and R. Panneerselvam, 2000. Influence of triadimefon on the metabolism of NaCl stressed radish. *Biol. Plant.,* 43: 67–72

Niharika, S., S. Malvika, H. Srivastava, N. Shankar and M. Srivastava, 1998. Influence of nitrogen source cytokinins and antioxidants on the responses of maize seedling to methionine sulfoximine. *Indian J. Expt. Biol.,* 36: 996–1001

Noureldin, N.A., M.Z. Hassan, R.K. Hassan and S.I. Abdel-Wahab, 2002. Performance of some soybean genotypes in sandy soil as influenced by some abiotic stresses. I. Effect of vegetative growth characteristics. *Ann. Agric. Sci. Ain Shams Univ. Cairo,* 47: 191–207

Prakash, L. and G. Prathapasenan, 1990. NaCl and gibberellic acid induced changes in the content of auxin and the activities of cellulose and pectin lyase during leaf growth in rice (*Oryza sativa*). *Ann. Bot.,* 65: 251–7

Prokopy, W.R., 1995. Phosphorus in acetic acid extracts. *Quickchem Method.,* 12: 115–7

Rajesh, A., R. Arumugamand and V. Venkatesalu, 1999. Responses of *Ceriops roxburghiana* to NaCl stress. *Biol. Plant.,* 42: 143–8

Renu, M. and C.L. Goswami, 1995. Trends in activity of some enzymes in cotton cotyledonary leaves with $GA_3$ and NaCl. *Crop. Res. Hisar.,* 10: 201–5

Saker, M.M., and H.A. El-Ashal, 1995. Stimulating effect of salt stress on alkaloid production of cultured Hyoscyamus cells. *Fitoterapia,* 66: 360–5

Shindy, W. and S. Orrin, 1975. Identification of plant hormones from cotton ovules. *Plant Physiol.,* 55: 550–4

Sinha, S., H. Srivastava and R. Tripathi, 1994. Influence of some growth regulators and divalent cations on the inhibition of nitrate reductase activity by lead in maize leaves. *Chemosphere,* 29: 1775–82

Sodek, L. and S. Wright, 1983. The effect of kinetin on ribonucleic acid, lipase and esterase levels in detached wheat leaves. *Phytochem.,* 8: 1629–33

Stefanov, B., L. Iliev and N. Popova, 1998. Influence of $GA_3$ and 4-Phenylurea-30 on leaf protein composition, photosynthetic activity, and growth of maize seedlings. *Biol. Plant.,* 41: 5763

Taiz, L. and E. Zeiger, 1998. *Plant Physiology.* Sinaver Associates, Inc., Publisher, Saunderland, Massachusetts, USA

Yamada, S., M. Osaki and T. Tadano, 1997. Effect of potassium nutrition on translocation of photosynthesized $^{14}$C and carbon nitrogen metabloism in leaves of various crop plants. *In:* T. Ando *et al.* (Eds), *Plant nutr. Sust. Food prod. Envir.,* 889–90, Kluwer Academic Publishers

Younis, M.E., M.A. Abbas and W.M. Shukry, 1994. Salinity and hormone interactions in affecting growth transpiration and ionic relations of *Phaseolus vulgaris*. *Biol. Plant.,* 36: 83–9

**(Received 25 March 2004; Accepted 10 April 2004)**