PHYTON — ANNALES REI BOTANICAE

VOL. 21, FASC. 2 PAG. 177—304 30. 9. 1981

Phyton (Austria)	Vol. 21	Fasc. 2	177—188	30. 9. 1981

Effect of Soil Salinity and IAA on Growth, Photosynthetic Pigments, and Mineral Composition of Tomato and Rocket Plants

By

F. M. Salama, S. E. A. Khodary and M. M. Heikal *)

Received October 12, 1980

Key words: Soil salinity, salt stress, IAA, growth, photosynthetic pigments, mineral composition; tomato, *Lycopersicon esculentum*, rocket, *Eruca sativa*.

Summary

Salama F. M., Khodary S. E. A. & Heikal M. M. 1981. Effect of soil salinity and IAA on growth, photosynthetic pigments, and mineral composition of tomato and rocket plants. — Phyton (Austria) 21 (2): 177—188. — English with German summary.

Sand culture technique was applied to investigate the effect of salinity and IAA on growth, photosynthetic pigments and mineral elements concentration of rocket and tomato plants. At certain salinity levels the growth of the shoots of the test plants was significantly reduced whether the plants were treated or not with IAA. The total pigment concentration, and pigment fractions of the leaves were variably affected under the treatments used. Sodium concentration showed an increased trend by salinization. Potassium level of tomato shoots exhibited an irregular picture, whereas its level showed an

*) F. M. Salama, S. E. A. Khodary, M. M. Heikal, Botany Dept., Faculty of Science, Assiut University, Assiut, Egypt.

increased values in those sprayed with IAA and subjected to −7 and −10 bars. Calcium level in the shoots of the test plants was significantly increased under the influence of most treatments. Magnesium concentration of tomato shoots showed an irregular trend, but its level in Rocket was generally increased by salinity. Phosphorus concentration was significantly decreased by salinization. Total nitrogen of tomato shoots showed a significant decrease while with respect to rocket the nitrogen level was significantly increased at certain salinity levels.

Zusammenfassung

SALAMA F. M., KHODARY S. E. A. & HEIKAL M. M. 1981. Wirkung des Salzgehaltes im Boden und von IAA auf Wachstum, Photosynthesepigmente und Mineralstoffzusammensetzung von Tomate und Rauke. — Phyton (Austria) 21 (2): 177—188. — Englisch mit deutscher Zusammenfassung.

Mittels Sandkulturen wurde der Einfluß von Salzgaben und von IAA auf das Wachstum, auf Photosynthesepigmente und den Gehalt an Mineralstoffen der Tomate (*Lycopersicon esculentum*) und der Rauke (*Eruca sativa*) untersucht. Bei bestimmten Werten des Salzgehaltes war das Wachstum der Testpflanzen unabhängig von IAA vermindert. Menge und Zusammensetzung der Blattpigmente wurden unterschiedlich beeinflußt. Der Na-Gehalt stieg mit zunehmender Salzgabe an, K ergab bei Tomate ein uneinheitliches Bild, zeigte jedoch nach Besprühen mit IAA bei −7 bis −10 bar ansteigende Werte. Der Ca-Gehalt stieg in den Sprossen der Testpflanzen in den meisten Fällen an, der Mg-Gehalt zeigte an Tomate ein unregelmäßiges Verhalten, stieg jedoch bei der Rauke mit der Salzgabe an. Phosphor nahm mit zunehmender Versalzung ab, bei der Tomate auch der Gesamtstickstoff, während dieser bei der Rauke bei bestimmten Salzgaben anstieg.

(Editor transl.)

1. Introduction

Two of the conspicuous effects of auxin at cellular level are the increase of the plasticity of the cell wall and the stimulation of respiration. No satisfactory theory is as yet available as far as the biochemical mechanism of either of these effects is concerned. Most of the work in this field is centered along the following lines: a) the attempt to elucidate the primary step of the hormone action presumably the binding of some macromolecular species (KEY *et al.* 1967), b) the understanding of the nature of the changes of cell wall structure, leading to the increase of deformability (RAY 1967). Despite lot of researches in the salinity field have claimed that salinization could show inhibition of the nutrient uptake (EL-SHOURBAGY & MISSAK 1975, LASHIN & ATANASIU 1972), it has been observed that the salinity may enhance the nutrient uptake (ASANA & KALE 1965).

Salinity on the other hand, has been found to affect the pigment content of certain plant species either increasing (DOSTANOVA, 1966) or decreasing its ratio (GARTNER & MYERS 1963, SHIMOSE 1973).

Treatment by saline solutions has also been found to reduce the growth (KADDAH & GHOWAIL 1964, HUTTON 1971).

In the present work, the influence of Salinity-auxin in relation to growth, pigment concentration, osmotic pressure, and some mineral elements composition of tomato and rocket plants is studied.

2. Materials and Methods

Introduced american tomato (*Lycopersicum esculentum*) and local breed rocket (*Eruca sativa*) were used. The seeds were sown in plastic pots of 1400 g air dry soil (sand/clay 2 :1 v/v). In order to regulate the distribution of the irrigating solutions a perforated plastic tube was introduced through the soil at the pot center. Plants were allowed to grow for 10 weeks at a soil water potential near field capacity. During this period plants were watered with 100 ml portions of full strength Hoagland nutrient solution (HOAGLAND & ARNON 1950). Five plants were left to grow per pot. Stress levels (ψ_s) were chosen at −3, −7, and −10 bars in addition to the control (−0.3 bar). The test plants were twice sprayed with 50 p. p. m. IAA solution (2 ml for each pot). For each treatment three pots were assigned at random.

Saline solutions were prepared according to (LAGERWERFF & HOLLAND 1960), and provided as irrigating solutions to adjust ψ_s to the desired level. A mixture of calcium chloride and sodium chloride was used, to prevent the toxic effect of sodium ions. The sodium adsorption ratio (SAR) was fixed at 12.5% in all solutions in order that their effects become mainly osmotic (LAGERWERFF & EAGLE 1961).

Treatment of plants with saline and IAA solutions began when seedlings were 8 weeks old. Plants were allowed to adjust to their ψ-levels for a period of 2 weeks. At the end of the experimental period transpiration was measured gravimetrically by weighing the pots at fixed times: 7, 10 a. m., 1, 4, and 7 p. m. The osmotic pressure of leaf sap was measured by the cryoscopic method (WALTER 1949) and details on this were described by (EL-SHARKAWI & ABDEL RAHMAN 1974).

Also the photosynthetic pigments were extracted and determined spectrophotometrically (METZNER *et al.* 1965). To determine the dry weight, shoots of the test plants were cut and dried in an aerated oven at 80° C until constant weight, and the water content was calculated. The dry samples were then ground into a fine powder which consequently assayed for mineral ions determinations. The flame photometer method (WILLIAMS & TWINE 1960) was used for sodium and potassium determinations.

Total nitrogen was estimated by the modified micro-Kjeldahl method (PAECH & TRACEY 1956). Likewise, phosphorus was determined colourimetrically (WOODS & MELLON 1941). On the other hand, calcium and magnesium were assayed by the versene titration method (SCHWARZENBACH & BIEDERMANN 1948).

Abbreviations: ψ_s = the osmotic potential of the soil solution; IAA = indole acetic acid; chl. = chlorophyll.

3. Results

Salinity has induced variable changes in the growth, osmotic pressure, transpiration, pigment concentration, and mineral composition of tomato and rocket plants as shown in Tables 1, 2, 3 and 4.

3.1 Growth:

The shoot growth of the test plants is represented as fresh and dry weight (Table 1). Salinity exerted a significant reduction in the fresh weight whether the plants were treated or not with IAA.

On the other hand, the dry weight of the shoots of the two test plants showed an irregular trend.

3.2 Water Content:

The shoot water content of each of the two test plants was almost significantly reduced at all the investigated treatments. The results also show that the water content of tomato shoots is relatively higher than that of rocket plants, (Table 1).

Table 1

Mean values of fresh, dry weights (in grammes) and water content (g H_2O/g dry wt.) of Tomato and Rocket shoots as influenced by salinity and IAA

Treatment	Tomato			Rocket		
	F. wt	D. wt	water content	F. wt	D. wt	water content
Control	11.30	0.87	12.10	14.00	1.30	9.70
Control+IAA	11.60	0.93	11.50*)	13.30	1.30	9.20
− 3 bar	9.50*)	0.95	8.90*)	8.60*)	0.88*)	8.80*)
− 7 bar	7.80*)	0.80	8.80*)	12.60*)	1.50*)	7.40*)
−10 bar	6.00*)	0.78	6.70*)	6.80*)	0.95*)	6.20*)
− 3+IAA	10.70	1.00*)	9.70*)	8.30*)	0.90*)	8.20*)
− 7+IAA	8.20*)	0.85	8.50*)	10.30*)	1.20	7.60*)
−10+IAA	6.60*)	0.73*)	8.00*)	6.60*)	0.79*)	7.40*)
L. S. D. at 5%	1.23	0.11	0.57	1.22	0.14	0.51

*) Significant at 5% level of probability (also in Table 2—4).

3.3 Osmotic Pressure:

Table 2 shows that osmotic pressure of the test plants was almost significantly increased at all treatments as compared with control, with the exception of tomato plants sprayed only with IAA where the osmotic pressure was significantly decreased, despite in the case of rocket plants sprayed only with IAA, the osmotic pressure was non-significantly altered.

3.4 Transpiration:

Generally, transpiration rate and total water transpired were significantly reduced in test plants either treated with salinity or treated with salinity and IAA in comparison with those of the control.

Transpiration rate and total water transpired of the plants treated with IAA only were higher than those of control plants. Transpiration rate shows higher levels in rocket plants than that of tomato ones (Table 2).

Table 2

Effect of salinity and IAA on: osmotic pressure (O. P.) (atmospheres), transpiration rate (T. R.) (mg/g lf f. wt./hr), and total water transpired (T. T. W.) in g/pot of Tomato and Rocket plants

Treatment	Tomato O. P.	Tomato T. R.	Tomato T. T. W.	Rocket O. P.	Rocket T. R.	Rocket T. T. W
Control	20.87	78.40	8.80	20.84	145.20	21.90
Control+IAA	16.74*)	83.70*)	9.70	21.24	184.60*)	25.30*)
— 3 bar	20.50	80.80	7.10*)	22.24*)	146.20	12.70*)
— 7 bar	24.64*)	36.10*)	2.80*)	24.64*)	116.70*)	14.50*)
—10 bar	23.44*)	38.40*)	2.30*)	24.84*)	117.10*)	8.00*)
— 3+IAA	20.84	82.20	8.70	24.40*)	179.10*)	15.10*)
— 7+IAA	24.80*)	60.70*)	4.00*)	21.64*)	117.80*)	12.70*)
—10+IAA	22.84*)	55.90*)	4.00*)	23.64*)	111.10*)	7.40*)
L. S. D. at 5%	0.74	4.66	1.06	0.66	14.00	3.03

3.5 Pigment Concentration:

The total pigment concentration and pigment fractions (chl. a, chl. b, and carotenoids) as mg/250 mg fr. wt of tomato leaves were increased only in plants treated with IAA only as well as in those grown under water stress (—3 bar) and treated with IAA. Otherwise, the total pigments and pigment fractions were decreased. The ratios of a/b were approximately unchanged at all treatments as compared with control. This means that the changes in the biosynthesis of chl. a were in parallel with those of chl. b.

On the other hand, total pigments and pigment fractions of rocket plants were significantly increased at all treatments, except those grown at —3 bar stress, where pigment concentration was significantly reduced (Table 3). It could be observed that plants grown at the various levels of water stress and treated with IAA were mostly of high pigment concentration as compared with those plants non-treated with IAA. It could be also emphasized that the biosynthesis of chl. a was in parallel to that of chl. b. (Table 3).

Table 3

Effect of salinity and IAA on photosynthetic pigments and pigment fractions (mg/250 mg lf. f. wt.) of Tomato (a) and Rocket plants (b)

a) Tomato

Treatment	a	b	c	a+b+c	a/b
Control	3.10	1.30	0.67	5.00	2.40
Control+IAA	3.50*)	1.60*)	0.69	5.70*)	2.20
− 3 bar	3.30	1.20	0.79*)	5.30	2.80
− 7 bar	2.00	0.73*)	0.47*)	3.20*)	2.60
−10 bar	2.10*)	0.60*)	0.61	3.30*)	3.80
− 3+IAA	3.50*)	1.40	0.72	5.60*)	2.60
− 7+IAA	2.70*)	1.20	0.50*)	4.40*)	2.80
−10+IAA	2.30	0.87*)	0.59*)	3.80*)	2.70
L. S. D. at 5%	0.31	0.24	0.08	0.54	N. S.

b) Rocket

Treatment	a	b	c	a+b+c	a/b
Control	2.90	1.00	0.79	4.60	3.00
Control+IAA	3.00	1.10*)	0.88*)	4.98*)	2.90
− 3 bar	2.50*)	0.90*)	0.72*)	4.10*)	2.80
− 7 bar	3.20*)	1.10*)	0.84*)	5.10*)	2.90
−10 bar	3.30*)	1.20*)	0.93*)	5.40*)	2.80
− 3+IAA	3.10*)	1.20*)	0.75	5.10*)	2.50
− 7+IAA	3.80*)	1.10*)	0.98*)	5.90*)	3.70
−10+IAA	3.40*)	1.20*)	0.88*)	5.50*)	2.80
L. S. D. at 5%	0.19	0.10	0.04	0.33	N. S.

a = chl. a; b = chl. b; c = carotenoids.

3.6 Mineral Composition:

3.6.1 Sodium:

Sodium concentration in the shoot of plants treated with IAA only was significantly decreased as compared with the control. Sodium level of the two test plants was significantly increased at the other treatments except tomato plants which were treated with IAA and grown at the different salinity levels, where sodium concentration was non-significantly changed. Generally tomato shoots were of higher sodium level than those of rocket plants (Table 4).

3.6.2 Potassium:

With regard to potassium concentration, it could be noticed that potassium level of tomato shoots showed an irregular trend, however it was significantly increased in plants treated with IAA and grown at —7, and —10 bars.

Table 4

Changes in mineral composition of Tomato (a) and Rocket (b) subjected to salinity and IAA treatments. Data are expressed as mg/g dry weight of the shoots

a) Tomato

Treatment	Na	K	Ca	Mg	P	N
Control	19.80	27.20	44.70	13.60	2.30	23.50
Control+IAA	16.60*)	31.80*)	45.00	13.20	1.93*)	23.90
— 3 bar	22.60	30.00*)	49.00*)	12.60*)	1.68*)	22.60*)
— 7 bar	26.10*)	20.00*)	71.00*)	10.20*)	1.61*)	18.20*)
—10 bar	26.32*)	21.30*)	67.00*)	17.00*)	1.72*)	17.70*)
— 3+IAA	19.60	25.50	51.30*)	11.20*)	1.49*)	20.10*)
— 7+IAA	20.30	29.80*)	62.70*)	14.00	1.66*)	20.50*)
—10+IAA	18.80	30.50*)	58.00*)	14.80*)	1.96	21.70*)
L. S. D. at 5%	2.98	2.35	3.59	0.88	0.07	0.49

b) Rocket

Treatment	Na	K	Ca	Mg	P	N
Control	6.50	43.80	35.70	7.80	3.20	19.60
Control+IAA	5.40*)	42.80	37.00	9.40*)	2.70*)	19.80
— 3 bar	11.40*)	41.70*)	37.00	9.00*)	2.20*)	22.10*)
— 7 bar	8.40*)	43.50	38.50*)	8.10	2.10	20.80*)
—10 bar	9.00*)	38.50*)	40.50*)	9.30*)	1.90*)	17.70*)
— 3+IAA	10.20*)	43.50	36.70	8.40	2.60*)	21.70*)
— 7+IAA	9.60*)	46.00*)	38.70*)	7.60	2.30*)	19.20
—10+IAA	10.90*)	40.00*)	42.70*)	7.20	2.30*)	19.90
L. S. D. at 5%	0.64	1.59	1.33	0.71	0.17	0.91

On the other hand, potassium concentration of rocket shoots was generally decreased at all the investigated treatments with the exception of those plants treated with IAA and grown at —7 bar, where potassium concentration was significantly increased as compared with the control (Table 4).

3.6.3 Calcium:

Table 4 shows that the calcium concentration in the shoots of each of the two test plants was significantly increased at all treatments, except in the case of tomato plants treated with IAA only. In rocket plants either treated or not treated with IAA and grown at —3 bar, calcium level was non-significantly increased.

3.6.4 Magnesium:

Magnesium level of tomato shoots showed an irregular trend at all treatments (Table 4). On the other hand, in case of rocket magnesium concentration showed an increase in control plants treated with IAA, and also in plants which were subjected to —3, —7, and —10 bars. Otherwise magnesium level of rocket plants treated with IAA and grown at the investigated salinity levels exerted more or less unchangeable trend (Table 4).

3.6.5 Phosphorus:

Table 4 shows that phosphorus level of each of the two test plants was significantly decreased at all treatments, with the exception of those sprayed with IAA and grown at —10 bar, where the decrease was insignificant as compared with control.

3.6.6 Nitrogen:

Nitrogen concentration in tomato shoots reflected a significant decrease at all treatments except the treated control plants with IAA where the nitrogen level was non-significantly increased, (Table 4).

With respect to rocket shoots, nitrogen concentration was significantly increased in plants subjected to —3 and —7 bars, while in plants grown at —10 bar where the nitrogen level showed a significant decrease. On the other hand, it could be emphasized that rocket plants treated with IAA and grown at —3 bar showed a significant increase of nitrogen level while those sprayed with IAA and subjected to salinity levels (—7, and —10 bars) showed non-significant changes in their nitrogen concentration (Table 4).

4. Discussion

The general reduction in the fresh and dry weights of the two test plants, subjected to salinity or salinity-IAA treatments may be partly due to the osmotic effect (Greenway 1973). The water content of tomato and rocket plants showed, in the present work, a significant decrease at all the investigated treatments. In this respect, Meiri *et al.* (1971) and Heikal (1977) observed also a remarkable decrease in water content in chloride salinated bean plants. The reduction in tissue water content is expected for water stressed plants (Gates 1955).

The increase in the osmotic pressure of plants grown at the investigated salinity levels is in agreement with the results obtained by Bernstein (1961) and El-Sharkawi & Salama (1973, 1976). This increase in osmotic pressure could be as a result of one or more of: increased photosynthesis, or translocation, decreased respiration, or conversion of nonsoluble metabolites to soluble forms.

A conversion mechanism, though being a positive process towards adjustment to stress, is rather catabolic in nature and serves to deplete reserve metabolites and hence leads to impaired growth (EL-SHARKAWI & MICHEL 1975). The plants which treated and those non treated with IAA, and grown at the investigated salinity levels showed a reduction in their transpiration rate. The above result (without using IAA is in agreement with that obtained by GALE *et al.* (1967) and BOZOUKE (1975).

The results of photosynthetic pigments concentration, showed that, the plastid pigments of the test plants was variably affected. The pigment concentration of both IAA sprayed and non-sprayed plants, and subjected to salinization treatments was generally decreased. These results, in part, are similar to those observed by (LAPINA & POPOV 1970). On the other hand, pigment concentration of rocket plants without using IAA was generally increased, this is supported by the results of HEIKAL (1975) and AHMED *et al.* (1977) by using some glycophytic plants.

Some differences in the mineral element composition of the two test plants were recorded as a result of different treatments. The accumulation of sodium with the rise of salinity level, particularly in rocket plants is similar to the results recorded by EL-SHOURBAGY & MISSAK (1975) and HEIKAL (1977) using some agricultural crops.

The irregular trend of potassium in the tested plants and grown at salinity effect was also postulated by KADDAH & GHOWAIL (1964) and RUSH & EPSTEIN (1976). On the other hand, the general decrease of potassium level of rocket plants was also in agreement with the results reached by RUSH & EPSTEIN (1976) and HEIKAL (1977).

The general increase in the calcium concentration of the test plants is in agreement with the results obtained by ASANA & KALE (1965) and HEIKAL (1977).

With regard to magnesium, it could be pointed out that its level did not exhibit a regular trend, but it varied according to the plant type and to the treatment used. In this respect, some authors (BIERHUIZEN & PLOEGMAN 1967) recorded an increase in magnesium concentration of salinized plants, while others LASHIN & ATANASIU (1972) and HEIKAL (1977), on the other hand recorded a considerable decrease. The decrease in phosphorus concentration of the two tested plants at all investigated treatments seems to be a dominant effect of salinity. Similar results were obtained by LUNIN & GALLATIN (1964) with some other crop plants.

Total nitrogen concentration of tomato plants seems to be reduced at all treatments. This reduction is in agreement with the results of HUTTON (1971) and LASHIN & ATANASIU (1972). With respect to rocket plants, nitrogen concentration showed irregular trend. This irregularity of nitrogen level was also observed by COHEN *e. al.* (1964) and HUTTON (1971). The general picture appears to imply that, except the sodium and calcium ions, a reduction rather than promotion in the accumulation of the other estimated nutrient elements of the two test plants, is the dominant effect of the salinity levels used. In addition a reduction in fresh and dry weights, transpiration rate, and water content were also recorded in plants either treated or non-treated with IAA and grown at certain salinity levels. This means that the treatment of salinized plants with indole acetic acid as a plant growth substance did not counteract the effect of salinity for the studied parameters of tomato and rocket.

5. Acknowledgements

The authors are sincerely grateful due to Professor Dr. A. F. Radi, Head of Botany Dept. Assiut University, Faculty of Science for the valuable help.

6. References

Ahmed A. M., Heikal M. M. & Shaddad M. A. 1977. Photosynthesis of some economic plants as affected by salinization treatments II: Safflower and maize. — Egypt. J. of Botany 20: 17—27.

Asana R. D. & Kale V. R. 1965. A study of salt tolerance of four varieties of wheat. — Indian. J. Plant Physiol. 8: 6—20.

Bernstein L. 1961. Osmotic adjustment of plant to saline media. I. Steady state. — Am. J. Bot. 48: 909—919.

Bierhuizen J. F. & Ploegman C. 1967. Salt tolerance of tomato. — Meded. Dir. Tuninb. 30: 302—310.

Bozouke S. 1975. Effect of sodium chloride upon growth and transpiration in *Statice* sp. and *Pisum sativum* L. — Proc. of 3th. MPP Meeting Izmir. Turkey, 37—42.

Cohen D., Kessler B. & Monselise S. B. 1964. Studies on water regime and nitrogen metabolism of citrus seedling grown under water stress. — Plant Physiol. 39: 379—386.

Dostanova R. K. H. 1966. Effect of Na_2SO_4 and NaCl on metabolism of plastid pigments in plants. — Fiziologia Rast. 13: 614—622.

El-Sharkawi H. M. & Salama F. M. 1973. Drought resistance criteria in some wheat and barley cultivars. II. Adjustment in internal water balance. — 7th. Arab. Sc. Congr., Cairo 5: 25—42.

— & Abdel-Rahman A. A. 1974. Response of olive and almond orchards to partial irrigation under dry forming practices in semi-arid regions II. Plant soil water relations in olive during the growing season. — Plant and Soil (Netherland) 31: 13—32.

— & Michel B. E. 1975. Effect of soil salinity aud air humidity on CO_2 exchange and transpiration of two grasses. — Photosynthetica 9: 277—282.

— & Salama, F. M., 1976. Salt tolerance criteria in some wheat and barley cultivares. II. Adjustment in internal water balance. — Bull. Fac. Sci., Assiut Univ. 5: 1—15.

— & Missak, N. L. 1975. Effect of growing seasons and salinity on growth mineral composition and seed-lipid characteristics of some *Ricinus communis* L. varieties. — Flora 164: 51—71.

GALE J., KOHL H. C. & HAGAN R. M. 1967. Changes in water balance and photosynthesis of onion, bean and cotton plants under saline conditions. — Physiol. Plant. 20: 408—420.

GARTER D. L. & MYERS V. I. 1963. Light reflectance and chlorophyll and carotene contents of grape fruit leaves as affected by Na_2SO_4, NaCl and $CaCl_2$. — Proc. Amer. Soc. Hort. Sci. 82: 217—222.

GATES C. T. 1955. The response of the young tomato plant to a brief period of water shortage. I. The whole plant and its parts. — Aust. J. Biol. Sci. 8: 196—214.

GREENWAY H. 1973. Salinity, plant growth and metabolism. — J. Aust. Inst. Agr. Sci. Vol. 1973. March: 24—34.

HEIKAL M. M. D. 1975. Physiological studies on salinity I. Effect of saline irrigation on growth and photosynthetic pigments of safflower and sunflower plants. — Bull. of Science and Technology, Assiut Univ. 4: 1—11

— 1977. Physiological studies on salinity III. Changes in water content and mineral composition of some plants over a range of salinity stresses. — Plant and Soil 48: 223—232.

HOAGLAND D. R. & ARNON D. I. 1950. The water culture method for growing plants without soil. — Calif. Agric. Exp. Sta. Cir.: 347—352.

HUTTON E. M. 1971. Variation in salt response between tropical pasture legumes. — SABRAO News Letter 3: 75—81.

KADDAH M. T. & GHOWAIL S. L. 1964. Salinity effect on the growth of corn at different stages of development. — Agron. J. 56: 214—217.

KEY J. L., BARNETT N. M. & LIN C. Y. 1967. RNA and protein biosynthesis and the regulation of cell elongation by auxin. — Ann. N. Y. Acad. Sci. 144, 49—62.

LAGERWERFF J. V. & HOLLAND J. P. 1960. Growth and mineral content of carrots and beans as related to varying osmotic and ionic composition effects in saline sodic sand cultures. — Agron. J. 52: 606—608.

— & EAGLE H. E. 1961. Osmotic and specific effects of excess salts on beans. — Plant Physiol. 36: 472—477.

LAPINA L. P. & POPOV B. A. 1970. Effect of NaCl on photosynthetic apparatus of tomato plants. — Fiziologia Rast. 17: 477—481.

LASHIN M. H. & ATANASIU H. 1972. Studies on the effect of salt conc. on the formation of dry matter, uptake of mineral nutrients and mineral composition of cotton plants during the vegetative growth period. — Z. Acker- und Pflanzenbau 135: 178—188.

LUNIN J., GALLATIN M. H. & BATCHELDER A. K. 1964. Effect of supplemented irrigation with saline water on soil composition and on yields and cation content of forage corps. — Soil. Sci. Soc. Am. Proc. 28: 551—554.

MEIRI A., KAMBUROFF J. & POLJAKOFF-MAYBER A. 1971. Response of bean plants to sodium chloride and sodium sulphate salinization. — Ann. Bot. 35: 837—847.

METZNER H., RAU H. & SENGER H. 1965. Untersuchungen zur Synchronisierbarkeit einzelner Pigmentmangel-Mutanten von *Chlorella*. — Planta 65: 186—194.

NIEMAN R. H. 1965. Expansion of bean leaf and its supperssion by salinity. Plant. Physiol. 40: 156—161.

PAECH K. & TRACEY M. V. (Edts.) 1956. Modern Methods of plant analysis, Vol. 1. — Springer-Verlag, Berlin—Göttingen—Heidelberg.

RUSH D. W. & EPSTEIN E. 1976. Genotypic responses to salinity. Differences between salt-sensitive and salt-tolerant genotypes of the Tomato. — Plant Physiol. 57: 162—166.

RAY P. M. 1967. Radioautographic study of cell wall deposition in growing plant cells. — J. Cell. Biol. 35: 659—674.

SCHWARZENBACH G. & BIEDERMANN W. 1948. Komplexone. X. Erdalkalikomplexe von 0,6-Dioxyazofarbstoffen. — Helv. Chim. Acta 31: 678—687

SHIMOSE N. 1973. Physiology of salt injury in crops. — X. Sci. Rept. Fac. Agr. Okayama Univ. 41: 69—78.

WALTER H. 1949. Grundlagen der Pflanzenverbreitung. Einführung in die Pflanzengeographie für Studierende an den Hochschulen. Standortslehre. — Ulmer, Stuttgart.

WILLIAMS C. H. & TWINE J. R. 1960. Flame photometric method for sodium, potassium and calcium. In: PAECH K. & TRACEY M. V. (Edts.), Modern methods of plant analysis, 5: 3—5. — Springer Verlag Berlin—Göttingen—Heidelberg.

WOODS J. T. & MELLON M. G. 1941. Chlorostannous-reduced Molybdophosphoric Blue colour method, in sulfuric acid system. In: JACKSON M. L., Soil chemical analysis, 141—144. — Prentice-Hall International Inc. London.