Phyton (Austria)	Vol. 20	Fasc. 1–2	159–173	15. 2. 1980

Dry Matter and Mineral Composition of some Oil Producing Plants as Influenced by some Salinization Treatments

By

M. M. HEIKAL, A. M. AHMED and M. A. SHADDAD *)

With 7 figures

Received June 19, 1979

Key words: dry matter, mineral salts, major elements, salinization salt stress, *Helianthus annuus*, *Ricinus communis*, *Linum usitatissimum*

Summary

Water culture technique was used to study the effect of different levels (0.0–100 meq/l) of sodium sulphate on dry matter yield and on the content of some nutrient elements (Na, K, Ca, Mg, P and N) of castor bean, sunflower and flax plants. Sodium content of the test plants was increased progressively with the rise of salinity level. The relatively low and moderate salinization levels (20 and 40 meq/l Na_2SO_4) almost induced a highly significant increase in total dry matter and in the content of most of the investigated elements in the test plants as compared with control plants. However, dry matter and the content of these mineral elements was mostly reduced with the rise of salinity from the level 60 meq/l up to the highest level used (100 meq/l).

Zusammenfassung

Trockensubstanz und Mineralsalzgehalt einiger Ölpflanzen unter dem Einfluß verschiedener Salzgaben

Es wurde der Einfluß verschieden hoher Gaben von Na_2SO_4 (0–100 mval/l) auf Trockensubstanz und Gehalt an einigen Nährelementen (Na, K, Ca, Mg, P und N) an Wasserkulturen von *Ricinus*, Sonnenblume und Lein untersucht. Der Na-Gehalt der Testpflanzen stieg mit der Salzgabe bis in die höchste untersuchte Konzentration (100 mval/l) an. Geringe Salzgaben (20–40 mval/l) führten zu einem signifikanten Anstieg der Gesamttrockensubstanz und des Gehaltes an den meisten untersuchten Elementen gegenüber den Wasserkontrollen. Weitere Erhöhung der Salzgabe von 60 bis 100 mval minderte meistens die Trockensubstanz sowie den Gehalt an diesen Elementen.

(Editor transl.)

*) M. M. HEIKAL, A. M. AHMED, M. A. SHADDAD, Botany Department, Faculty of Science, Assiut University, Assiut, Egypt.

Introduction

Salinity is a problem associated with many of the arid regions of the world. The salt tolerance of plants and the changes in their physiological activities and growth have recieved considerable attention throughout the last half century as evidenced in reviews of literature such as those by HAYWARD & BERNSTEIN (1958) and BERNSTEIN (1975). KADDAH & GHOWAIL (1964), EVDOKIMOV (1969), HUTTON (1971) and POLJAKOFF-MAYBER & GALE (1975) study the effect of salinization treatments on growth and production of some glycophytic plants. Mineral nutrition of plants under saline conditions has also been reviewed (LASHIN & ATANASIU 1972, HELLEBUST 1976 and HEIKAL 1977). In addition a number of investigators (GATES *et al.* 1966, EL-SHOURBAGY & MISSAK 1975 and HEIKAL 1977) demonstrated that salinity induced a disturbance in nitrogen metabolism of some plants. Due to the variations in the level and duration of salinization treatments as well as the type of the plants used, the results were always inconsistant. This inconsistancy induced the necessity to investigate routinely the ability of our economic plants to tolerate saline conditions. The present study was conducted to obtain informations regarding the influence of various concentrations of Na_2SO_4 in water cultures upon dry weight yield and mineral composition of the oil producing castor bean, sunflower and flax plants in the vegetative phase.

Material and Methods

Culture technique:

Castor bean (*Ricinus communis* var. Hindi) sunflower (*Helianthus annuus*) and flax (*Linum usitatissimum* var. Giza 4) seeds obtained from the University Farm were germinated as described by RADI *et al.* (1973). Thereafter individual seedlings were selected and cultivated for 10 days into glass pots containing two liters of ½ concentration of PFEFFER's nutrient solution. The micronutrients were added to the nutrient solutions as described by ARNON & HOAGLAND (1940). Selected seedlings were then transferred to the experimental nutrient solutions with varying concentrations of Na_2SO_4 (0.0—1000 meq/l). The experiment was carried out in four replicates. To keep the nutrient elements and salinity levels as close to their initial values as possible, the culture solutions were renewed every three days. In addition the culture solutions were aerated 10 minutes daily. The plants were left to grow for 60 days in green house at the normal time of growing under the various treatments of salinity. At the end of the experimental period, leaves, stems and roots from plants grown in one pot were taken to determine the dry weights. The dry samples were then ground into a fine powder and then assayed for mineral ion determinations.

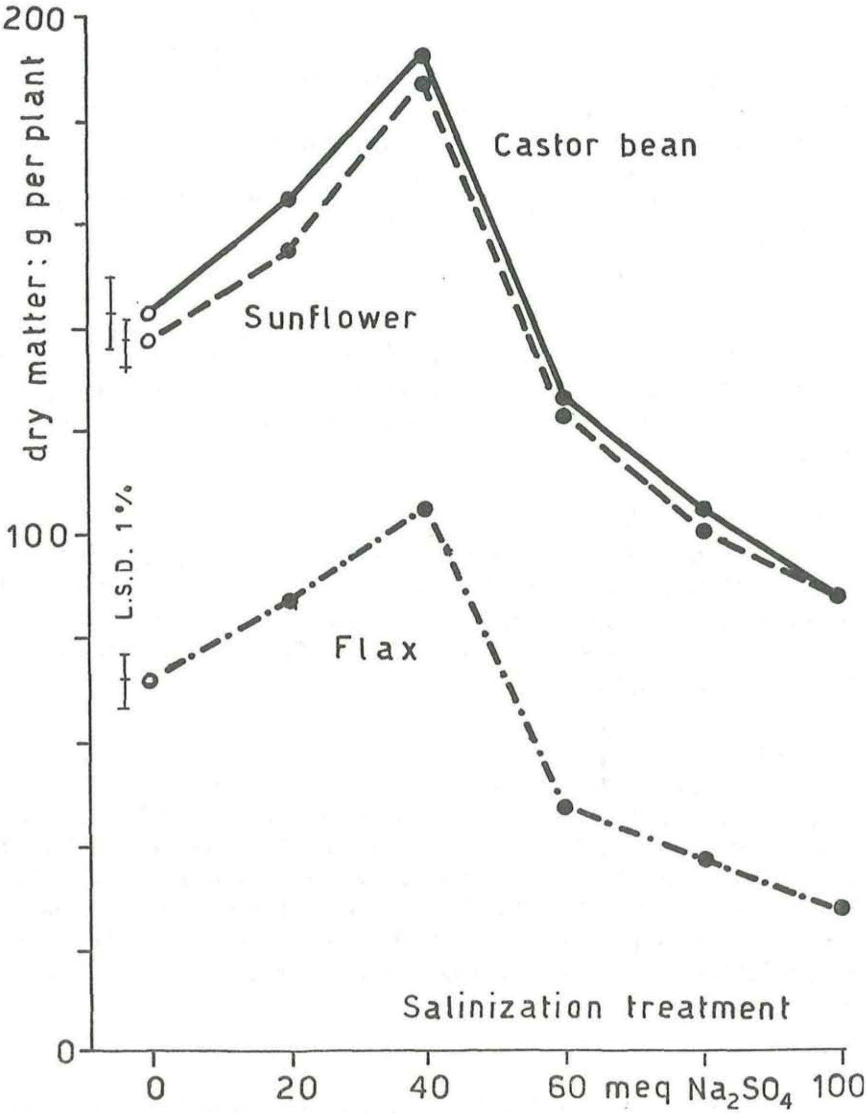

Fig. 1. Total dry matter yields (g per plant) of castor bean, sunflower and flax, salinized for 60 days with different levels of sodium sulphate. — Signatures: Closed circles mean highly significant differences between the values indicated and the control ($p \leqq 1\%$). Values marked with half closed circles differ from the control with lower significance (p within 1 and 5%). The least significant differences (L. S. D., $p = 1\%$) are indicated on the left side of each diagram

Methods of analysis:

The flame photometer method (WILLIAMS & TWINE 1960) was used for sodium and potassium determination. Calcium and magnesium were determined by versene titration method (SCHWARZENBACH & BIEDERMANN 1948). Phosphorus was estimated colorimetrically as described by WOODS & MELLON (JACKSON 1958). TCA soluble and insoluble nitrogen were determined by microkjeldahl method (PAECH & TRACEY 1956). The data were expressed as mg/g dry matter and were always statistically analysed to calculate the least significant difference.

Results

The different levels of sodium sulphate variously affected the total dry weight yield and the mineral composition of the principal plant parts (leaves, stems and roots) of castor bean, sunflower and flax as shown in Figs. 1—7.

Total dry matter yield:

The results in Fig. 1 reveal that the total dry matter yield of the test plants was highly significantly increased with the rise of salinization level up to 40 meq/l, where it exhibit its maximum values. Thereabove these values decreased consistantly with the rise of salinization up to the highest level used (100 meq/l).

Sodium:

Sodium content was highly significantly increased in the different organs of the test plants with the rise of sodium sulphate level. This increase was almost linear with increasing salt concentration. The accumulation of sodium was greater in the roots of castor bean and sunflower than in their leaves and stems (Figs. 1, 2). However in flax, the leaves accumulated much more sodium than the stems and roots (Fig. 4). In general it can be noticed that the different organs of castor bean accumulated less sodium than those of sunflower and flax.

Potassium:

Potassium content of the leaves of castor bean and sunflower was highly significantly increased with the increase of Na_2SO_4 added up to the level 80 meq/l and 60 meq/l respectively. In case of roots and stems the content of potassium was also significantly increased but only at the levels of 20 and 40 meq/l Na_2SO_4. With the rise of Na_2SO_4 concentration up to the highest level the content of patassium of either roots or stems decreased significantly (Figs. 2, 3). In case of flax, the different organs exhibited significant reduction in their potassium content (Fig. 4). This reduction was

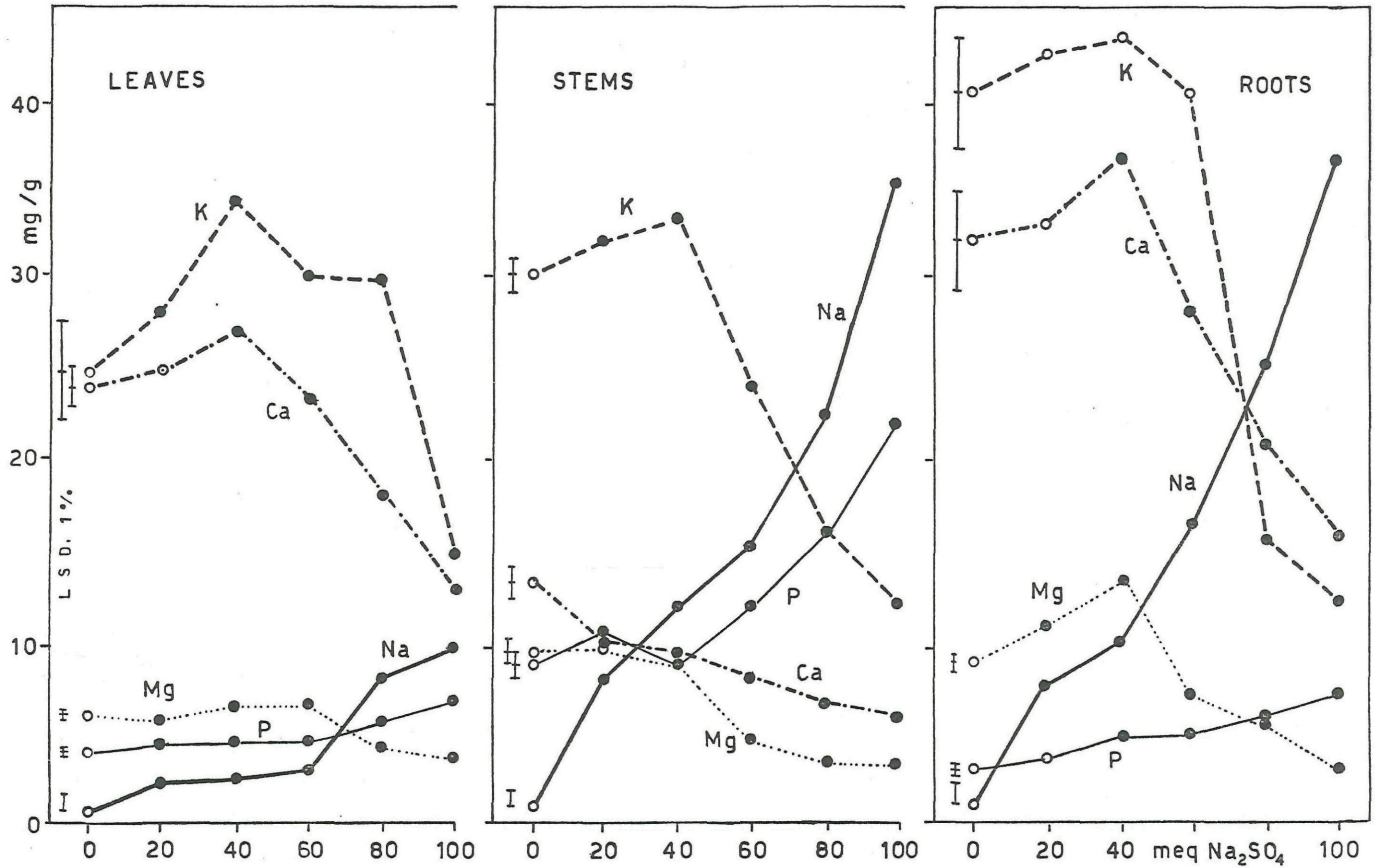

Fig. 2. Castor bean: Effect of different levels of sodium sulphate when supplied for 60 days on the distribution of some mineral elements (mg/g dry matter). Signatures see Fig. 1

more pronounced as the concentration of Na_2SO_4 increased, except in case of stems at 20 and 40 meq/l where the content was on the other hand highly significantly increased.

Calcium:

Calcium content of the different organs of the three test plants was almost highly significantly increased at relatively low and moderate Na_2SO_4 levels, except in case of castor bean stems where the content of calcium was always reduced whatever the salinization level used. On the other hand, with the rise of salinization level from 60 up to 100 meq/l the content of calcium of the different organs of the test plants was significantly reduced (Fig. 2—4).

Magnesium:

The results presented in Fig. 2 indicate that in case of castor bean, the different levels of Na_2SO_4 resulted in a significant reduction in magnesium content of the different organs, except in case of leaves at 40 and 60 meq/l and roots at 20 and 40 meq/l where the content of magnesium was markedly increased. Magnesium content of sunflower leaves was significantly reduced at all salinity levels (Fig. 3). This reduction was almost linear with the increase of salt concentration. In stems and roots the content of magnesium was on the other hand significantly increased with the rise of Na_2SO_4 concentration up to the level 60 meq/l. Thereabove its content was markedly decreased. In case of flax (Fig. 4) the content of magnesium of leaves and stems was significantly increased at relatively low and moderate levels (20 and 40 meq/l), but it decreased at higher levels. Magnesium content of flax roots was highly significantly increased at all Na_2SO_4 levels. This increase was almost linear with the rise of salinity level.

Phosphorus:

Fig. 2 shows, that phosphorus content of the principal organs of castor bean was highly significantly increased at all Na_2SO_4 levels. This increase was almost linear with the rise of salinity level. In case of sunflower (Fig. 3), the low and moderate salinization levels (20 and 40 meq/l) did not induce any significant effect on the content of phosphorus in leaves. However these levels induced significant increase in phosphorus content of stems and roots. At relatively high levels (60—100 meq/l), while the contents of phosphorus of leaves and roots were markedly decreased, that of stems was nearly unaffected (Fig. 3). In case of flax the different levels of Na_2SO_4 induced a highly significant increase in phosphorus content of leaves. The stems and roots also accumulated phosphorus but only at relatively low and moderate salinization levels. At higher levels the content of phosphorus decreased significantly especially in case of roots (Fig. 4).

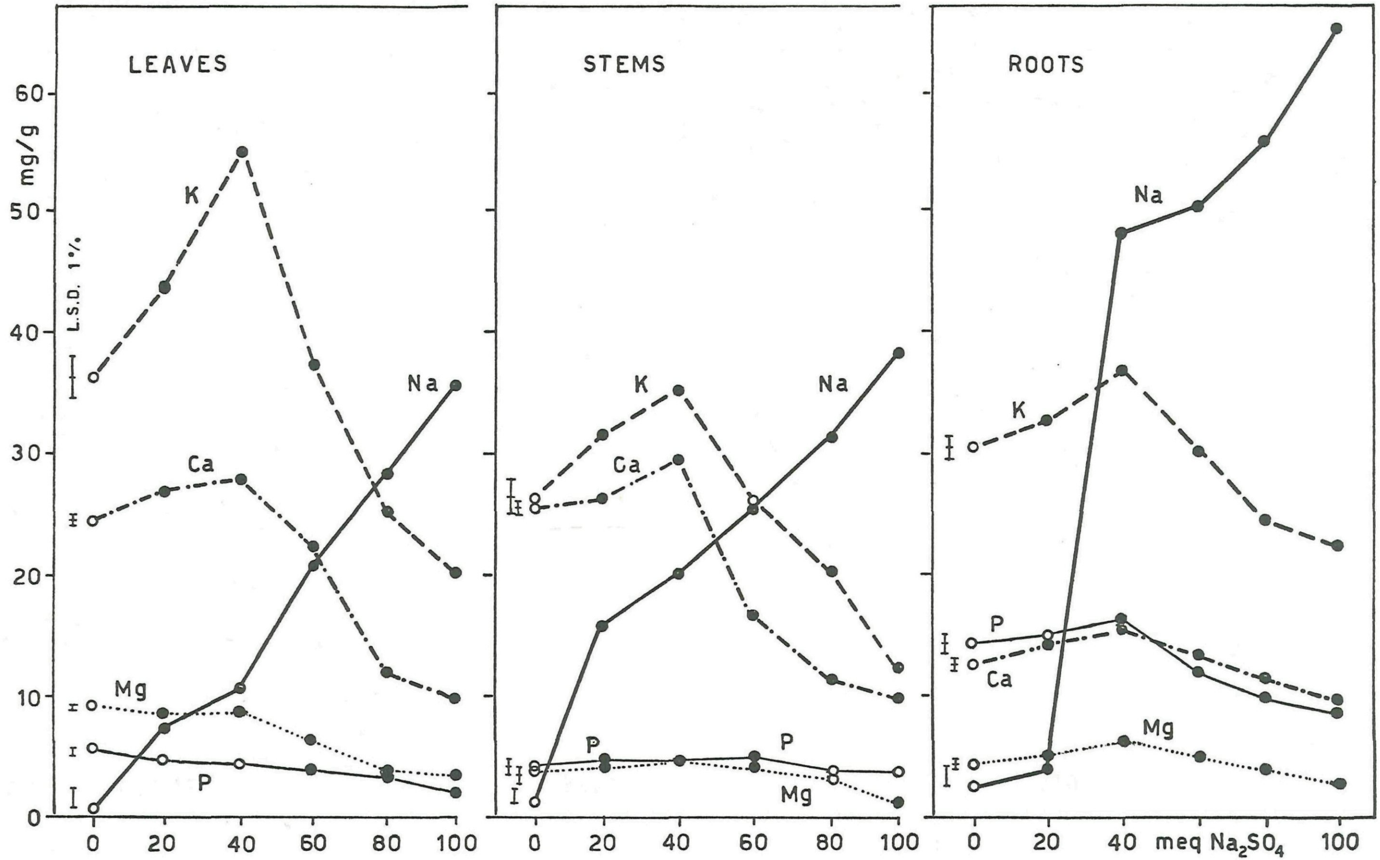

Fig. 3. Sunflower: Effect of different levels of sodium sulphate when supplied for 60 days on the distribution of some mineral elements (mg/g dry matter. Signatures see Fig. 1

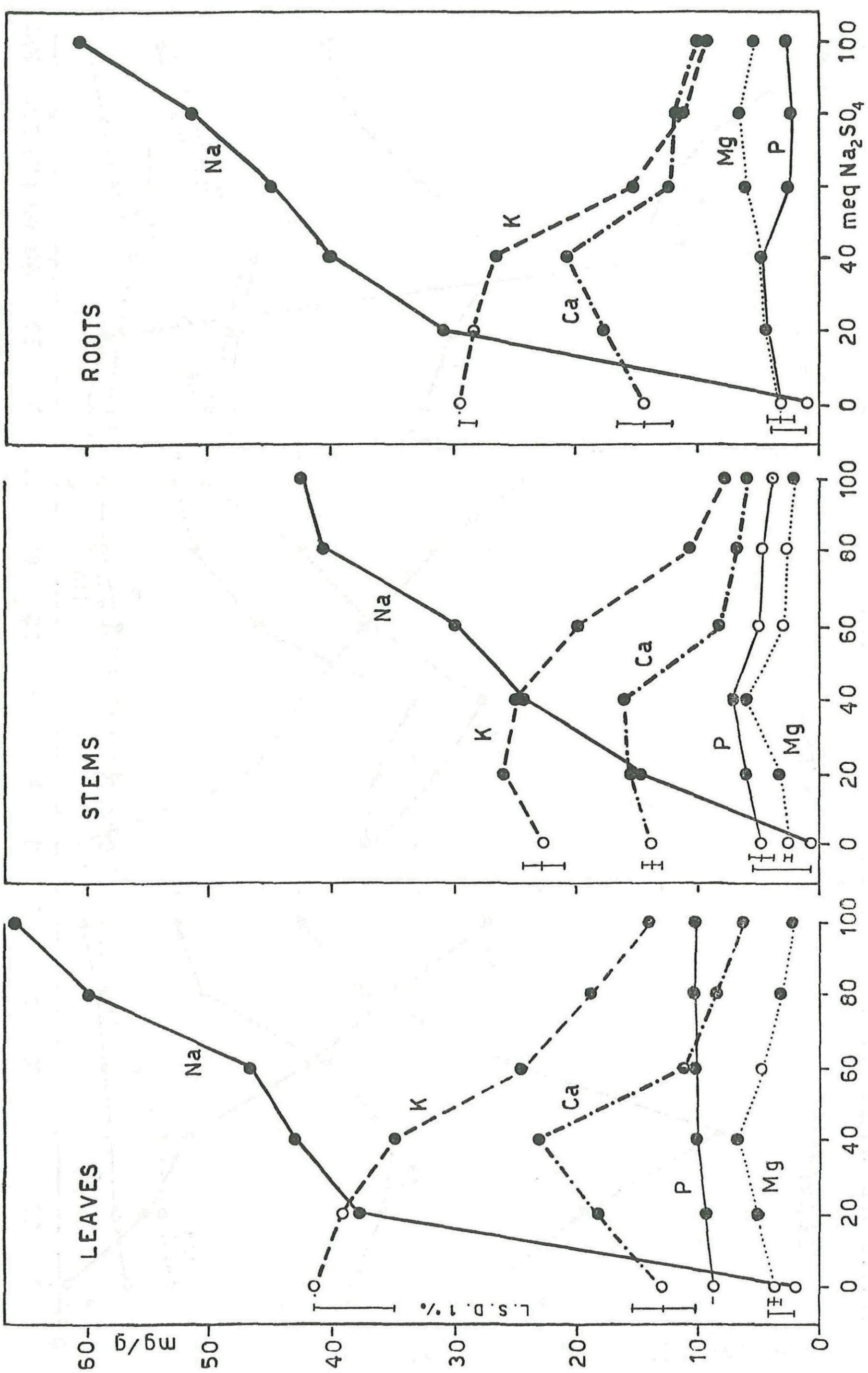

Fig. 4. Flax: Effect of different levels of sodium sulphate when supplied for 60 days on the distribution of some mineral elements (mg/g dry matter) Signatures see Fig. 1

Nitrogen:

The content of total as well as of TCA soluble and insoluble nitrogen of moderately salinized castor bean leaves was highly significantly increased (Fig. 5). However the high salinization levels (80 and 100 meq/l) induced non-significant effect on total nitrogen content. This non-significant effect was however associated with a highly significant increase in TCA insoluble nitrogen fraction at the expense of the TCA soluble one. Total nitrogen content of stems and roots was almost highly significantly decreased with the increase in Na_2SO_4 concentration in the nutritive media. In case of sunflower the rise of salinization up to the level 60 meq/l resulted generally in a significant increase in nitrogen fractions and consequently in the total nitrogen of the principal plant parts (Fig. 6). However, with further rise of salinization up to the highest level used, the content of total as well as of nitrogen fractions of the principal parts decreased significantly. In case of flax the contents of total as well as nitrogen fractions of leaves and stems were significantly decreased at various salinization levels (Fig. 7). On the other hand, flax roots exhibited a significant increase in their nitrogen content at all salinization levels, except at the highest level used, where the nitrogen content was considerably decreased.

Discussion

The increase in the total dry matter yield of the test plants at the relatively low and moderate salinization levels is in accordance with the results obtained by some authors using various plants (Jennings 1968 and Bernstein 1975). However, under high salinization treatments a considerable reduction in the yield was observed. In this respect Greenway (1973), suggested that energy expenditure, during osmotic adjustment to salinity is one of the main factors in reducing plant growth.

Considerable differences in the content of the mineral elements in the principal plant parts of the test plants were induced under the various sodium sulphate levels. The increase in the sodium content of the principal parts of the test plants with salinity is in agreement with the results obtained by Morani & Fortini (1963) working with oats; El-Shourbagy & Missak (1975) using three varieties of castor bean and Heikal (1977) working with some agricultural plants. The extent of sodium accumulation with saline solution varied among the principal plant parts. In this respect sodium was more accumulated in stems and roots than in leaves of castor bean and sunflower plants. In accordance with this. Jacoby (1965) and Lahaye & Epstein (1969) reported that in many glycophytes most of sodium being retained in the roots or in the stems. Also, the extent of sodium accumulation varied among the three plants tested; the highest was estimated in flax plants.

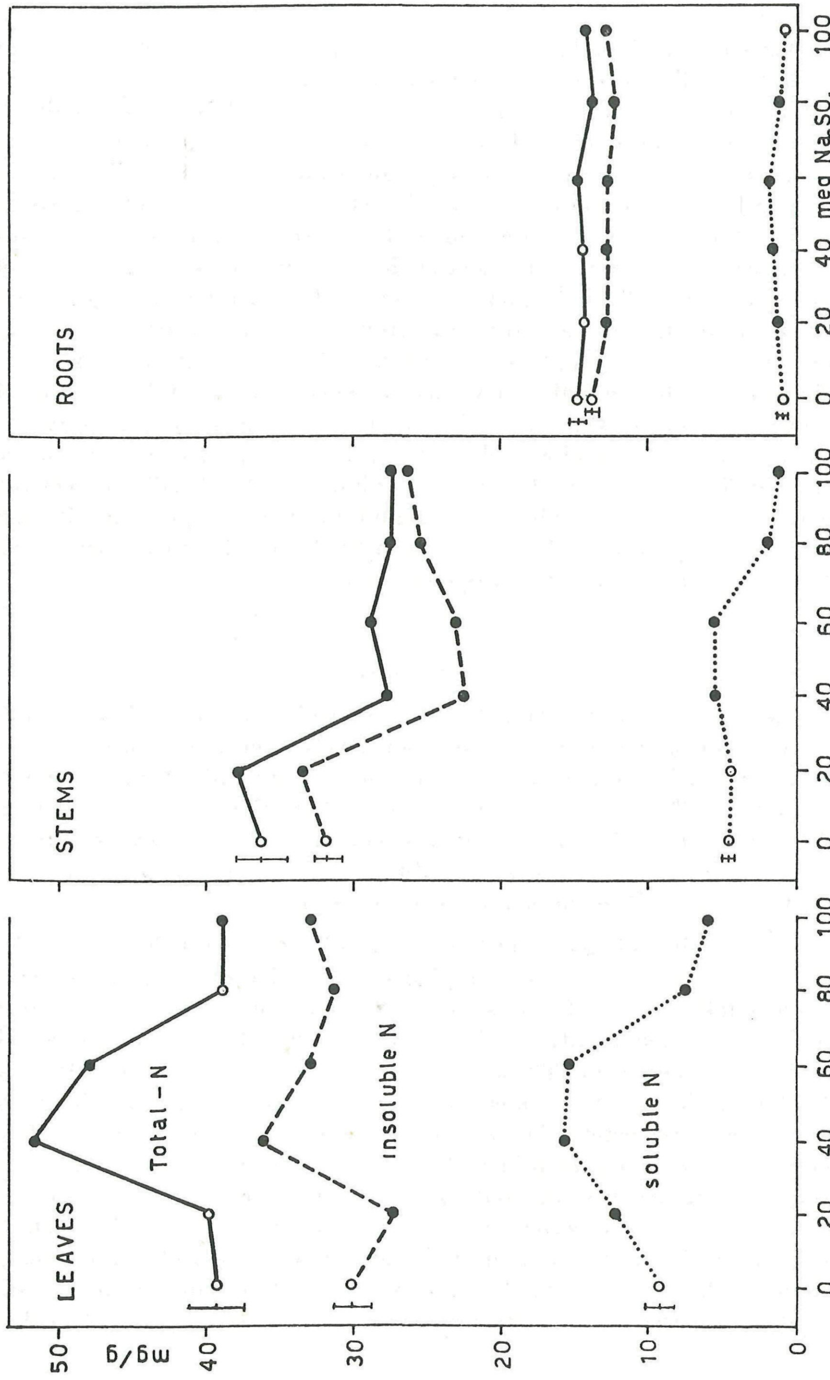

Fig. 5. Castor bean: Nitrogen content of leaves, stems and roots of plants exposed to different levels of sodium sulphate in the growth media for 60 days (mg/g dry matter). Signatures see Fig. 1

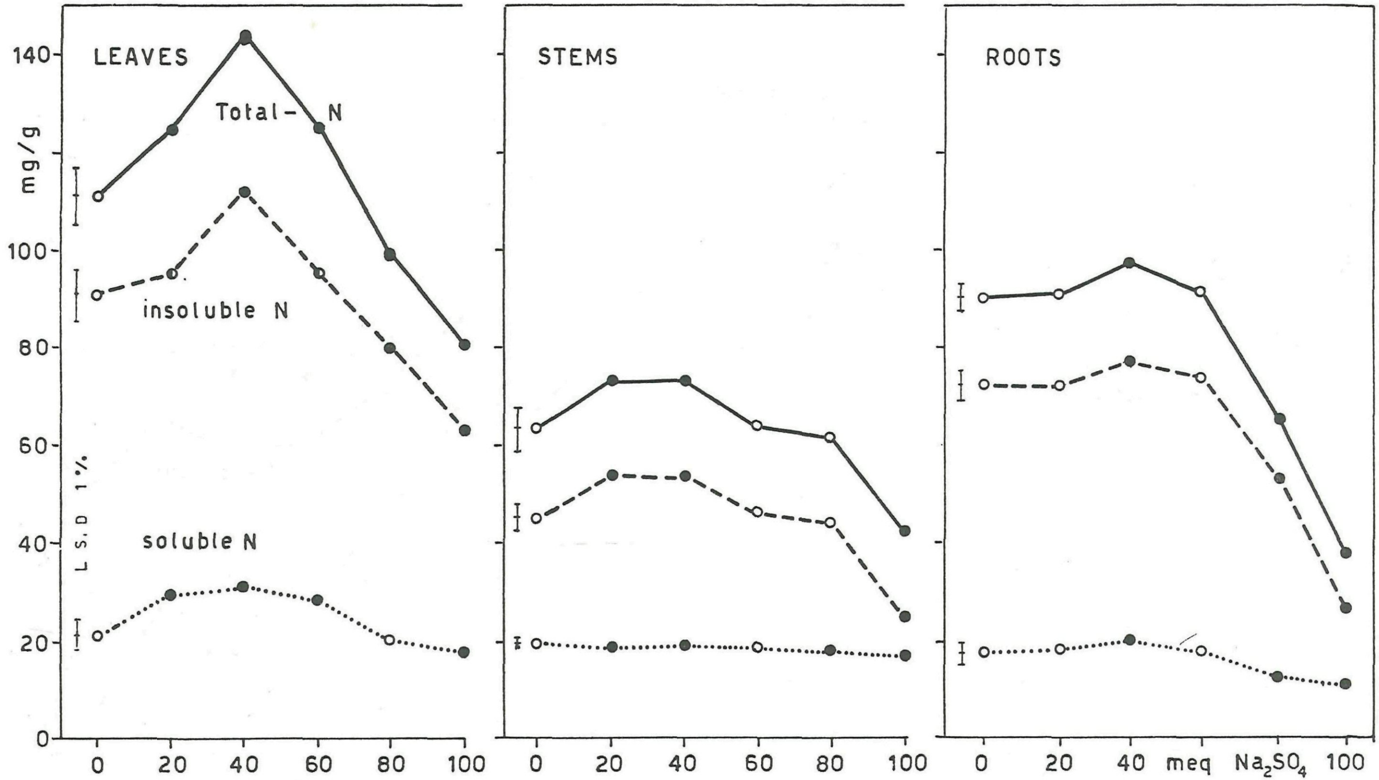

Fig. 6. Sunflower: Nitrogen content of leaves, stems and roots of plants exposed to different levels of sodium sulphate for 60 days (mg/g dry matter). Signatures see Fig. 1

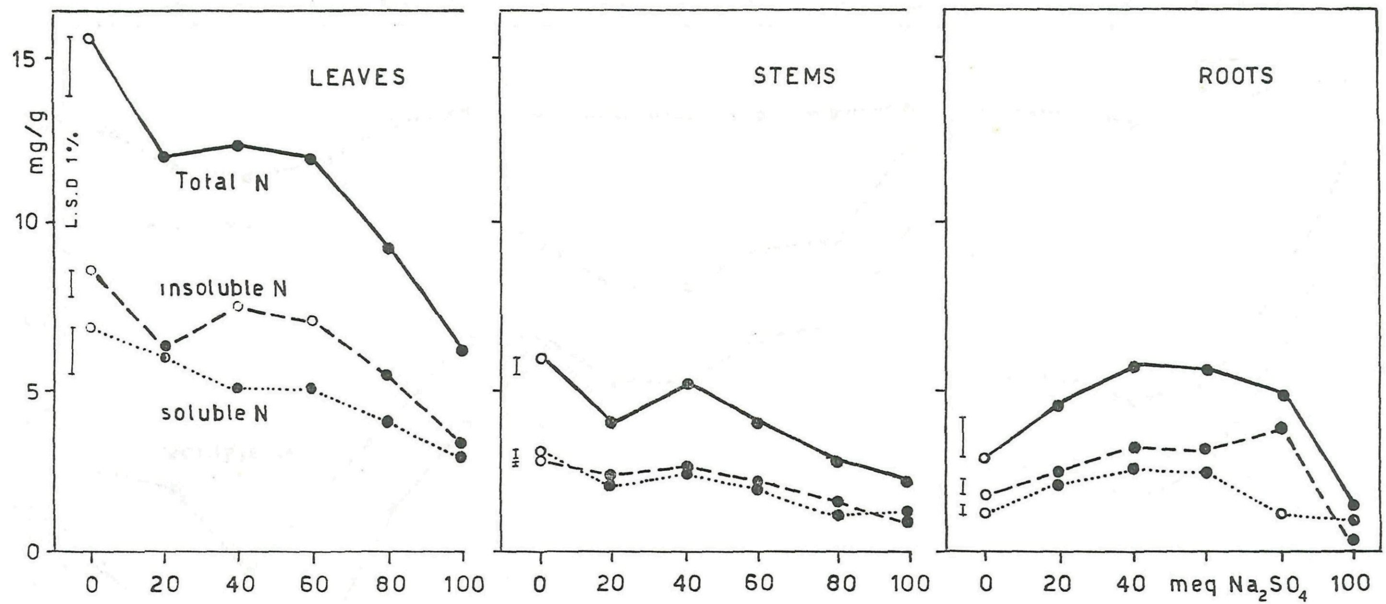

Fig. 7. Flax: Nitrogen contend of leaves, stems and roots of plants exposed to different levels of sodium sulphate for 60 days (mg/dry matter). Signatures see Fig. 1

The general increase in potassium content of moderately salinized castor bean and sunflower plants was also reported by SHIMOSE (1963) and WILSON *et al.* (1970) working with matrush and glycine respectively. On the other hand, salinity almost induced an obvious reduction in K-content of flax plants. Such a drastic effect was also reported by KADDAH & GHOWAIL (1964) and HEIKAL (1977) working with some agricultural plants.

The increase in calcium content observed in most of the principal parts of the test plants at relatively low and moderate salinization levels is in agreement with the results obtained by ASANA & KALE (1965) using four varieties of wheat and HEIKAL (1977). However, with the rise of salinization up to the highest level used a reduction in Ca content of the different organs of the test plants was recorded. This reductions adds more support to the results obtained by LASHIN & ATANASIU (1972) and RADI *et al.* (1976) working with some crop plants.

With regard to magnesium, it can be said that its content did not exhibit a regular trend, but it varied according to the plant type and plant organ as well as to the salinity level used. In this respect, while some authors (BIERHUIZEN & PLOEGMAN 1967) recorded an increase in Mg-content of salinized plants, some others (LASHIN & ATANASIU 1972 and HEIKAL 1977) recorded, on the other hand, a considerable decrease.

The increase in phosphorus content of most of the principal parts of the test plants seems to be a dominant effect of salinity. Similar results were also obtained by MORANI & and FORTINI (1963) and WILSON *et al.* (1970) working with oat and glycine respectively. In this respect, GATES *et al.* (1970) stated, that the increase in phosphorus content of roots may be associated with some mechanisms for controlling the salt entering the roots and especially preventing sodium from passing to the tops.

The leaves of castor bean as well as the three organs of sunflower plants exhibited a considerable increase in their total nitrogen content when grown on moderately salinized solutions. This is in agreement with results obtained by BERNSTEIN (1962) und HEIKAL (1977). In flax, on the other hand, the content of TCA soluble and insoluble nitrogen fractions and consequently the total nitrogen of leaves and stems were reduced with salinity. This reduction in nitrogen content which was also obtained by some other authors (HUTTON 1971 and LASHIN & ATANASIU 1972) lending support to a salt-induced nitrogen deficiency hypothesis (KLEINKOPF *et al*, 1975).

From the obtained data, it appears that, salinity resulted generally in a promotion rather than an inhibition in total dry weight and in the accumulation process of the investigated nutrient elements in the test plants, grown at least at lower and moderate salinity levels than when grown at higher salinity levels. Also, AHMED *et al.* (1978a, b) recorded, that the lower and moderate Na_2SO_4 levels, induced a significant increase in growth, pigment content and photosynthetic activity of these test plants. Therefore, these oil producing plants can be considered as moderate salt tolerant plants.

References

AHMED A. M., HEIKAL M. M. & SHADDAD M. A. 1978a. Photosynthetic activity, pigment content and growth of *Ricinus communis* plant as influenced by salinization treatments. — Proc. Ann. Meeting of Saudi Arabian Biol. Soc. (in press).

— — & — 1978b. Photosynthetic activity, pigment content and growth of *Helianthus annuus* and *Linum usitatissimum* plants as influenced by salinization treatments. — Bull. Fac. Sci. Assiut University (in press).

ARNON D. I. & HOAGLAND D. R. 1940. Crop production in artificial solutions and in soils with special reference to factors influencing yields and absorption of inorganic nutrients. — Soil. Sci, 50: 463—485.

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

BERNSTEIN L. 1962. Salt effected soils and plants. The problems of the arid zone. — Proceeding of the Paris Symb. Arid Zone Research, UNESCO 18: 139—174.

— 1975. Effects of salinity and sodicity on plant growth. — Ann. Rev. Phytopathology 13: 295—312.

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

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

EVDOKIMOV V. M. 1969. Tolerance of some crops during ontogensis to Cl-salts. — Sb, Irad. Aspir, molod. nauch. Sotr. Veses Inst. Rasteniev. 10: 164—168.

GATES C. T., HAYDOCK K. P. & CLARINGBOLD P. J. 1966. Response to salinity in *Glycine*. Differences in cultivars of *Glycine javanica* in dry weight, nitrogen and water content. — Aust. J. of Exp. Agr. and Ani. Hus. 6: 374—379.

— — & ROBINS M. F. 1970. Response to salinity in *Glycine*. 4. Salt concentration and the content of phosphorus, potassium, sodium and chloride in cultivars of *Glycine wightii* (*G. javanica*). — Aust. J. of Exp. Agr. and Ani. Hus. 10: 99—110.

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

HAYWARD H. E. & BERNSTEIN L. 1958. Plant growth relationships on salt-affected soils. — Bot. Rev. 24: 8—10.

HEIKAL M. M. D. 1977. Physiological studies on salinity. 6. Changes in the water content and mineral composition of some plants over a range of salinity stresses. — Plant and Soil 48: 223—233.

HELLEBUST J. A. 1976. Osmoregulation. — Ann. Rev. Plant Physiol. 27: 485—505.

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

JACKSON M. L. 1958, Soil chemical analysis. — Prentice-Hall International Inc., London.

JACOBY B. 1965. Sodium retention in excised bean stem. — Physiol. Plantarum. 18: 730—739.

JENNINGS D. H. 1968. Halophytes, succulence and sodium in plants — a unified theory. — New Phytol. 67: 899—911.

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

KLEINKOPF G. E., WALLACE A. & CHA W. J. 1975. Sodium relations in desert plants. 4. Some physiological responses of *Atriplex confertifolia* to different levels of sodium chloride. — Soil Sci. 120, 45—48.

LAHAYE P. A. & EPSTEIN E. 1969. Salt toleration by plants. Enhancement with calcium. — Science. 166, 395—396.

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

MORANI V. & FORTINI S. 1963. Sodium in the mineral of *Avena sativa*. — Plant and Soil 1: 140—142.

PAECH K. & TRACEY M. V. 1956. Modern Methods of Plant Analysis, Vol. I. — Springer-Verlag Berlin—Göttingen—Heidelberg.

POLJAKOFF-MAYBER A. & GALE J. 1975. Ecological studies 15: Plants in saline environments. — Springer-Verlag Berlin—Heidelberg—New York.

RADI A. F., MOUBASHER A. H. & HEIKAL M. M. 1973. Nutrient uptake by plants as affected by calcium and magnesium concentration. — Proc. Agric. Tim. Acad. 3: 14—18.

RADI A. F., HEIKAL M. M., AHMED A. M. & SHADDAD M. 1976. Physiological studies on salinity. 3-Effect of salinity on the contents of some cations in cotton, safflower and maize plants. — Bull. Fac. Sci., Assiut Univ. 5: 215—225.

SHIMOSE N. 1963. Physiology of salt injury in crops. 3. Salt tolerance of matrush plants. — J. Sci. Soil. (Tokyo) 34: 147—149.

WILLIAMS C. H. & TWINE J. R. 1960. Flame photometric method for sodium, potassium and calcium. In: PAECH K. & TRACEY M. V. (Eds.) 1962, Modern methods of plant analysis, 5: 3—5. — Springer Verlag Berlin—Göttingen—Heidelberg.

WILSON J. R., HAYDOCK K. P. and ROBINS M. F. (1970). Response to salinity in *Glycine*. 5. Changes in the chemical composition of three Australian species of *G. wightii* (*G. Javanica*) over a range of salinity stresses. — Aust. J. exp. Agric. Anim. Husb. 10: 156—165.