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Growth, Photosynthesis and Fat Content of Some Oil Producing Plants as Influenced by Some Salinization Treatments

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Summary

Using water culture technique some experiments have been performed to investigate the effect of 60 days salinization treatments on some growth parameters (leaf area dry weight) pigments content, photosynthetic activity and fat content of the oil producing caster bean, flax and sunflower plants. Moderate salinization treatments up to the level 40 meq NaCl resulted generally in a considerable increase in the values of these parameters. There above these values appeared to decrease again consistantly with the rise of salinization level. However the fat contents (mg/g dry weight) of variously salinized plant organs, remained higher that those of control plants, even after salinization with the higest level used (100 meq). Thus it can be generally assumed that these plants have a certain affinity to tolerate, at least, moderate saline condition, under which they exhibit better growth as well as higher fat content in their vegetative parts, compared with non-salinized plants.

Zusammenfassung

Wachstum, Photosynthese und Fettgehalt einiger ölliefernder Pflanzen unter dem Einfluß von Kochsalz

In Wasserkulturversuchen wurde die Wirkung 60-tägiger Behandlung mit Kochsalzlösungen auf Wachstum (Blattfläche, Trockengewicht) Photosyntheseaktivität und Fettgehalt von *Ricinus communis*, *Linum usitatissimum* und *Helianthus annuus* untersucht. Mäßige Salzgaben bis 40 mM NaCl führten zu einer beträchtlichen Vergrößerung der genannten Parameter. Darüber hinaus ergab sich eine Abnahme dieser Werte mit steigender Salzzufuhr. Die Fettgehalte der Stämme, Blätter und Wurzeln der unterschiedlich mit Salz kultivierten Pflanzen blieben selbst bis in die höchsten angewandten Konzentrationen (100 mM NaCl) über denen der salzfreien Kontrollen. Daraus ist auf eine gewisse Neigung dieser Pflanzen zu schließen, wenigstens mäßig halische Bedingungen

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zu ertragen, unter denen sie ein besseres Wachstum sowie höhere Fettgehalte in ihren vegetativen Organen als die Kontrollen zeigen. (Editor)

Introduction

In arid saline regions, cultivation of crop plants can be mainly achieved either after washing of excess salts by repeated flooding with fresh waters, or by selecting plants adapted to such saline soil conditions. Since sufficient amounts of fresh water are not always available, the second alternative seems to be more applicable. Therefore a considerable number of investigations were made to study the effect of salinization treatments on growth and production of some glycophytic crop plants (see e. g. POLJAKOFF—MAYBER & GALE 1975; BERNSTEIN 1975), as well as halophytic and succulent plants (see e. g. JENNINGS 1968). Consequently some metabolic processes were also subjected to investigation.

As regards photosynthesis as well as pigment biosynthesis, it has been found that in glycophytic plants, these processes were generally reduced in proportion to salt concentration (GALE & POLJAKOFF—MAYBER 1970, HOFFMAN & PHENE 1971, AHMED, HEIKAL & SHADDAD 1978a). In halophytes and succulent plants, on the other hand, low concentrations of salts do not reduce, and may even enhance photosynthesis and pigment biosynthesis (GALE & POLJAKOFF—MAYBER 1970, SHOMER—ILAN & WAISEL 1973, WILLERT 1973, WINTER 1974, DOWNTON & TÖRÖKFALVY 1975, TIKU 1976).

The fat content, in relation to salinity has not been intensively studied. However, some correlations were made between the lipid content and salinity in some higher plants (KUIPER 1969, TWERSKY & FELHENDLER 1973) as well as in the halophytic alga *Dunaliella* (BEN—AMOTZ & AVRON 1973, FRANK & WEGMANN 1974). It was assumed that lipids which could be synthesized via photosynthesis (KAUSS 1967, FRANK & WEGMANN 1974) may act as osmoregulators (BEN—AMOTZ & AVRON 1973).

The need to select some plants to be cultivated in saline soils induced the necessity to conduct a series of investigations using our economic plants to test their ability to tolerate salinity and to follow the changes that might take place in their physiological activities during salinization treatments. From some of these investigations (AHMED, HEIKAL & SHADDAD 1977, 1978a, 1978b) an impression was obtained that oil producing plants generally exhibit a certain degree of tolerance to salinity conditions. Accordingly it was intended to follow the growth and some metabolic activites of this group of plants, when subjected to salinization treatments. In this paper the effects of salinization treatments on growth, photosynthesis and fat content of castor bean, flax and sunflower plants were studied.

Materials and Methods

Water cultures as described by RADI, MOUBASHER & HEIKAL (1973) were principally used to provide controlled concentrations of the nutritive elements as well as of the salinizing agent. Three oil producing plants, namely castor bean (*Ricinus communis*), flax (*Linum usitatissimum*) and sunflower (*Helianthus annuus*) were tested in this investigation. The seedlings after being left to grow on full nutrient medium (Arnon & Hoagland 1940) for about 20 days, were transferred to the same solution but with varying concentrations of NaCl (0—100 meq). They were then left to grow for another 60 days. In order to keep the nutrient elements as well as the salinizing agent as close to their initial concentrations as possible, the culture solutions were renewed every three days.

At the end of experimental period, the growth parameters, namely leaf area and dry weight per plant were estimated by the method recommended by Bremner & Taha (1966). The total photosynthetic pigments were determined colorimentrically by the method recommended by Metzner, Rau & Senger (1965). The photosynthetic activity was obtained by the determination of the radioactivity (cpm/g leaf dry weight) after ^{14}C light fixation using in principal the technique applied by Bassham & Calvin (1957) and the apparatus described by Metzner (1968). The fat contents in the various plant parts (leaves, stems, root) were quantitatively extracted in petroleum ether (b. pt. 60—80° C) using the weight method given by Meara (1955) and then calculated as mg/g dry weight of the corresponding plant tissue. From the dry weight of each of the three plant parts, the total fat content per plant could be calculated. The data were always statistically analysed for the least significant difference as given by Sendecor & Cochrane (1967).

Results

Salinity variously affected the different physiological activities of castor bean, flax and sunflower. Moreover, the highest salinity level used (100 meq) induced a deleterious effect on the growth of flax and after about 6 weeks, the plants wilted, eventually withered and died.

Growth Parameter

The results in table 1 reveal that the values of leaf area and dry weight of each of the three plants tested, increased significantly with the rise of salinization up to the level 40 meq NaCl, where these two growth parameters exhibited their maximum values. Thereabove the values of these growth parameters decreased again consistantly with the rise salinization up to the highest level used. In spite of the similarity in trends observed in the three plants, the magnitudes of these two parameters depended mainly on the plant tested. Accordingly it can be seen that, irrespective of the salinization level used, flax exhibited comparatively the highest values of leaf area and at the some time the lowest values of dry weight compared with those of castor bean or sunflower plants.

Table 1

Effect of 60-days salinization treatments on leaf area (dm^2/plant) and dry weight (g/plant) of castor bean, flax and sunflower plants

Salinization treatment (meq NaCl)	Castor bean Leaf area	Castor bean dry weight	Flax Leaf area	Flax dry weight	Sunflower Leaf area	Sunflower dry weight
00	8.06	14.20	24.50	7.15	10.10	13.50
20	14.06 **)	15.80 **)	28.60 **)	7.45 **)	11.10 **)	14.53 **)
40	18.10 **)	22.20 **)	31.70 **)	8.73 **)	12.00 **)	17.00 **)
60	13.26 **)	16.70 **)	23.60 *)	6.11 **)	8.30 **)	12.50 **)
80	6.00 **)	12.60 **)	8.20 **)	3.18 **)	6.00 **)	9.70 **)
100	4.30 **)	10.50 **)	—	—	5.20 **)	9.12 **)
L.S.D. 5%	0.96	1.20	0.90	0.20	0.30	0.32
L.S.D. 1%	1.40	1.50	1.28	0.30	0.43	0.44

*) Significant differences as compared with the control.
**) Highly significant differences as compared with the control.

Pigments Content and Photosynthetic Activity

The results in table 2 reveal that the total pigments content (mg/g dry weight) as well as the relative photosynthetic activity (cpm/g dry weight) of each of the three plants tested, increased significantly with the rise of salinization up to the level 40 meq NaCl, where they reached their maximum

Table 2

Effects of 60-days salinization treatments on total content of photosynthetically active pigments (mg/g dry weight) and relative photosynthetic activity (cpm/g dry weight) of castor bean, flax and sunflower plants

Salinization treatment (meq NaCl)	Castor bean Pigments	Castor bean Photo-synthesis $\alpha \times 10^6$	Flax Pigments	Flax Photo-synthesis $\alpha \times 10^6$	Sunflower Pigments	Sunflower Photo-synthesis $\alpha \times 10^6$
00	7.68	5.05	29.40	16.60	19.10	11.97
20	7.98 **)	7.20 **)	30.40 *)	18.80 **)	20.61 **)	13.53 **)
40	8.97 **)	11.65 **)	31.40 **)	21.00 **)	25.16 **)	15.30 **)
60	8.14 **)	6.10 **)	21.60 **)	15.40 **)	17.10 **)	11.46 **)
80	5.53 **)	3.36 **)	13.20 **)	9.50 **)	15.40 **)	9.73 **)
100	4.57 **)	1.67 **)	—	—	12.70 **)	4.90 **)
L.S.D. 5%	0.05	0.18	0.98	0.89	0.54	0.20
L.S.D. 1%	0.06	0.26	1.40	1.26	0.76	0.30

*) Significant differences as compared with the control.
**) Highly significant differences as compared with control.

values. Thereabove the values of these two parameters diminished again to reach their minimum at the highest level used. It is also noticeable that flax, irrespective of the salinization level used, exhibited higher values of pigment contents and photosynthetic activities than those of either castor bean or sunflower.

Fat Content

From the results in table 3 it can be seen that the fat contents of the principal plant organs (leaves, stems and roots) of each of the three plants tested, increased significantly with the increase of NaCl concentration in the nutritive medium up to the level of 40 meq NaCl, where they reached their maximum contents. Thereabove these contents tend to decrease again consistantly with the rise of salinization level, but they remained higher than those of the control plant, even under the highest salinization level used. Moreover when the fat contents were calculated per plant, their values were highly magnified to reach, under moderate salinization treatments more than the double of that of the control plant, especially in castor bean and sunflower plants. In addition it can be generally observed in the three plants tested, and irrespective of the salinization level used, the leaves exhibited always the highest fat content and the roots on the other hand the lowest one. Also it is worthy to notice that generally the principal parts of flax plant exhibited higher contents of fats compared with those of either castor bean or sunflower plant.

Discussion

The dominant increase in the values of growth parameters, pigments content, photosynthetic activity and fat content, observed with the three oil producing plants after being moderately salinized, is generally in accordance with the results obtained previously by Ahmed, Heikal & Shaddad (1977, 1978a) using cotton and safflower plants respectively. Similarly some other authors recorded such a stimulation in growth and photosynthesis (Jennings 1968, Gale & Poljakoff—Mayber 1970, Shomer—Ilan & Waisel 1973, Willert 1973, Winter 1974). However these authors used mainly halophytic and succulent plants. In glycophytic plants on the other hand salinization generally reduced photosynthesis in proportion to salt concentrations (Gale, Kohl & Hagan 1967, Hoffman & Phene 1971).

The significant increase in the contents of fats, which was recorded in the test plants after being, salinized even with the highest concentration of NaCl used, is in accordance with the results obtained by Twersky & Felhendler (1973) working with cotton plant. They recorded a direct relation between the salinity of irregation and lipid concentration. Applying another technique and using a series of five stocks of grape varieties of

Table 3

Effect of 60-days salinization treatments on the fat content (mg/g dry weight) of the principal plant parts (leaves, stems, roots) as well as of the whole plant body of castor bean, flax and sunflower plants (Total/plant, mg)

Salinization treatment (meq NaCl)	Castor bean Leaf	Castor bean Stem	Castor bean Root	Castor bean Total/plant	Flax Leaf	Flax Stem	Flax Root	Flax Total/plant	Sunflower Leaf	Sunflower Stem	Sunflower Root	Sunflower Total/plant
00	58.0	33.0	13.0	490.8	101.0	61.7	45.0	554.4	81.0	42.3	20.0	657.0
20	77.7 **)	42.0 **)	19.0 **)	752.2	123.3 **)	91.7 **)	53.0 **)	860.5	91.70 **)	52.0 **)	24.7 **)	863.8
40	97.3 **)	48.7 **)	20.0 **)	1132.3	160.0 **)	103.7 **)	55.3 **)	862.1	98.70 **)	63.3 **)	29.7 **)	1203.9
60	80.0 **)	38.0 **)	17.0 **)	739.1	130.0 **)	100.0 **)	58.0 **)	610.8	96.30 **)	61.0 **)	33.3 **)	828.6
80	66.7 **)	34.0 *)	16.0 **)	349.6	121.0 **)	65.0 *)	64.0 **)	319.2	83.7 *)	50.0 **)	35.0 **)	625.7
100	61.0 *)	34.0 *)	14.0 **)	274.9	—	—	—	—	83.0 *)	48.3 *)	36.7 **)	469.8
L.S.D. 5%	2.2	1.0	0.7	—	4.5	3.2	3.0	—	2.1	4.2	1.2	—
L.S.D. 1%	3.1	1.5	1.0	—	6.2	4.5	4.3	—	3.0	6.0	1.7	—

*) Significant differences as compared with the control.

**) Highly significant differences as compared with control.

different salt tolerance, KUIPER (1968) found that the content of lipids increased with increasing capacity for uptake of chloride and salt tolerance. In another experiment with bean KUIPER (1969) recorded that the addition of different lipids increased the uptake of chloride to the root. The observed salt tolerance of these oil producing plants as well as the enhancements in their activities after being salinized, which appear to be a general feature of the oil producing plants tested may strengthen the impression that these plants may have their own mechanism(s) to counteract at least the effect of mild salinization treatments. This mechanism(s) could be coordinated with the biosynthesis of fats or a certain fat fraction. In accordance with this, FRANK & WEGMANN (1974) working with the halophytic alga *Dunaliella*, found that the increase in ion content in the nutritive medium was always associated with an increase in glycerol biosynthesis. They accepted the assumption made by BEN-AMOTZ & AVRON (1973) that the increase in glycerol synthesis in the halotolerant *Dunaliella* is a means of osmoregulation mechanism. The formation of glycerol is assumed to take place via photosynthesis (KAUSS 1967, FRANK & WEGMANN 1974). Hence the distribution of the light fixed radioactive carbon amoung the various metabolic activities as well as the fractionation of fats in the various plant parts, to detect if there is a perferential synthesis and accumulation of a certain fraction during salinization treatment, could be of a special importance. The elucidation of these two problems, which is now going on, may share in throwing some light on the mechanism by which these oil producing plants can counteract the toxic effect of at least mild salinity conditions. In addition this assumption must be tested with other oil producing plants.

Away from these discussions it can be generally said that these three oil producing plants, could not only tolerate moderate salinization level, but also they exhibited better growth which was associated with relatively higher contents of fats. Thus it can be finally said that these plants could be of a special economic importance to be cultivated in saline soils.

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