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EFFECTS OF SEAWATER ON GROWTH AND PRODUCTIVITY OF SUNFLOWER

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1. EFECTS OF SEAWATER ON GROWTH AND PRODUCTIVITY OF SUNFLOWER

Saline soil and water conditions are reducing the value and productivity of considerable areas of land. Water having a salt content of more than 2.500 mg/l is already considered unsuitable for most agricultural purposes.

Some years ago we started a series of investigations to assess to what extent growth and yield of oil bearing species are depressed by increased water salinity. To begin wiht, the effect on sunflower was studied of water salinized with sodium chloride only. Saline soils and water, however, rarely contain only one kind of salt. Mostly we encounter mixtures of different constituents such as calcium sulphate, sodium sulphate and sodium chloride, each of which has its specific effects on plant growth. Soils in which sulphate predominates for example have a strong dehydrating action on the plant, whereas the specificity of the chloride ion lies in an increased hydration of the tissues and results in succulence. Our subsequent experiments were therefore concerned with the influence of mixtures of sodium chloride and sodium sulphate. In the experiment to be discussed now the effect was assessed of water that had been salinized with a salt mixture, which, but for a few minor differences, was identical with natural sea salt.

When assessing the effect of salinity on plants, one hast to distinguish between biological and agronomical salt tolerance. In the applied literature particularly that on oilseed crops, for obvious reasons emphasis is laid on the latter. One can even say that salt

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TABLE 1

The composition of artificial seawater as compared with that of natural seawater in grams per 1000 liter at a density of 1023

Compound			
Sodium	Na^+	10,752	10,752
Potassium	K^+	390	390
Magnesium	Mg^{++}	1,295	1,295
Calcium	Ca^{++}	416	416
Strontium	Sr^{++}	13	13
Fluoride	F^-	1.30	1.30
Chloride	Cl^-	19,345	19,346
Bromide	Br^-	66	66
Iodide	I^-	0.05	0.38
Phosphorus	P	0.06	0.18
Sulphate	SO_4	2,701	2,700
Bicarbonate	HCO_3	145	145
Boric Acid	H_3BO_3	27	27
Nitrate	NO_3	0.50	nil

tolerance is usually expressed in reference to a salinity level that causes a certain decline in yield.

Yet, the agronomical aspect can never be satisfactorily studied without taking notice of the biological one. One reason is that in determining the toxicity of salts not their original concentration in the medium is decisive but the amounts that actually accumulate in the cells. Moreover, salts, which at higher concentrations act as specific toxins, in samll amounts often stimulate life processes. Thirdly, the rate of accumulation and toxicity not only vary for each plant species, but even for the various organs of one plant. Finally, it is important to also closely follow the salt content of the soils in its interaction with plant growth.

Summarizing, this study was undertaken to determine the effect of water that had been had been salinized with increasing amounts of artificial sea salt on growth and productivity of sunflower plants and the effect on the mineral composition of the soil and the plant organs. Besides, at fixed times the total salinity of the soil was determined. So we think we have obtained a workable understanding of the behaviour of this crop under experimental conditions of increased salinity.

2. MATERIALS AND METHODS

The experiment was conducted in a greenhouse with the hybrid cultivar Fransol. The plants were grown in large plastic baskets which had been filled with a black, sandy soil of low fertility and high porosity. Percentage of humus was 1.9; percentage of sand was 91.8; pH 5.0. The composition of the salt mixture, as far as components present in amounts of over 250 mg per 1000 liter are concerned, is shown in Table 1.

The plants were given water containing 1, 3 or 5 g of this salt mixture per liter. The seeds were planted in non-saline soil and supplied with non-saline water until one week after germination. Differential salination was then initiated with fivefold dilutions of the concentrations mentioned. The salt levels were increased stepwise in the course of one week till the final values. To minimize salt accumulation in the soil, the plants were watered with twice the amount needed for drain-off.

Soil samples were taken at 10 to 15 cm depth at weekly intervals and the electrical conductivity (EC_e) of the soil extract was determined at a soil/water ratio 1:4. On harvest sodium, chloride and sulphate were determined in the neutral extracts of soil, roots, stems, leaves, empty inflorescences and seeds.

3. RESULTS AND CONCLUSIONS

The plants that were grown on salinized water flowered 62 days after emergence; the untreated controls flowered 3 days later. The electrical conductivity of the ground increased until the dates of flowering and decreased thereafter (fig. 1). The same was found in all the previous experiments. Perhaps there is a relationship between the flowering state and metabolic processes which indirectly influence the salt level in the soil. This need not necessarily mean a change in salt absorption because also the leaching from the soil might be influenced by the developmental state of the plant. At every concentration the salt content of the plant parts increased in the order root $<$ stem $<$ leaf, and decreased in the order leaf $>$ inflorescence $>$ seed (Table 2).

The salt content of the roots was higher than that of the soil. We tried to quantify these differences by giving marks from 1 to 6 to the soil and the organs for their contents of sodium, chloride and sulphate (1 standing for the lowest concentration) (Fig. 2). The effect of the salt treatment on the vegetable growth is shown in Table 3.

At 5 g/1 the biomasses of both the roots and the above-ground parts of the plants were reduced by 30%. Also plant height was 30% smaller than in the controls. As is shown in Table 4 the size of the

TABLE 2

Salt distribution (in % of dry matter) resulting from seawater treatment of sunflower

Material	Control			1 salt g/1			3 g salt/1			5 g salt/1		
	Na^+	CL^-	$SO^=$	Na^+	CL^-	$SO^=$	Na^+	CL^-	$SO^=$	Na^+	CL^-	$SO^=$
Seed	$<$ 0.01	0.20	0.19	$<$ 0.01	0.09	0.81	0.02	0.24	1.32	0.04	0.29	1.93
Head	0.01	1.51	0.34	0.13	3.28	0.44	0.37	4.38	0.56	0.50	5.43	0.64
Leaf	0.02	1.26	3.32	0.67	5.39	2.32	0.71	6.43	1.98	1.15	7.92	2.81
Stem	0.05	1.65	0.11	1.76	5.13	0.24	3.60	9.07	0.73	4.85	14.16	0.63
Root	0.21	0.37	0.10	1.32	2.54	0.30	1.89	3.36	0.52	3.34	7.45	0.85
Soil	0.01	0.02	0.01	0.05	0.08	0.02	0.06	0.17	0.02	0.11	0.29	0.02

TABLE 3

Effect of artificial seawater on biomass

Total salt (g/1)	Dry weight (g/plant) root	Dry weight (g/plant) shoot	Plant height (cm)
Control	6.3	109.0	132
1	4.0	83.2	123
3	4.0	77.4	104
5	4	66.7	95.5

TABLE 4

Effect of artificial seawater on yield components

Total salt (G/l)	Diameter head	Diameter centre	Seed (g/plant)	1000-Grain weight (g)	Oil (% dry matter)	C18:2 (% of oil)
Control	14.6	4.7	41.7	17.5	40.6	63.3
1	12.1	4.6	33.0	14.2	40.8	59.9
3	11.5	4.6	27.5	14.2	37.6	61.0
5	11.6	4.5	23.0	11.0	34.8	57.5

TABLE 5

Salt distribution (in % of dry matter) resulting from seawater treatment of sunflower after return to fresh water irrigation

Material	Control			1 g salt/1			3g salt/1			5g salt/1		
	NA+	CL⁻	SO⁼	Na+	CL⁻	SO⁼	Na+	CL⁻	SO⁼	Na+	Cl⁻	SO⁼
Seed	0.01	0.21	0.11	0.01	0.10	0.62	0.01	0.18	1.12	0.01	0.29	1.44
Head	0.01	1.16	0.43	0.02	2.75	0.17	0.13	4.02	0.50	0.21	5.05	0.39
Leaf	0.01	1.27	4.29	0.20	4.73	1.75	0.46	5.55	1.87	0.70	6.26	2.76
Stem	0.04	0.95	0.09	0.70	4.03	0.48	1.99	5.35	0.40	3.12	8.62	0.63
Root	0.24	0.37	0.01	1.23	2.05	0.26	0.92	1.69	0.46	1.27	2.62	0.12
Soil	0.02	0.01	0.01	0.02	0.52	0.02	0.04	0.11	0.03	0.06	0.20	0.01

head was reduced by salinity, but the size of the area of unfilled seeds in the centre was unchanged. As a result of the decrease in the number of seeds and in grain weight total seed yield in grams per plant was depressed by about 50% at 5 G/1.

Oil content was reduced, but to a much smaller extent than the seed yield. Oil composition and linoleic acid content in particular were not affected. In part of the experimental plants the salt treatment was stopped after 7 weeks, to see to what extent they were still able to recover at this stage. The salt contents of the vegetative parts of these plants in fact decreased as appears from Table 5 when compared with Table 2. Neither biomass nor seed yield, however, were less depressed than in the plants that received salinized water until the end of the experiment. Seven weeks after emergence, flower initiation had already taken place. This means that the number of florets is fixed, and the number of seeds can therefore not be expected to increase by a return to unsalinized water. But because grain weight did not increase either it is clear that at the stage mentioned the photosyntetic apparatus had already suffered irreparable harm.

Although in the main line the relationships, which were established here, appeared to be constant over the years, in detail the results of the different experiments varied. Obviously, at equal salinities growth and productivity of the plants are influenced by the climate and the kind of soil and by the plant variety employed. Therefore it seems difficult to base detailed conclusions on one experiment conducted at one location, as is sometimes done.

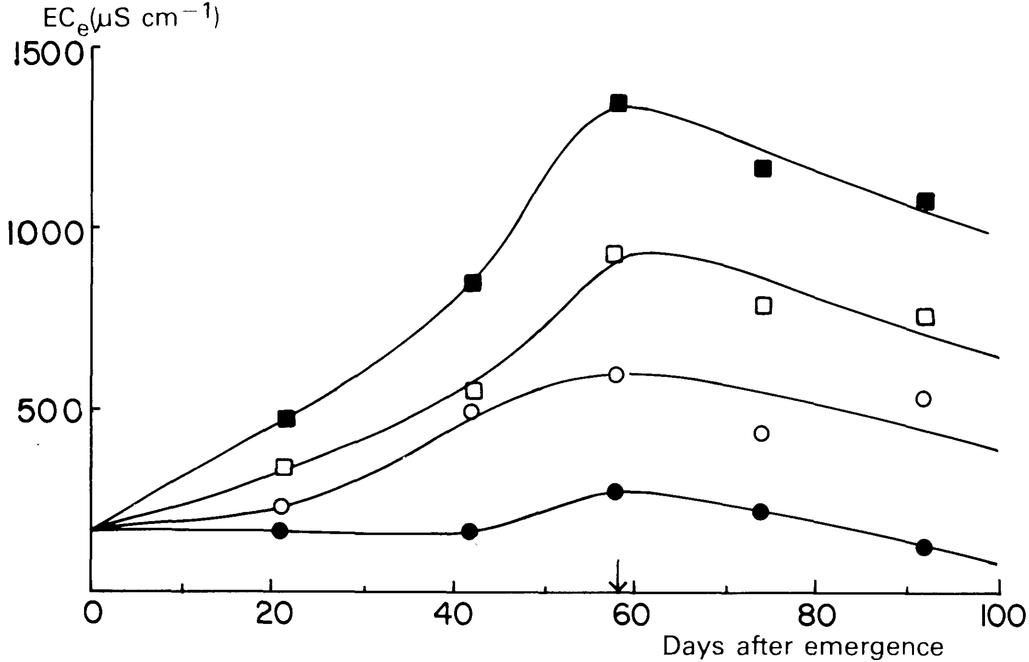

Fig. 1.— Influence of seawater treatment of sunflower plants on the course of soil salinity (expressed as electrical conductivity EC_e of soil extract):

● control,
○ lg/l,
□ 3g/l,
■ 5g/l,
↓= anthesis.

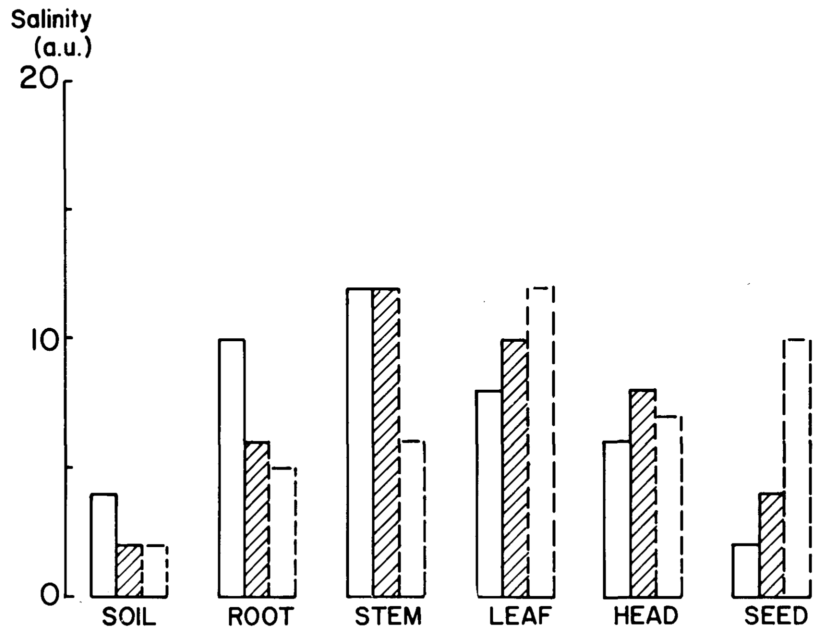

Fig. 2.— Effect of seawater irrigation on ion contents of soil and organs of sunflower (in arbitrary units):
sodium,
chloride,
sulphate.