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Use of Sea-Water Dilutions for Irrigation in Sand Dunes in the Northern Coasts in Libya

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ABSTRACT

An experiment was conducted to investigate the possibility of growing some crops in sandy soils irrigated with sea-water dilutions, plant species tested were: alfalfa, barley, beets, flax, safflower, and wheat. Sea-water dilutions employed were: 10, 20, 30, 40, 50, 70, and 100 % besides the control in which fresh water was used. The experiment included lysimeters, pots, and nursery plots. Plants were grown in a highly permeable sandy soil taken from Tajora sea shore.

The experiment was carried out for a period of 78 days during which the growth of plants was observed and recorded. At the end of the experimental period, samples were taken from beets only. These samples were then properly dried and analyzed for Na, K, P, Ca, and Mg.

Growth observations showed the thresholds to salinity in irrigation water to be: 4,150, 12,300, and 21,000 ppm. of T.D.S. for flax and safflower, alfalfa, beet and wheat and barley, respectively.

The dry weight of beet plants increased by the use of sea-water dilutions. Maximum increase was obtained at the 10 % dilution ratio. This was attributed to the probable presence of ions of certain elements at a higher concentration in sea-water than in fresh water.

The plant contents of almost all nutrients tested were increased when sea-water was included in irrigation. However, the concentration of the same nutrients was not materially affected. Despite the presence of sodium at a high concentration in the sea-water dilutions, no corresponding increases were shown in the plant uptake of that element. Potassium behaved in a reverse manner. Although its concentration in sea-water dilutions was low, the plant uptake of K was relatively high.

These findings may be considered promising in using sea-water dilutions for the irrigation of some agricultural crops in Libya.

INTRODUCTION

In areas where available water resources are getting short of satisfying agricultural needs, man have always endeavoured to find additional water. One of the most interes-

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ting developments in that search is the use of sea-water dilutions as well as brackish water for irrigation. The great vistas for development in this direction were opened by the new extraordinary progress in ecological climatography and hydrology, and physiological research concerning the raised salt tolerance of plants grown on highly permeable sand (5).

A number of experiments have been carried out during the last decade to irrigate with highly saline water in highly permeable soils (2,3,6,17,20,22,25).

In the coastal zone of Libya, enormous water reserves of sea-water dilutions exist in the boundary between fresh and sea-water. An additional source exists at the boundary between fresh and sea-water in the variously salinized, sandy ground water aquifers in several wadis in the same zone. The highly permeable soils in the vast coastal sandy belt in this zone afford a great potentiality for utilizing these enormous water resources. These have initiated a line of research at the University of Tripoli to investigate the possible utilization of such resources.

The work presented here is aimed at satisfying the following objectives:

1. To study the possibility of growing 6 plant species on soils similar to those of the coastal belt under irrigation with sea-water dilutions or brackish water.
2. To study the behaviour of these species under such conditions and hence, determine the thresholds of their salt tolerance.
3. To elucidate the actual factors that determine the anticipated tolerance of beet (*Beta Vulgaris* L.) to salinity.

MATERIALS AND METHODS

Soil samples from three localities in the coastal zone of Tripolitania were considered. These were taken from Sorman, 60 kilometres to the west; El-zawia, 40 kilometres to the west; and Tajora, 27 kilometres to the east of Tripoli. They were chosen in view of their texture, abundance, and nearness to the sea shore. The particle size distribution diagram for representative samples was determined and plotted. The electrical conductivity of their saturated extracts were also measured. Tajora area was then selected because of the texture and higher permeability of the sample. The physico-chemical characteristics of that soil were subsequently evaluated and tabulated.

Mediterranean sea-water used in the experiment was taken from Tajora sea shore. Chemical analysis of representative samples was carried out and the composition of the salt content was tabulated.

Experimental Design

The experimental design is shown schematically in Figure 1. It consists of lysimeters, pots and nursery plots along with the flow system used.

Lysimeters and Pots

Eight identical bottomless 200 liter barrels (90 cms long and 50 cms in diameter) painted white were mounted and fixed over another eight half-barrels of the same diameter placed on a gentle slope. The lower half-barrels were filled with coarse gravel to allow adequate drainage and prevent capillary rise from any accumulated water at the bottom to the root zone. The upper barrel was filled with dune sand taken from Tajora area.

Thirty pots, each with a capacity of 9 kg and a surface equivalent to 500 cm^2 were

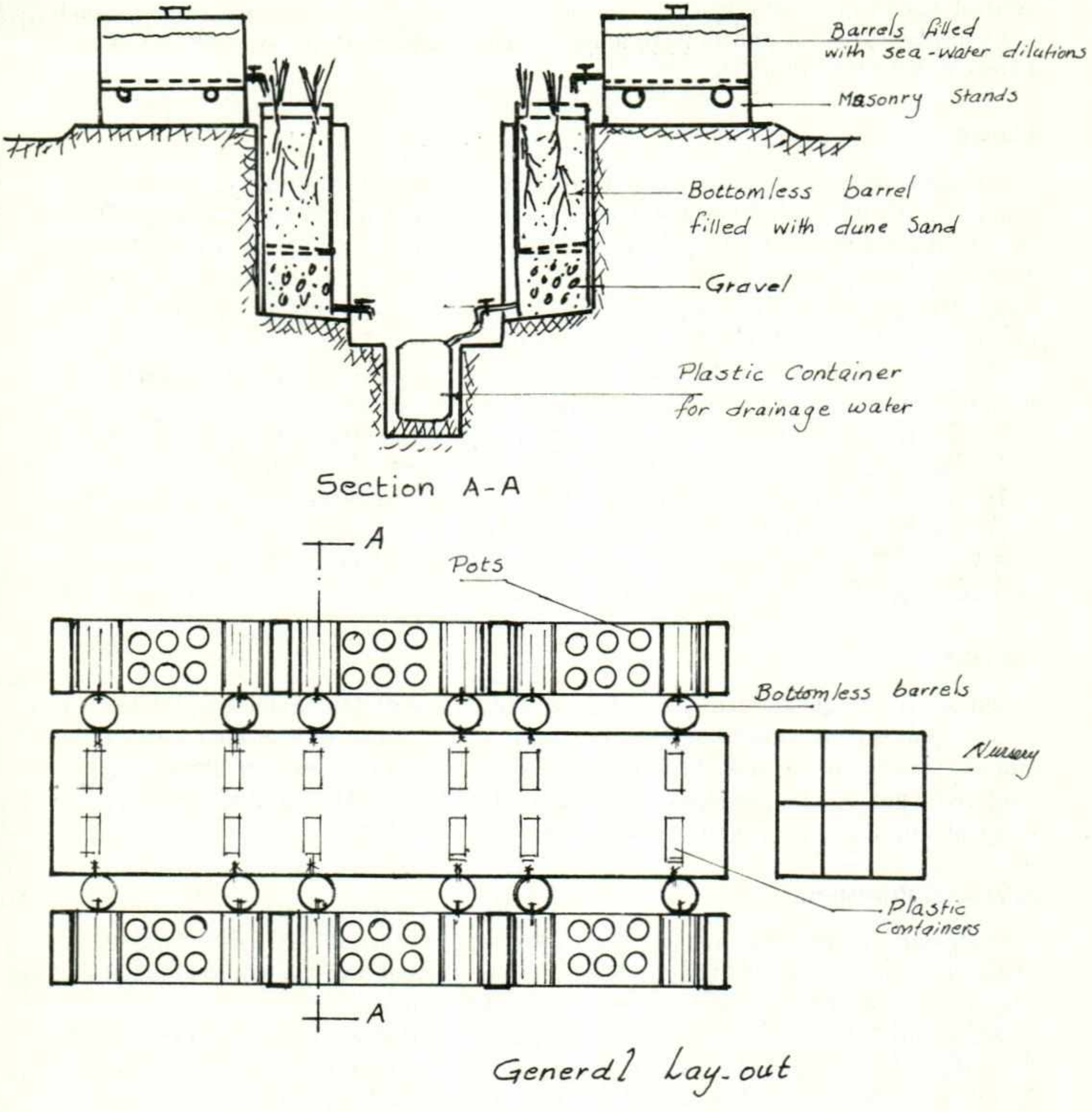

Fig. 1. Schematic plan and cross section for the experiment.

divided into five groups and placed on boards between the solution barrels of the flow system. A small nursery plot 2.15 × 3.25 metres and 60 cm deep was divided into 6 equal parts. Soils in both pots and nursery were the same as that placed in the lysimeter barrels.

Flow System

Eight barrels each having capacity of 200 litres filled with sea-water dilutions were laid horizontally on the upper structure as shown in Figure 1. Taps and tube connections fixed to each barrel delivered the desired amount of sea-water solutions to the corresponding lysimeteres laid underneath or to the neighbouring pots. The sea-water dilutions used were 10, 20, 30, 40, 50, 70, and 100% sea-water. Fresh water obtained from a local well (chemical analysis shown in Table 7) was used to prepare the dilutions and for the control treatment (zero dilution). The lower half-barrel was directly connected through tap and plastic tube connections to a 50 litre plastic container placed underneath each barrel to collect the drainage water.

Planting

Six plant species were experimented with. Five of these species were regarded as preliminary trials. These were germinated in the nursery and irrigated with fresh water. They were then transplanted to the pots and irrigated continuously with sea-water dilutions. These species were selected either for their economic value or drought and salt resistance. The species are: Alfalfa (*Medicago sativa* L.); barley (*Hordeum vulgare,* L.); flax (*Linum usitatissimum*, L.); safflower (*Carthamus tinctorius* Lam.).

The sixth species: beet (*Beta vulgaris* L.) was directly planted in the lysimeters and irrigated with the various sea-water dilutions described previously.

Irrigation water was applied in all at daily intervals. In highly permeable soils, such a technique is recommended for proper irrigation with sea-water dilutions (20).

The beets planted in the lysimeters and the five species transplanted into the pots were continuously observed and compared to the control. The growth, rate of growth, and any symptoms of nutrient deficiencies were directly recorded. Germination percentages for both beets and barley corresponding to the different salinity levels were also estimated.

Sampling

Samples of beet plants were taken at the end of the experiment. Each sample consisted of three plants collected at random from each barrel. Plants were cleaned with a cloth and soil material was removed from the root system. Samples were then placed in paper bags and dried in an oven at 60°C for a period of 3 days. After drying, samples were weighed, and then kept for subsequent analysis.

Analytical Procedures

Dry plant samples were first ashed using the wet combustion method (6), and the remaining residue was solubilized in deionized H_2O where it was brought to volume. The plant extracts were then used to determine the following elements:

Potassium and sodium were determined using a Carl Zeiss flame-photometer mode PF5. Phosphorus was measured in the plant extracts following the chlorostannous phosphomolybdic acid blue colour in the sulphuric acid system (15). Calcium and magnesium were determined according to the procedure of Bullock and Maier (7) and Bullock *et al.* (8).

RESULTS AND DISCUSSION

The physico-chemical characteristics of soil used in the experiment are shown in Table 1. A particle size distribution diagram for the same is presented in Figure 2. The soil is shown to be uniform and highly permeable with an average permeability rate of 225 cms/hour. It was for this quick percolation rate that no significant salt accumulation was observed in the barrel. The total soluble salts (T.S.S.) measured in a soil sample before the experiment was 92 ppm. Analysis of the successive soil layers sampled from the lysimeter irrigated with 180 liters of the 40% diluted sea-water (with a T.S.S. of 16,500 ppm. NaCl) is shown in Table 2. A simple calculation showed that during a period of four months a total amount of 2.95 kilograms of sea salt, with 2.20 kilograms of NaCl

Table 1 Physico-chemical characteristics of soil used in the experiment and taken from Tajora area.

Fine gravel	3%	Total Ca CO_3	50%
Coarse sand	23%	pH	6.8
Medium sand	45%	Total soluble salts	92 ppm.
Fine sand	28%		
Very fine sand	1%		
Salt	0		

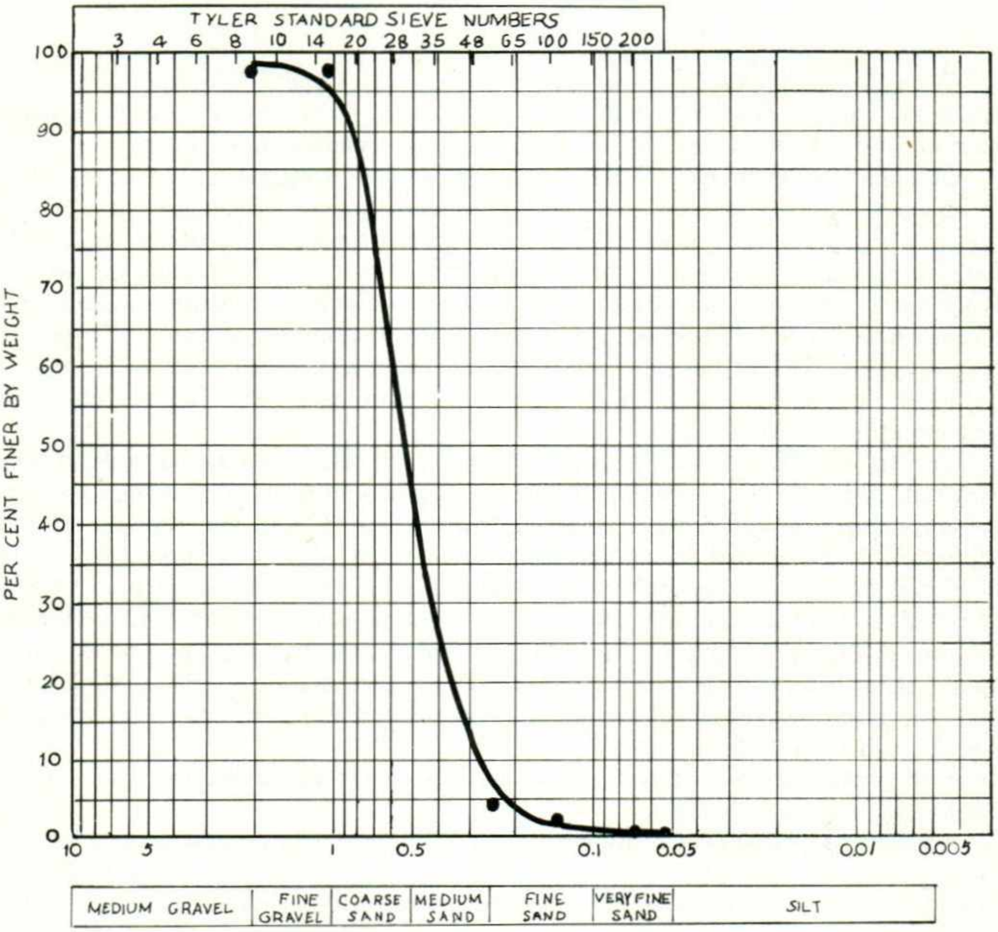

Fig. 2. Grain size distribution diagram for samples taken from Tagora area.

was poured through the bottomless barrel. The total accumulated salt in the soil did not exceed 6% of the amount poured. Hence, it is justifiable to conclude that no significant salt accumulation is feared in similar soils if irrigated continuously with 40% diluted sea-water or at any lower concentration.

Intensive root development was observed for both beet and barley to the full barrel depth for all barrels. This is believed to ensure compensation for any damage in the active surface roots and consequently adequate absorption at all times even under high salt concentrations.

Table 2 Analysis of a soil profile after irrigating with diluted sea-water of a T.S.S. of 16,500 ppm. including 12,400 ppm. NaCl.

Soil depth cms	T.S.S. in ppm in soil	Total amount of salt in soil in gms	T.S.S. Irrigation water gms	Percent of salt retained/salt added
0–20	422	31		
20–30	429	15		
30–40	460	15	3,000	6.3
40–50	512	18.8		
50–90	768	114.5		

Composition of solids in sea-water used in ppm, m.eq/1 and in % of the T.S.S. is presented in Table 3. The total soluble salt is 41,400 ppm. Previous analysis of East-Mediterranean water gave 41,000 (4) which is in close agreement with our analysis.

Germination percentages for barley and beet are shown together in Fig. 3 versus different levels of sea-water dilutions. A 60% germination rate is observed for beet at 16,600 ppm. (40% dilutions). A time lag of 7 days was yet recorded in comparison to control. It is clear that reasonable germination is expected for both at 30% sea-water dilution. A total salt concentration of 12,400 ppm (30% dilution) is therefore suggested as a threshold for germination of both beet and barley. A 93% germination percentage for barley was reported by Lopes (20) on a sandy soil when the soil was humidified with saline solutions of 12,000 ppm slat concentration. However, a 52% germination was observed for beet at a concentration of 13,600 ppm.

Growth of the five species transplanted from nursery beds into pots and irrigated with sea-water dilutions were compared to those irrigated with fresh water. Symptoms and abnormalities in growth for these species are summarized in Table 4. It is noticed that the threshold limit of growth for safflower and flax is 10% dilution (4,150 ppm T.S.S.). The limit for wheat and beet growth could be justified at 30% dilutions (12,300 ppm T.S.S.). Beyond this limit some dwarfness and yellowish colour was observed for alfalfa. Wheat showed dwarfness and dryness in leaf tips and then in the whole leaf beyond the same limit. Barley however showed normal growth at 50% dilution (21,000 ppm T.S.S.). Some dwarfness was observed and plants reached maturity at a maximum concentration of 70% dilution (28,500 ppm T.S.S.).

A 50% dilution ratio is therefore considered to be the advisable upper limit for the water used to irrigate barley.

According to Allison (1), resistance of plants to salt may be defined as the degree at which osmotic equilibrium between the internal osmotic pressure of the plants and the medium in which the roots are living can be reached without sacrificing growth. This

Table 3 Sea-water composition at Tajora sea shore (South Mediterranean).

Cations	ppm	Percentual composition	meq/l	annions	ppm	Percentual composition	meq/l
Sodium Na^+	14,400	34.8	617	Chloride Cl^+	22,000	53.1	619
Magnesium Mg^{++}	680	1.60	56	Sulphate SO_4	3,460	8.4	71.6
Calcium CA^{++}	315	0.8	15.45	Carbonate CO_3	Trace	0	0
Potassium K^+	562	1.3	14.40				
Total Cations	15,957	38.5	702.82	Total Anions	25,460	61.5	690.6
Total S. Salt	41,417						

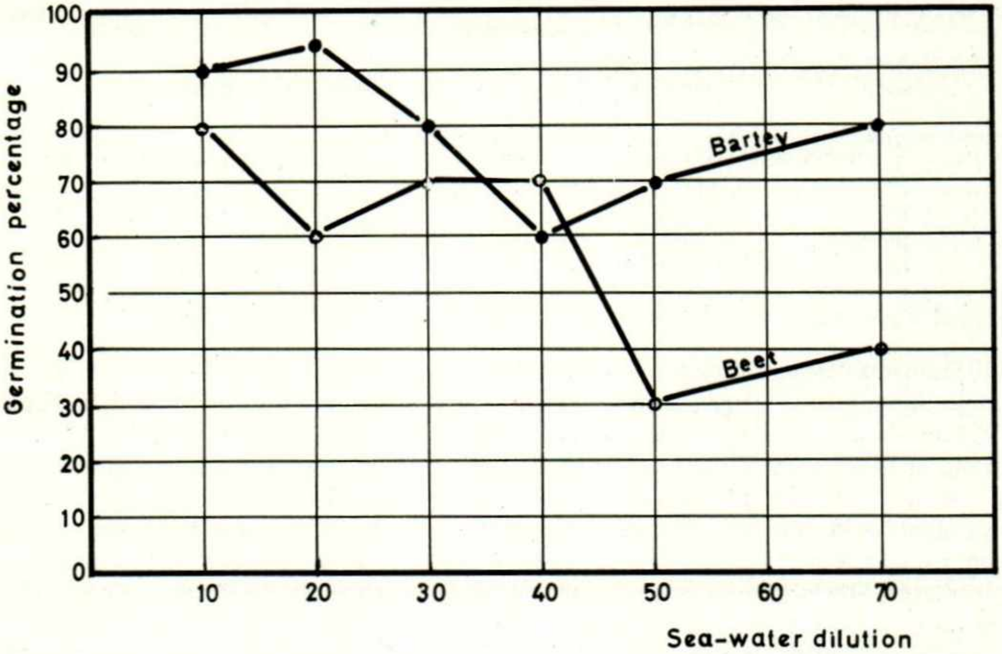

Fig. 3. Germination percentage for both barley and beet versus sea-water dilution in percentage.

Table 4 Growth in percent and observed symptoms of deficiency due to increase in T.S.S. for different levels of sea-water dilutions.

Sea-Water dilution in percentage T.S.S. Mg/1	Irrigation Water					
	10% 4,140	20% 8,300	30% 12,400	40% 16,600	50% 20,700	70% 29,000
Barley	100 Normal			90 Dryness of leaf and retardation in growth		80
Alfalfa	100 Normal	90 Deep in colour	80 Dwarfness	50 Yellowish in colour		10 Yellowish in colour and dryness of leaf
Wheat	100 Normal			80 Dwarfness and dryness of leaves	70	No growth
Safflower	50 Yellowing in colour and dryness of leaves			5 Complete dryness		No growth
Flax	Yellow colour, dry leaf tips.			No growth		

process may be the cause of reduction in growth at higher salt concentrations in the medium as shown for tested wheat, alfalfa, and barley.

Beet growth after 46 days from planting is shown in plate 1. These are for beet plant irrigated with 4150,8300, and 12,500 ppm T.S.S. together with those for the control.

Table 5 shows the data obtained for the dry weight and nutrients content of beet plants.

Table 5 Dry weight and total content of Na, K, Ca, and Mg in beet plants as affected by sea-water dilutions.

Sea-water dilutions[1] %	Dry weight of one plant (gm)	Plant content of nutrient mg/plant Na	K	P	Ca	Mg
0	0.2376	1.75	0.75	0.21	0.53	0.22
10	1.5153	7.00	3.50	1.18	2.22	1.05
20	0.7845	5.25	2.50	0.74	1.31	0.66
30	0.5333	3.75	2.00	0.57	0.85	0.48
40	0.3980	2.50	1.25	0.38	0.62	0.32

[1] Dilution percentages are referred to the ratio of sea-water to fresh water used in irrigation.

Examination of the data given for the dry weight reveals that the use of sea-water along with fresh water in irrigation has resulted in increasing plant growth. Such an increase differed in its magnitude depending on the ratio of sea-water dilutions used. A dilution ratio of 10% has stimulated beet growth to about seven times that of the control.

However, raising the dilution ratio above 10% caused plant growth to be reduced if compared with the 10% treatment, although it was still higher than that given by the control. This occurred progressively as the percentage of sea-water was successively increased. This may be attributed to the probable presence of ions of certain elements in sea-water at higher concentrations than that in fresh water. These ions are possibly of specific importance to the growth of beet plants. Examples of such ions are those of boron, cobalt, vanadium and strontium (14,18,19,21).

Data presented for the plant content of Na, K, P, Ca, and Mg indicate an almost identical behaviour for the various elements. Plant content of each nutrient was increased when sea-water was used in irrigation. This followed the trend exhibited by the dry weight. As plant growth was increased by the use of sea-water, more nutrients were acquired compared to the control.

It was therefore thought to show the data of plant analysis as concentrations to detect any differences between the various nutrients. Table 6 presents such data for the same nutrients. The concentrations of both Na and K in beet plants were materially lowered at the 10% dilution ratio compared to the control. This was certainly due to the excessive growth given under this treatment. As the dilution ratio was increased above 10%, the concentrations of both elements were increased again to where they reached values close to that of the control. This may be referred to the relative decreases in plant growth under the conditions of dilution ratios higher than 10%. It is therefore interesting to note that

Table 6 Concentration of Na, K, P, Ca, and Mg in beet plants as affected by sea-water dilutions.

Sea-water dilutions[+] %	Concentration of nutrients in plant tissue mg/100 gm dry matter Na	K	P	Ca	Mg
0	737	316	88	233	92
10	462	231	77	147	69
20	669	318	94	167	84
30	703	375	107	159	90
40	629	314	96	155	81

[1] Dilution percentages are referred to the ratio of sea-water to fresh water used in irrigation.

despite the presence of large amounts of sodium in sea-water used in the various dilutions, the amount of that element absorbed by plants was in proportion to the needs of plant growth. This in turn resulted in no excessive accumulation of Na per unit of growth.

The fact that the soil used in this experiment was highly calcareous (about 50% $CaCO_3$) might also have helped in this respect. Calcium has been ascribed a specific role in modifying the absorption mechanism of sodium and other cations in various plants (11,14,23).

Such does not exactly apply to the case of potassium. Although the concentration of K in sea-water is much lower than that of Na, the concentration of the former in plant tissues was relatively high. It may thus be stated that the phenomenon of selectivety in ion absorption by plants seems to be of special importance in this respect. Several other investigators have pointed to such a phenomenon (10,12,13,24). Moreover, it was shown by Bernstein (2), and Clay and Hudson (9) that the uptake of sodium from the soil is blocked by the existence or potassium in the plant. So, plant in media of relatively high Na concentration will react to Na invasion by increased acquisition of K in order to restore the balance between these ions in their internal environment. It was further postulated that on restoring this balance, a beneficial effect would be expected in stimulating the growth at a greater rate and subsequently shortening the growth period.

Data presented in Table 7 may help to visualize the relationship between plant uptake of either sodium or potassium and their respective existence in irrigation water used in the experiment. It is clear that the uptake of both nutrients by beet plants was nearly independent of their actual concentration in irrigation water applied.

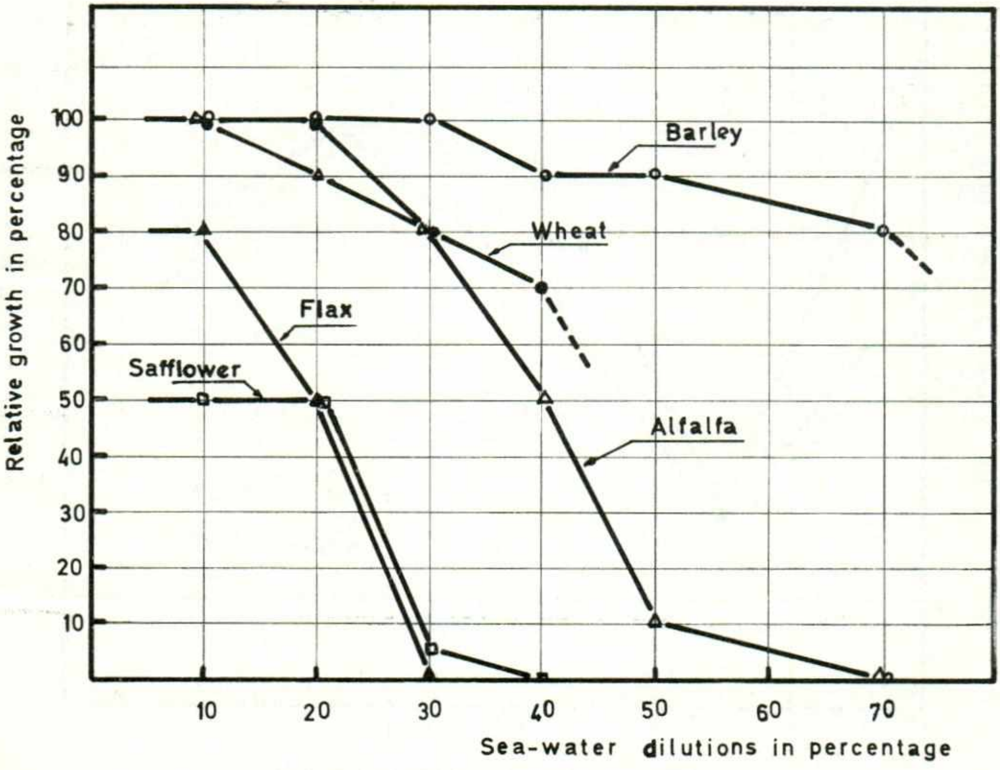

Fig. 4. Relative growth versus sea-water dilutions of applied irrigation water.

Table 7 Concentration of Na, K, Ca and Mg in both irrigation water and beet plants at the various sea-water dilutions.

Sea-water dilutions %	Irrigation water ppm				Plant tissues ppm			
	Na	K	Ca	Mg	Na	K	Ca	Mg
0	393	3	55	16	7,370	3,160	2,330	920
10	1,440	56	50	68	4,620	2,310	1,470	690
20	2,880	112	64	136	6,690	3,180	1,670	840
30	4,320	168	96	204	7,030	3,750	1,590	900
40	5,760	224	128	272	6,290	3,140	1,550	810

The contradictory behaviour of K with regard to Na is also observed. This may be used to substantiate the previously mentioned explanation.

Figures 5 and 6 represent the same relationship for sodium and potassium. It is noticed that although both nutrients behave parallel to each other, such behaviour was manifested differently in response to the level of each nutrient in irrigation water.

Values given in Table 7 for the concentration of phosphorus in plant tissues show no definite trend. However, it is noticed that the use of sea-water in irrigation did not affect

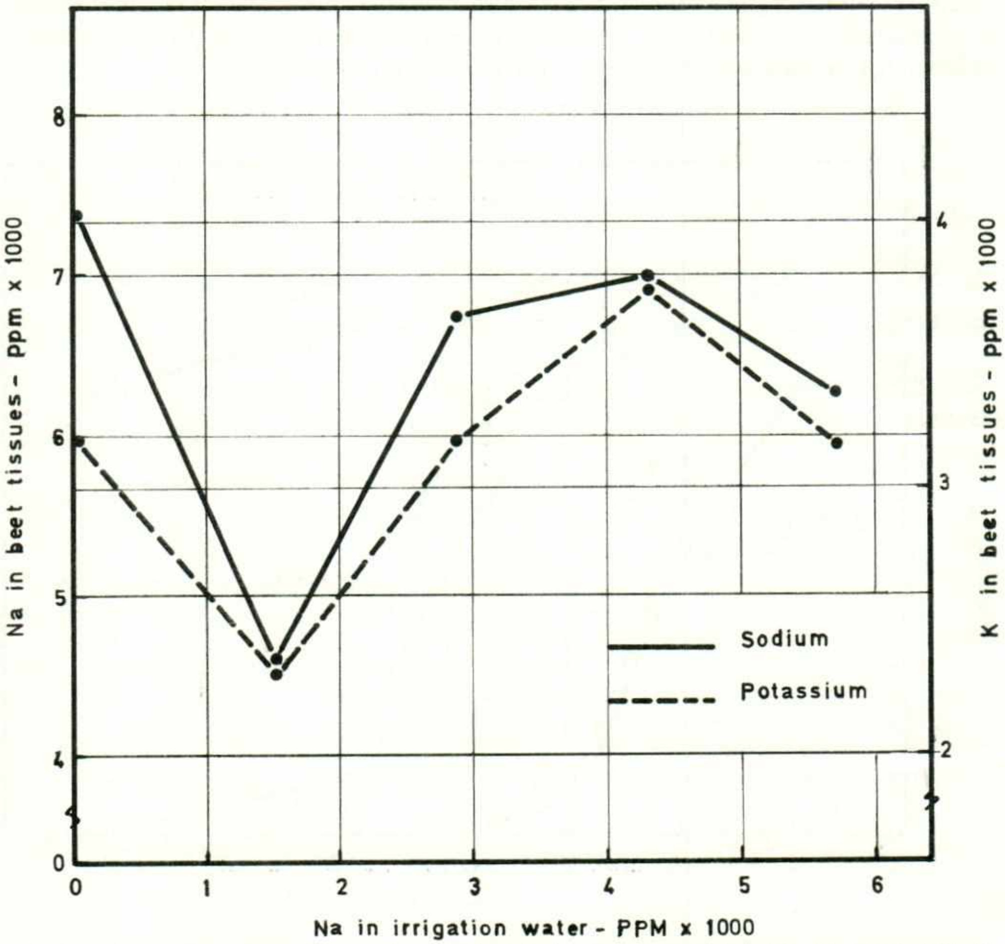

Fig. 5. Concentration of sodium and potassium in beet plants as affected by the level of Na in irrigation water.

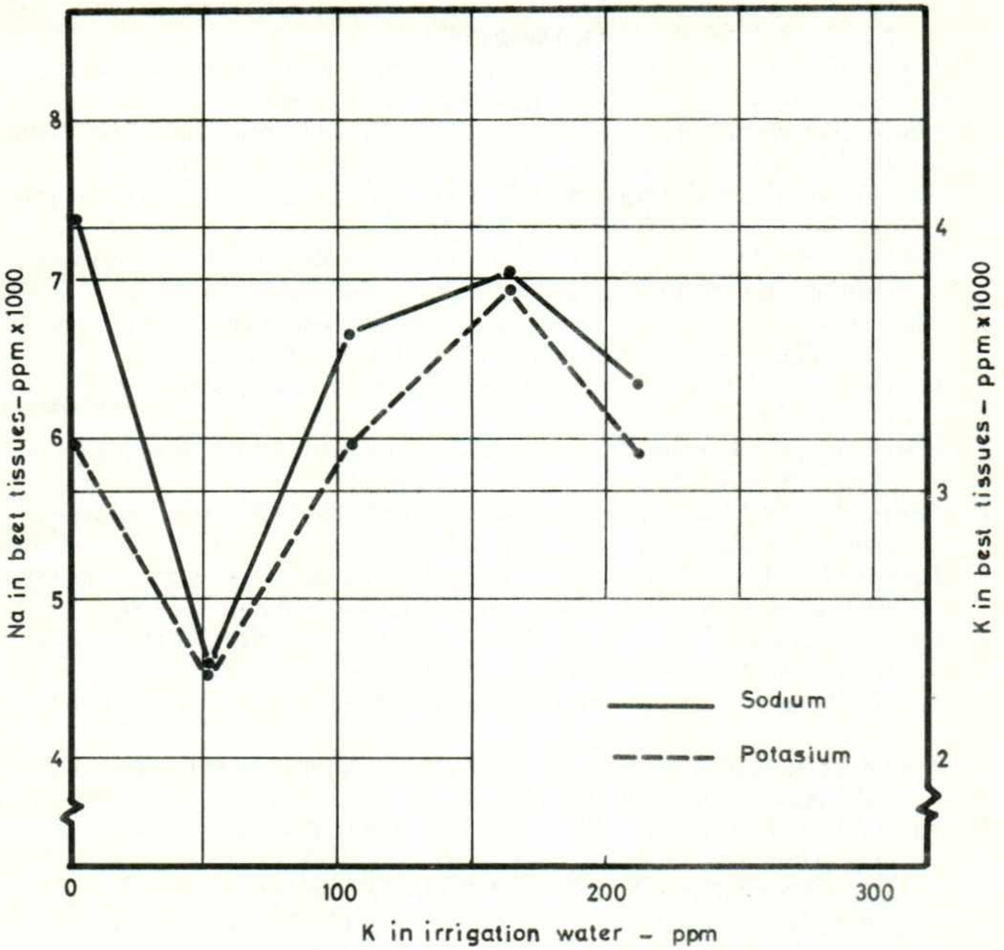

Fig. 6. Concentration of sodium and potassium in beet plants as affected by the level of potassium in irrigation water.

the status of P in beet plants. This may be explained on the basis that the absorption of P by plant roots was probably not affected by the presence of high salt content in irrigation water.

The concentration of either calcium or magnesium in plant tissues behaved in a similar manner to potassium and sodium. However, the differences due to treatments were not as great. Examination of the data presented in Table 7 for calcium and magnesium shows that the level of either nutrient in irrigation water was not directly reflected in the plant. As the level of Ca or Mg in sea-water dilutions was raised above 10%, no appreciable effect was manifested in the concentration of the same elements in beet tissues.

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