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FERTILIZATION AND SALINE WATER IRRIGATION

Blaustein Institute for Desert Research (BIDR)
Ben Gurion University of the Negev
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Introduction

Research in Israel has advanced well during this first year of the project. The Philippino team, new to the problem and to the logistics of this type of work, have made great progress towards the establishment of field experiments with peanut plants, in spite of the fact that funding became available only in May 1987. Dr. Enrique P. Pacardo, University of the Philippines at Los Banos, spent about two months working with Israeli researchers (Dr. Herman Lips and Dr. Jiftah Ben Asher) at Sede Boqer. During this period, a detailed experimental plan for the first year was worked out, and a complete drip irrigation system will be purchased from the Philippino agents of Netafim (Israel).

Dr. Ben Asher will travel to the Philippines towards the end of 1987 to establish an experimental field in cooperation with Dr. Pacardo and his coworkers at a selected site. Mr. Jose Reano, a Ph.D. student of UPLB, will join the Plant Adaptation Research Unit in Sede Boqer for an initial period of 10 months.

Dr. Eduardo O. Leidi, from the University of Cordoba (Spain), has joined our unit at Sede Boqer as a post-doctoral fellow supported by this grant. Mr. Dale Magnuson, a Ph.D. student from Michigan State University, is working on field experiments for this project under the direction of Dr. J. Ben Asher and is partially supported by this grant. Mr. Robert E. Sternberg, a Ph.D. student from the University of Pretoria, has joined the group for June-August 1987. He is participating in field experiments on corn together with Mr Magnuson. Mrs. Amparo Serra, from Valencia, has been helping with greenhouse experiments and is partially supported by this CDR grant. Ms. Elana Salomon (half-time) and Ms. Anat Hagin (full-time) are working on analysis of plant material. They are both supported by other financial sources from the Blaustein Institute for Desert Research.

We would like to express our appreciation to the Experimental Agricultural Station of Ramat Negev for their great help in setting up and running field experiments with saline water.

We would like to point out that work during the period covered by this report was made possible in Israel only due to the advancement of funds authorized by Ben Gurion University of the Negev. Money for the Philippine group was not available until May 1987, a situation that caused a delay in the experimental work of this group.

Most of the results obtained are presently being prepared for publication in scientific journals and are presented in this report in the style used for scientific papers.

RESEARCH IN ISRAEL

(1) PEANUTS

(1a) Interactions between KNO_3 and NaCl on the growth of peanut plants in hydroponics.

Summary

Peanut plants (Arachis hypogaea L.) are moderately sensitive to salinity. The use of KNO_3 as a means of reducing the salt hazard in peanut plants was tested by spray-hydroponics (aeroponics) with 50 mM NaCl and 1,3,5,7, and 9 mM KNO_3 in the nutrient solution. The addition of KNO_3 was associated with an increase in dry matter in the shoot, root length, chlorophyll content, nitrate reductase activity, and the reduction of salt injury symptoms in the leaves, with an optimum at 5-7 mM KNO_3. This recovery was not associated with proline content in the shoots or roots. Mean root diameter, which was abnormally thick in 1 mM KNO_3, became thinner when the KNO_3 concentration increased, until it reached a normal value at about 6 mM KNO_3. Sodium and chloride concentrations in the shoots sharply decreased with an increase in the KNO_3 concentration, but not in the roots. The interactions of Na-K and Cl-NO_3 suggest that K^+ and NO_3^- inhibited Na^+ and Cl^- translocation from the roots to the shoots, so that the photosynthetic system was not harmed.

Intoduction

Salt hazards of nonhalophytes grown in nutrient solutions is often due to an excess of ions in the growth medium rather than its osmotic potential (Greenway and Munns 1980, Kawasaki et al. 1983, Wyn Jones 1985). The disorder might occur either by specific toxicity of the ions, such as Na^+ and Cl^-, or even by an excess of a nutrient such as K^+ (Wyn Jones 1985). This kind of disorder may be balanced by a relatively high concentration of other ions, like K^+ and Ca^{2+} against Na^+ (Kawasaki et al. 1983) and Cl^- against NO_3^- and $H_2PO_4^-$ (Kafkafi et al. 1982, Glass 1983).

Considering that the major ions in saline water, which are also hazardous to nonhalophytes are Na^+ and Cl^-, the effect of salinity on crop production may be decreased by increasing the K^+ and NO_3^- concentration in the growth medium. This approach was tested, but with confusing results ( ). It is so believed by the authors, that the complexity of salt tolerance in different plants on one hand, and the different experimental conditions (i.e. other ions present, aeration, etc.) on the other hand, resulted in these conflicting results.

In the present paper, an experiment is described that studied the effect of K^+ and NO_3^- concentration in the growth solution on the salt-sensitivity of plants grown in saline, thouroughly aerated, nutrient solution.

Materials and Methods

Peanut plants (*Arachis hypogaea* L. var. Shulamit) were grown in an aeroponics system (nutrient solutions are sprayed over the plants roots) for 66 days. The aeroponic system was composed of 5 independent, 8 m long channels, which allowed the testing of 5 solution types at a time. All the plants were grown in 50 mM NaCl in the presence of 1,3,5,7 and 9 mM KNO_3. All other nutrients were supplied at the same concentration level to all the treatments: 0.5 mM $H_2PO_4^-$, 1 mM Mg^{2+}, 2 mM Ca^{2+}, 4 mg L^{-1} Fe-EDDHA, and micronutrients according to Hoagland and Arnon (1950). The plants were germinated on moist paper towels for 7 days. The tap-roots were then trimmed leaving 6 cm and the seedlings were transferred to the aeroponic system. Sodium chloride was added to the nutrient solutions in two doeses to avoid extreme stress, two days after transplantation. The nutrient solutions were sampled twice a week and analyzed for K^+ and NO_3^- and the depletion of these ions was compensated for by the addition of nutrients. The nutrient solutions were completely changed every two weeks.

Plants were sampled during the growth period, two plants at a time from each treatment, and the following deteminations were made in the roots and shoots: dry matter, content of minerals, proline, chlorophyll and nitrate reductase activity. Root length was measured by the line intersect method (Tennant 1975), and mean root diameter was calculated, assuming the roots to be smooth cylinders. Proline content of different plant parts was determined during the growth period by the acid-ninhydrin method (Bates et al. 1973). Chlorophyll was extracted from leaf discs (4.5 mm in diam., 5 discs per treatment) in 100% methanol. Quantitative detemination was done by spectroscopy according to Arnon (1949). Nitrate reductase activity was determined by the *in situ* method (Ben-Zioni and Heimer 1977). At the end of the 66 day growth period, five plants were sampled from each channel and analyzed as described above.

Results

Dry matter production in the shoots grown in 50 mM NaCl was largely stimulated by increasing the KNO_3 concentration (Table 1). Growth of a plant under the absence of NaCl but receiving 1 mM K^+ and 3 mM NO_3^- (from a previous experiment under identical conditions) is indicated in the same figure as a reference. Increasing the KNO_3 concentration up to 7 mM resulted in additional dry matter production (Table 1). Salt symptoms in the leaves (chlorotic and necrotic leaf borders), which were evident at low KNO_3 concentrations, completely disappeared at higher concentration of those nutrients.

Table 1: Dry matter production allocated to the shoots and roots of peanut plants grown for 66 days in 50 mM NaCl and Hoagland nutrient solutions with different levels of KNO_3.

KNO_3 mM	Shoot	Root	Total	Shoot/root
	<--- g/plant--->			
1	11.7	3.7	15.4	3.16
3	14.2	4.5	18.7	3.16
5	32.0	5.6	37.6	5.71
7	37.7	6.2	43.9	6.08
9	28.7	6.3	35.0	4.56

Table 2: Mineral concentration in peanut plant parts (mmoles/Kg dw).

KNO_3 mM	N	P	K	Ca	Mg	Na	Cl
	<----------mmoles/kg dw---------->						
			Shoot				
1	1745	76	703	442	343	293	1025
3	2182	69	630	474	433	138	797
5	2338	64	551	508	397	81	501
7	2149	65	582	483	384	58	398
9	2631	66	693	471	414	104	589
LSD 0.05	430	9	85	52	65	149	221
			Root				
1	1700	221	406	431	289	1430	1055
3	1921	204	481	403	311	1222	996
5	2390	133	610	332	339	1072	977
7	2336	180	625	392	228	1076	1012
9	2083	175	701	389	304	1160	934
LSD 0.05	277	81	94	118	120	223	75

Table 3: Mineral content of peanut plant parts.

KNO_3 mM	N	P	K	Ca	Mg	Na	Cl
	<-----mmoles----->						
			Shoot				
1	20.4	0.9	8.2	5.2	4.0	3.4	12.0
3	31.0	1.0	8.9	6.7	6.1	2.0	11.3
5	74.8	2.0	17.6	16.3	12.7	2.6	16.0
7	81.0	2.5	21.9	18.2	14.5	2.2	15.0
9	75.5	1.9	19.9	13.5	11.9	3.0	16.9
			Root				
1	6.3	0.8	1.5	1.6	1.1	5.3	3.9
3	8.6	0.9	2.2	1.8	1.4	5.5	4.5
5	13.4	0.7	3.4	1.9	1.9	6.0	5.5
7	14.5	1.1	3.9	2.4	1.4	6.8	6.3
9	13.1	1.1	4.4	2.5	1.9	7.3	5.9
			Total				
1	26.7	1.7	9.7	6.8	5.1	8.7	15.9
3	39.6	1.9	11.1	8.5	7.5	7.5	15.8
5	88.2	2.8	21.0	18.1	14.6	8.6	21.5
7	95.5	3.6	25.8	20.6	15.9	9.0	21.3
9	88.6	3.0	24.3	16.0	13.8	10.3	22.8

The results presented in Table 1 are the means for 5 plants which were sampled after 66 days of growth. Dry weight (Table 1) and mineral content in shoots and roots were measured (Table 2). Dry matter in the shoots increased with the addition of the KNO_3 concentration, showing an optimum at 7 mM. Differences in dry matter of the roots were not significant. The nitrogen content increased with KNO_3 both in the shoots and roots (Table 3). The decrease which was observed in the Cl^- concentration was moderate in roots, but very pronounced in the shoots. The major salt hazard to the plants was correlated with the Na^+ concentration in the shoots, which decreased with higher concentrations of KNO_3.

The alleviation of salt effect by increasing the KNO_3 concentration was also evident in the development of roots as estimated by root length (Fig. 2).

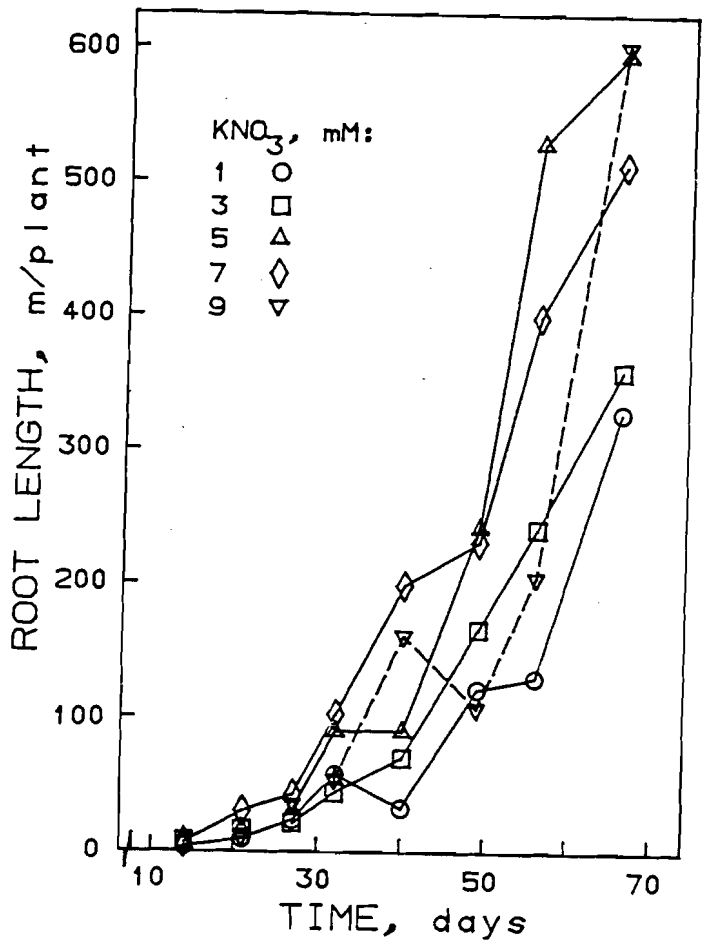

Figure 1: Root length of peanut plants as affected by the concentration of KNO_3 and 50 mM NaCl.

Mean root diameter, which was abnormally thick in 50 mM NaCl and 1 mM KNO_3, decreased with an increase in the KNO_3 concentration, reaching a diameter typical of roots grown without salt at about 6 mM KNO_3, but increased again at higher concentrations (Fig. 2). The outlook of roots affected by 50 mM NaCl was reversed for normal roots by the addition of KNO_3.

Peanut plants have the capacity to adapt osmotically to 50 mM NaCl and, consequently, the lack of osmotic adaptation is not the reason for lower dry matter production and growth. The presence of Na^+ and Cl^- interfere, however, with the uptake of nutritional ions such as K^+ and nitrate. One can overcome this interference by increasing the concentration of K^+ and NO_3^- in the nutrient medium. The effects of added KNO_3 are evident in the content of K^+ and Na^+ (Fig. 3), Cl^- and total nitrogen (Fig. 4), as well as the correlation between the K/Na ratio in the shoot with dry matter production (Fig. 5).

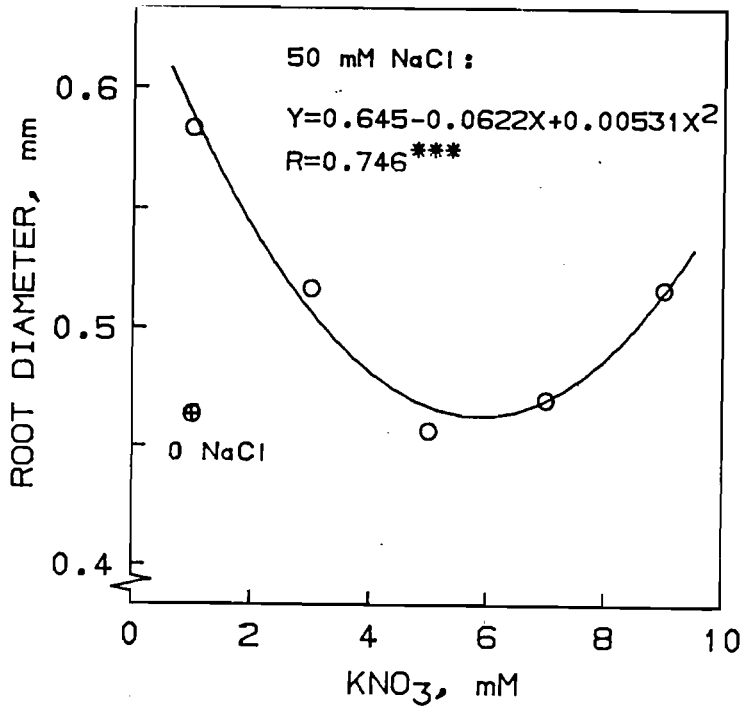

Figure 2: Mean root diameter of peanut plants grown in 50 mM NaCl as affected by increasing the concentration of KNO_3 .

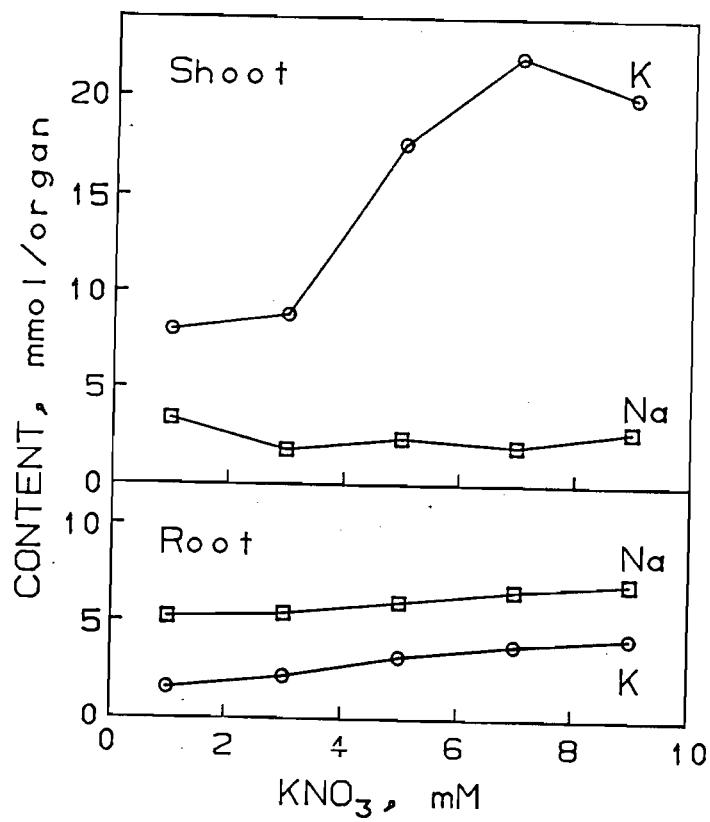

Figure 3: Content of K^+ and Na^+ in shoots and roots of peanut plants.

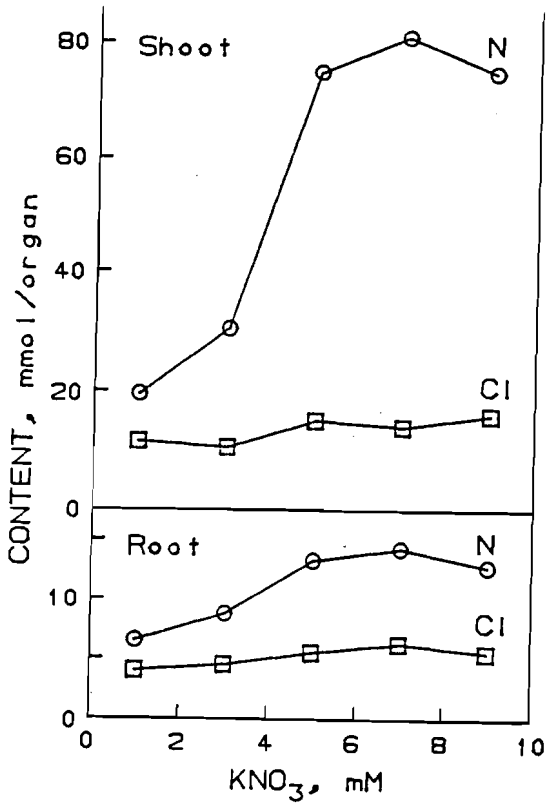

Figure 4: Content of nitrogen (N) and Cl^- in shoots and roots of peanut plants.

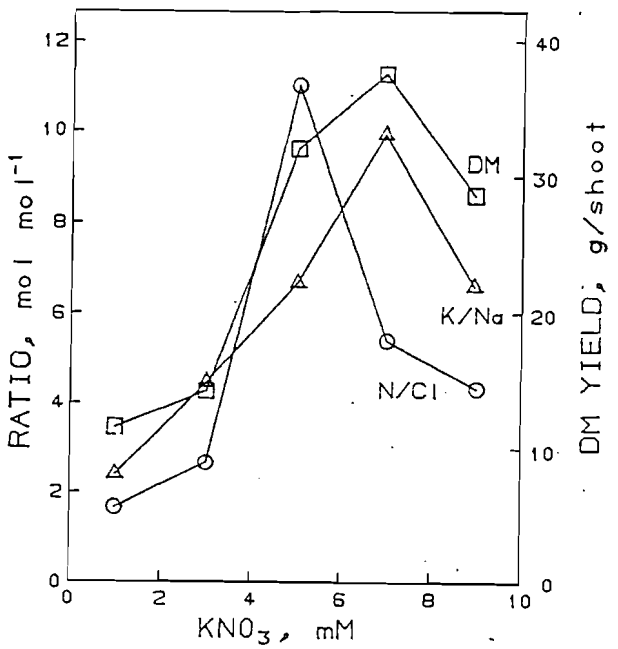

Figure 5: Changes in dry matter, K/Na and N/Cl^- ratios in shoots of peanut plants.

The chlorophyll content increased with KNO_3, up to 5 mM (Fig. 6). Nitrate reductase, the key enzyme in the assimilation of the inorganic nitrate into organic nitrogen, followed a similar pattern by increasing the KNO_3 concentration (Fig. 6) in the same pattern as chlorophyll and dry matter in the shoots (Table 1).

The proline content increased during the growth of peanut seedlings, either in the roots or shoots (Fig. 7). After this stage, a rapid decline in proline content occurred. It appears that the rate of decline in the

proline content between the 8th and the 14th day was similar in 1 and 9 mM KNO_3. Later growth stages, however, were characterized by low proline levels (Fig. 7). The pattern of proline accumulation, which generally takes place in response to salinity or osmotic shocks, is practically identical in all the treatments exposed to 50 mM NaCl and all concentrations of KNO_3 tested.

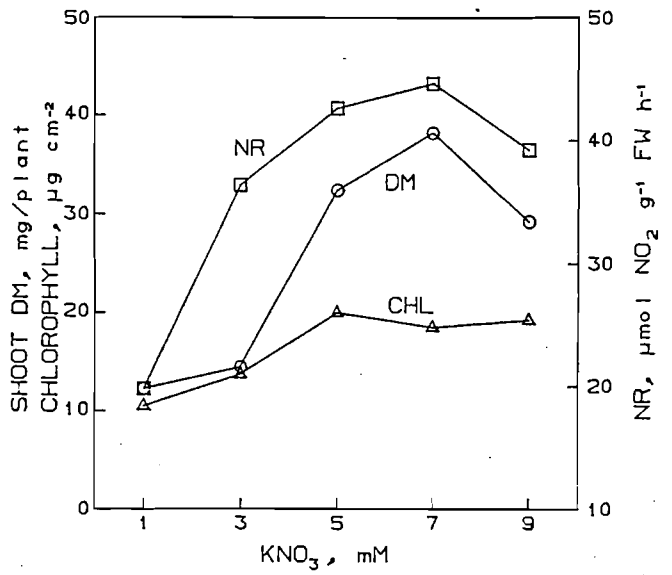

Figure 6: Changes in chlorophyll content of leaves and nitrate reductase activity.

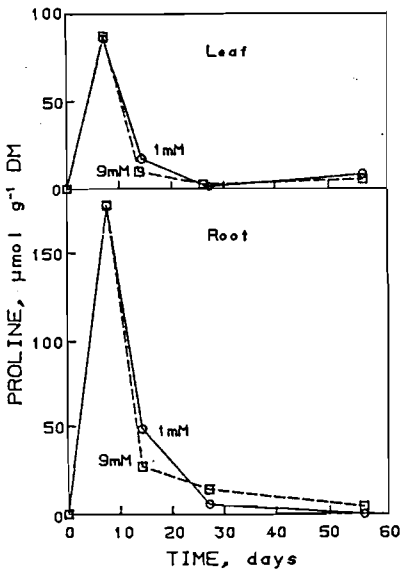

Figure 7: Proline concentration in peanut seedlings grown on 50 mM NaCl in the presence of 1 and 9 mM KNO_3 .

Discussion

The experiments were conducted without a NaCl-free treatment, which might invite criticism. On the other hand, only five treatments could be tested at a time, and dedicating one aeroponic channel to NaCl-free treatment should cause the loss of valuable information. Some reference, however, is given by comparing the dry matter yield and root length and diameter of this plant (Figs. 1 and 2) with a previous test, grown without salt under similar conditions.

Potassium nitrate reduced the concentrations of Na^+ and Cl^- in the plant, but not their total amounts in the plants (Tables 2 and 3). If plant ion absorption was not suppressed, these ions should have been absorbed in increasing amounts while the plant produced more dry matter. In fact, both Na^+ and Cl^- percentage in the plant dry matter decreased with increased KNO_3 concentration (Table 1) while their total amount in the plant did not (Figs. 4 and 5). These findings indicate that the decrease of Na^+ and Cl^- percentage was not just because of the dilution of these ions in a large amount of plant material, but K^+ and NO_3^- actually reduced the absorption of Na^+ and Cl^- by the plant. The major drop in the content of Na^+ and Cl^- with increasing KNO_3 concentration was mainly in the shoot, and only to a smaller degree in the root, which indicates that the plant eliminated Na^+ and Cl^- hazards by suppressing their transport from the root to the shoot.

The accumulation of proline in peanut seedlings during the first week of germination cannot be accounted for by proline formed in the storage protein (arachin) of the seed. Such an event must be supported by the activation of genes and enzymes involved in proline biosynthesis. Under the conditions of this experiment, 50mM NaCl and KNO_3 concentrations between 1 and 9 mM did not have a s ubstantial effect pn the level pf proline and its biosynthetic system, suggesting that osmotic adaptation of the seedlings was complete in all treatments.

Consequently, the change in dry matter production was not the result of different degrees of osmotic adjustment to the saline media, but rather the different rates of nitrogen uptake facilitated by K^+.

(1b) Irrigation of peanut plants with brackish water under field conditions.

Although these expeiments were carried out before the beginning of funding by AID/CDR, we considered this information useful and relevant to get a better understanding of our entire work with peanut plants irrigated with brackish water.

Summary

The concept that the hazards of salinity to sensitive crops can be reduced by adequate fertilization was studied. Peanuts plants (Arachis hypogeae L., var. Shulamit) were grown for two years on sandy dunes with 1.0 to 6.5 dS m^{-1} irrigation water and different concentrations of K^+ and NO_3^- , which were applied by the trickle-irrigation system. The results show that dry matter production in 4.5 dS m^{-1} was about the same as 1 dS m^{-1} when 11.6 mM KNO_3 were applied. Similar results were obtained with pod yield in 1983, but not in 1984 when an increase in the salinity of the water from 1 to 4.3 dS m^{-1} abruptly reduced pod yield. As in the experiments described in section 1a of this report, the major effect of salinity on the crop was due to K/Na uptake ratios by the plants.

Although these experiments were carried out before the beginning of funding by AID/CDR, we considered this information useful and relevant to get a better understanding of our entire work with peanut irrigated with brackish water.

Materials and Methods

The interaction between KNO_3 fertilizer and the salinity of the irrigation water was tested in the field in the Ramat Negev Experimental Station (Israel). Combinations of 3 levels of water salinity (1.0, 4.3 and 6.4 dS m^{-1}) and three concentrations of KNO_3 (3.9, 11.6 and 15.4 mM) were tested in 6 randomized blocks. Each experimental plot consisted of two soil beds, 2x10 m each, with four rows of plants in each bed, which were irrigated by two extensions with 2 l h^{-1} drippers, speced 0.5 m along the line. Peanut seeds were inoculated with rhizobium prior to sowing. The field was planted on mid-April and irrigated by sprinkling for 10 days with fresh water. The differential treatments were then applied. The field was irrigated every 3 days in equal amounts to all treatments, according to Class A Evaporation pan ratio, as recommended by the Israeli Agricultural Extension Service.

Plants were sampled along 1 m of row on Aug. 30, and dried at 60°C for dry matter determinations. The soil was excavated perpendicularly to an emitter, and undisturbed soil samples were taken in a matrix of 5x5, 0-35 cm horizontally and 0-40 cm vertically from the emitter. The roots were separated by screening and their lengths were measured. The soil samples were extracted with water in a 1:1 soil-water extract, and analyzed for EC of the extract. At the end of the season, the plants with the pods were picked up manually, dried in the field, and weighed for strow and pod yield.

Results

Hey and pod yields of peanuts grown in the field with 3 salinity water levels and three KNO_3 concentrations are presented in table 4. Salinity slightly reduced the hay yield and 11.6 mM KNO_3 gave the highest yield, at all the salinity levels tested. The effect of KNO_3 and salinity on pod yield was completely different: salinity was most hazardous to pod yield as was high concentrations of KNO_3 in fresh water.

Table 4: Hay and pod yield (Mg ha^{-1}) of peanuts grown in the field and irrigated by trickling with water of different salinities and KNO_3 concentrations.

EC_{25}	KNO_3 concentration, mM					
dS m^{-1}	3.9	11.6	15.4	3.9	11.6	15.4
	<----------Hay---------->			<----------Pods------->		
1.0	7.32^{a-d}	8.48^{a}	7.56^{a-c}	5.95^{a}	2.56^{b}	1.37^{c}
4.3	7.64^{a-c}	8.12^{ab}	6.00^{b-d}	0.47^{d}	0.49^{d}	0.37^{d}
6.4	5.05^{d}	6.15^{a-d}	5.17^{d}	0.21^{d}	0.24^{d}	0.22^{d}

Within each yield component, different letters represent significance groups ($p<0.05$) according to the Duncan's New Multiple Range.

Figure 8 presents the distribution of total soluble salts in the soil profile, perpendicularly to the trickling extension. The values in this figure were calculated from the measured EC of the soil extracts and the measured soil moisture content, assuming that the majority of the ions in the extract are originated from the soil solutions.

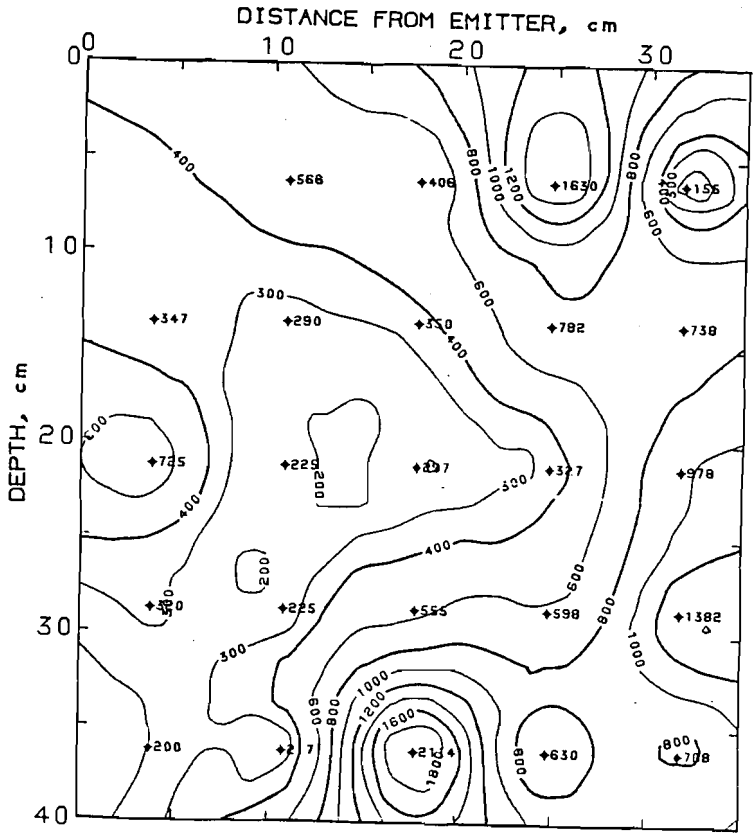

Figure 8: Distribution of total soluble salts concentration in the soil solution (me L^{-1}) of sand dune irrigated by trickling of brackish water of 6.4 dS m^{-1}, and with 15.4 mM KNO_3.

Discussion

Salts were leached from the vecinity of the emitter, leaving about 20 cm of leached soil, and were then accumulated, maingly at the soil surface. The row of plants was located 15-20 cm from the trickling line. This profile respresent actually a radial section of the soil volume wetted by a single emitter, so most of the area under the plants was occupied by a relatively high concentration of salt at the upper soil level.

Gynophores in this experiment died (prior to pod production) when touching the saline soil surface due to their high sensitivity to salinity (see 1c for further details). This was presumably the main reason for the difference between hay and pod yield for plants irrigated with brackish water (table 4).

Irrigation by trickling with brackish water may be beneficial to many crops but not in the case of peanut growing in sand, due to the unique characteristics of the commercial yield production through gynophores.

(1c) Effect of salinity on the development of peanut gynophores.

Introduction

The yields obtained for peanut plants in the field (1b) were extremely low, even for the control treatments. As we obtained much better responses to fertilizer when growing peanut plants in hydroponics, it seemed that the reason for the poor yield was the accumulations of salt at the border of the wetted soil of the trickle irrigation emmiter. Salt accumulated largely in the area where the gynophores descended from the shoot and touched the ground. This would imply that the gynophore development was extremely sensitive to salinity, much more so than the vegetative development of the plants. An experiment to assess the sensitivity of the gynophores seemed unavoidable.

Materials and Methods

Peanuts plants were grown in hydroponics as in (1a), with 7 mM KNO_3. At the beginning of flowering, polyethylene bags with sand were placed adjacent to the hydroponic channels in which the peanut plants were grown. Part of the gynophores was allowed to reach the side bags, which were irrigated frequently with water at levels of NaCl varying from 0 to 800, which is the range found under field conditions at short distances from the trickle irrigation emmiter. Additional treatments of $CaCl_2$ and CaS04 were also tested to study the possible effect of Ca^{++} to alleviate salinity inhibition of gynophore development.

Results and Discussion

No gynophore survived at salt concentrations above 400 mM NaCl. Results, therefore, show gynophore development in the presence of 0 to 400 mM NaCl (Table 5). Total number of gynophores directed to the sand bags adjacent to the the peanut plants are indicated. Percentage of pod produced by these gynophores, the fraction gynophores which penetrated the sand but did not form pods and the fraction of gynophores that did not penetrate the sand or form pods are summarized in Table 5.

As allready mentioned, all gynophores died in the presence of 400 mM NaCl. Ca^{++} either as $CaCl_2$ or $CaSO_4$ did not reduce mortality due to NaCl. These results explain the low pod yield obtained in the field (section 1b).

The accumulation of salt in the trickle irrigated area was hazardous in the case of peanut because of the sensitivity of the gynophores to salinity. Trickle irrigation, therefore, should be avoided during the reproductive stage, when growing peanuts on sand.

Table 5: The effect of NaCl, $CaCl_2$ and $CaSO_4$ concentrations on the growth and development of peanut gynophores in sand.

TREATMENTS			GYNOPHORES			
NaCl mM	$CaCl_2$ mM	$CaSO_4$ g/plant	Total number	% Pods produced	% Pods which penetrated but died	% Pods which did not penetrate
0	0	0	54	100	0	0
0	50	0	98	74	12	13
0	0	10	54	89	0	11
200	0	0	42	29	17	54
200	50	0	53	34	17	45
200	0	10	98	37	39	24
400	0	0	72	0	62	38
400	50	0	44	0	41	59
400	0	10	50	4	62	34

(1d) Interactions between KNO_3 and NaCl on the vegetative and reproductive growth stages of peanut plants in sand pots.

Introduction

Several experiments with peanut plants (Arachis hypogaea L, var. Shulamit) grown on sand dunes and drip irrigated with brackish water (section 1b in this report) were carried out by Dr. M. Silberbush, Dr. J. Ben Asher and Dr. H. Lips in previous years. Reproductive growth (growth of gynophores and subterraneous formation of pods) was very sensitive to salinity. Vegetative growth responded quite well to enhanced fertilization with KNO_3. These experiments also pointed out that the drip irrigation method caused an accumulation of salts at the border of the wetting zone of the emitter. The salts thus accumulated inhibited development of the gynophores that descended from the shoot over the salt accumulation area.

This experiment was designed to study the extent of salt sensitivity of peanut gynophore development and pod formation. We also separated effect of salt (NaCl) on vegetative and reproductive stages of development.

Materials and Methods

The experiment was carried out in a greenhouse at Sede Boqer. Peanut plants were planted and grown in plastic bags with 3 Kg gravel over which were aded 10 Kg dune sand, previously passed through a 1 mm sieve. The experiment consisted of 6 random blocks. Treatments tested were:

Salinity: tap water or 50 mM NaCl
Nitrogen concentrations: 2 and 6 mM
Inorganic nitrogen forms: NO_3^-, NH_4^+ and NH_4NO_3.

Ammonium was added as $(NH_4)_2SO_4$, nitrate as $Ca(NO_3)_2$. The experiment began on June 24, 1986. Fresh nutrient solutions were added in excess of field capacity every second day to avoid depletion of nitrogen and accumulation of salts in the soil. The onset of flowering took place on August 8, 1986, at which time three random blocks were harvested to analyze the effect of the treatments on vegetative growth. Leaves and stems were collected separately and dried for two days at 60°C. Dry mass of these parts was determined and part of the homogenized dry matter was used later for extraction and chemical analysis.

The three remaining blocks were used to determine the effect of the treatments on reproductive growth. Side pots were attached to pots with plant pots without treatments of NaCl. Gynophores were directed to the side pots, which received solutions with different concentrations of NaCl (4 replicates for each treatment), every second day. NaCl concentrations in the side pots were: 0, 50, 100, 150 and 200 mM.

The last three blocks were harvested on October 10, 1986. Gynophores on the different side pots were classified as "vital" or "dead". The total number of gynophores produced by the plants and the number of pods produced were determined. All the plant parts were oven dried at 60°C for 2 days to determine dry mass production.

Results

Analysis of the different components of the yield showed no siginificant difference between the levels of nitrogen used (2 and 6 mM). Dry matter production and its allocation to different shoot parts (Table 6) was largest when supplying nitrogen as NH_4NO_3, although under field conditions the use of NH_4^+ gave a similar result. The similarity of the peanut plants response to these two forms of inorganic nitrogen is presumably due to the fact that nitrification of ammonium takes place in the field, and we are dealing in both cases with NH_4NO_3.

Table 6: Dry mass (g) of leaves and stems for 47 day old peanut plants. Nitrogen concentration (2 or 6 mM) did not significantly affect the results.

	<-----Leaves------>			<------Stems------>			<------Shoot------>		
mM NaCl	0	50	% contr.	0	50	% contr.	0	50	% contr.
N-form									
NO3	3.04	3.12	102.6	1.47	1.12	76.2	4.51	4.24	94.0
NH4NO3	5.85	5.16	88.2	2.40	1.68	70.0	8.25	6.84	82.9
NH4	5.73	4.48	78.2	2.08	1.45	69.7	7.81	5.93	75.9

Concentration of mineral elements in the leaves (Table 7) was interesting in several respects: (a) concentrations of nitrogen, phosphorous, Ca^{++} and Mg^{++} are not affected significantly by salinity; and (b) NH_4NO_3 exhibits the smallest concentration of Cl^- in the leaves, and was also the best growing treatment under saline conditions.

Table 7: Mineral concentration in the leaves (mmoles/kg dw).

Treatments (mM)			Total N	P	K	Ca	Mg	Na	Cl
NaCl	NO_3^-	NH_4^+	<----------mmoles/Kg dry weight ---------->						
0	2-6	0	1853	49	515	557	255	10	78
0	0	2-6	2387	87	597	602	250	9	119
0	1-3	1-3	2311	92	560	639	290	13	88
50	2-6	0	2169	56	510	651	275	41	589
50	0	2-6	2575	112	627	597	262	48	530
50	1-3	1-3	2391	98	588	622	275	44	516

Table 8: Mineral content of leaves.

Treatments (mM) NaCl	NO_3^-	NH_4^+	Total N	P	K	Ca	Mg	Na	Cl
			<---------- mmoles/plants ---------->						
0	2-6	0	5.63	0.15	1.57	1.69	0.78	0.03	0.24
0	0	2-6	13.96	0.51	3.49	3.52	1.46	0.05	0.70
0	1-3	1-3	13.24	0.53	3.21	3.66	1.66	0.07	0.50
50	2-6	0	6.77	0.17	1.59	2.03	0.86	0.13	1.84
50	0	2-6	13.29	0.58	3.24	3.08	1.35	0.25	2.73
50	1-3	1-3	10.71	0.44	2.63	2.79	1.23	0.20	2.31

It seems that the capacity of the plants to develop under different conditions (high or low salt) is not reflected in the mineral concentration of the leaves or the stems (Tables 7 and 9). These results support our previous observations that plants will try to produce additional leaves at a given standard and, under stress conditions such as salinity, will not compromise producing leaves of a lower standard. This conclusion is especially true for the nitrogen concentration of leaves which seems not to be affected by the level or type of inorganic nitrogen or by salinity.

Uptake of nitrogen and its eventual assimilation into organic nitrogen compounds may be, therefore, a major factor determining growth of the plant.

Table 9: Mineral concentration in stems (mmoles/Kg dry weight).

Treatments (mM) NaCl	NO_3^-	NH_4^+	Total N	P	K	Ca	Mg	Na	Cl
			<---------- mmoles/Kg dry weight ---------->						
0	2-6	0	1137	34	600	455	193	37	44
0	0	2-6	1311	69	661	447	319	21	76
0	1-3	1-3	1479	60	644	435	345	33	43
50	2-6	0	1147	46	528	458	252	373	640
50	0	2-6	1367	94	629	445	315	287	680
50	1-3	1-3	1332	97	607	434	330	337	692

Table 10: Mineral content of stems (mmoles).

Treatments (mM) NaCl	NO_3^-	NH_4^+	Total N	P	K	Ca	Mg	Na	Cl
			<---------- mmoles/plant						---------->
0	2-6	0	1.67	0.05	0.88	0.67	0.28	0.05	0.11
0	0	2-6	3.15	0.17	1.59	1.07	0.77	0.05	0.29
0	1-3	1-3	3.08	0.12	1.34	0.90	0.72	0.07	0.18
50	2-6	0	1.28	0.05	0.59	0.51	0.28	0.42	0.66
50	0	2-6	2.30	0.16	1.06	0.75	0.53	0.48	0.89
50	1-3	1-3	1.93	0.14	0.88	0.63	0.48	0.49	0.75

Leaf production by the plant was optimal when using NH_4NO_3 or NH_4. When using NH_4NO_3 the inhibition of leaf growth induced by 50 mM NaCl was less than 12% (Table 6), although the inhibition of pod production was as high as 55% (Table 11). Pod yield was not only reduced, but the resulting pods were of very poor quality.

Table 11: Gynophore and pod production.

	Gynophores/plant			Pod g dw/plant			Pods/pot*	
mM NaCl ->	0	50	% control	0	50	% control	0	50
N-form								
NO_3^-	45.8	84.5	184.5	16.9	15.7	92.9	20.0	30.0
NH_4^+	63.8	113.0	177.1	31.6	15.0	47.5	34.5	32.5
NH_4NO_3	95.0	135.0	142.1	46.5	18.7	40.2	45.5	42.0

* Pods which developed in the growth pots only.

One of the striking effects of salinity on peanut plants is the stimulation of gynophore formation (Table 11), which seems to be largest in plants receiving nitrate, but is significantly increased also in plants receiving nitrogen as ammonium nitrate or ammonium sulphate. Another observation which may be of great interest to

The percent of gynophores which were allowed to form pods in these esperiment was about 50% of the total number of gynophores produced by the plants. Using these data we attempted to calculate the potential yield, would all the gynophores produced allowed to form pods (Table 12). This is presumably an overestimation of what the plant can produce under unprotected field conditions, but the calculation constitutes a useful tool to plan future experiments in the field.

Table 12: Observed and potential yield of peanuts.

	Observed partial yields Kg dw/plant			Potential yield Kg dw/plant		
mM NaCl ->	0	50	% control	0	50	% control
N-form						
NO_3^-	0.34	0.47	139.3	0.77	1.33	171.4
NH_4^+	1.09	0.49	44.7	2.02	1.70	84.1
NH_4NO_3	2.12	0.79	37.1	4.42	2.53	57.1

Discussion

Peanuts appear to be quite tolerant to 50 mM NaCl, indicating that peanuts can be irrigated at this level of salinity when salt accumulation around the plants is avoided. The retarded growth due to nitrate as compared to ammonium or ammonium-nitrate deserves a more thorough study because it does not agree with the possitive response to nitrate observed in hydroponics (section 1a), although it does agree with the restults obtained in the field studies (section 1b, table 4).

The explanation for this discrepancy may reside on the calcareous, low buffered sund, which was used both in the field and the pot experiments. Nitrate fed plants increase the pH around their root uptake areas due to an excess uptake of anions over cations, to a pH level detrimental to plant growth. This level may cause problems of solubility and/or availability of some mineral nutrients such as phosphate or calcium. An indication for this effect is the relatively low percentage of P in the leaves of nitrate fed plants (table 7).

Additional studies of salt sensitivity at different pH levels are presently being carried out in our laboratory.

(2) WHEAT

Introduction

Wheat (*Triticum aestivum* L.) var. was chosen for this experiments due to its relative sensitivity to salinity, because we considered important to expand our studies to a non-leguminous species of plants and because wheat is of economical importance in many countries.

Peanut plants showed a greater effectiveness of ammonium and ammonium nitrate to alleviate salinity damage. This fact may have to do with ability of this legume to grow on organic nitrogen (amino acids and amides) delivered by the root to the shoot of the plant following the symbiotic assimilation of atmospheric nitrogen.

Study of the effect of various forms of inorganic nitrogen to alleviate salinity damage, was therefore persued with wheat plants, which do not form N_2 assimilating nodules and grow generally on nitrate in well aerated soils.

The experiment described here studied the interactions between nitrogen and salinity on the vegetative and the reproductive stages of wheat development. The results shown here are partial and most of the data are presently processed and will be presented in our second report.

(2a) Effect of nitrate or ammonium nitrogen on aliviation of salinity damage.

I. Vegetative growth

Materials and methods

Wheat seeds were germinated in polyethylene bags as described in section 1d. Plants were irrigated with nutrient solutions twice a week during the early stages of growth (30 days) and every two days thereafter.

NaCl was added to a final concentration of 50 mM to the corresponding treatments. Nitrogen was applied at two concentrations, 2 and 6 mM, at four different NO_3^- /NH_4^+ ratios: 1/0, 1/1, 1/3, 0/1.

K^+ was added at concentrations of 0.5 and 5 mM. Combinations of nitrogen inorganic forms, K^+, Ca^{2+}, SO_4^{2-} were combined in each treatment as to minimize differences in concentration of accompanying ions.

The experiment was set up with 4 replicates as randomized blocks, three of which were harvested at the appearance of inflorescence and one was left until grain filling and drying was completed. The first harvest (vegetative growth) was separated into leaves, stems, primary shoots and tillers and roots. The material collected was oven-dried at 60^0 for 48 hours. The dry material was later used for extraction and analysis of mineral content.

Length and mean diameter of roots were determined prior to drying, according to the line intersect method (Tennant, 1975).

Results

Concentration of K^+ had no significant effect on the vegetative growth of wheat plants grown in sand, as indicated by the analysis of variants.

Ammonium was a more effective nitrogen source than nitrate at 6 mM when supplied with or without 60 mM NaCl (Fig. 9). This preference for ammonium nitrogen was not observed to a significant extent when the level of nitrogen supplied was 2 mM.

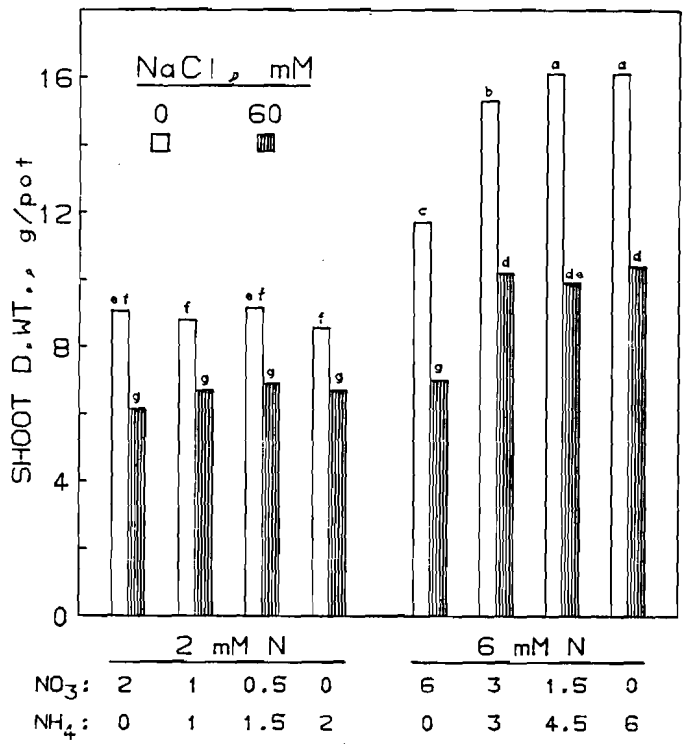

Figure 9: Dry matter in shoots of wheat plants grown in sand, with or without 60 mM NaCl, in different concentrations and proportions of nitrate and ammonium nitrogen. Different letters represent significant groups ($p<0.05$) according to the Duncan's New Multiple Range Test.

Most of the dry matter of the shoot of wheat is usually in the secondary shoot, namely the tillers. The number of tillers/pot (6 plants) and their dry weight are presented in table 13. There is a general correlation between the two group parameters and they both behave in the same pattern as the shoot dry matter (Fig. 9)

Nitrogen concentration did not affect root length. However, NH_4/NO_3 ratio resulted in a curvilinear response of root length either with or without NaCl with an optimum about 1:1 ratio (Fig. 10).

Table 13: Number of dry weight of whest tillers grown in water salinities, and different concentrations and forms of nitrogen.

	N concentration							
	2 mM				6 mM			
NH_4/NO_3	0	0.5	0.75	1.00	0	0.5	0.75	1.00
mM NaCl	Number of tillers							
0	14^{f}	12^{f}	11^{fg}	12^{fg}	28^{c}	29^{b}	31^{b}	35^{a}
60	10^{fg}	10^{fg}	9^{g}	11^{fg}	16^{e}	22^{d}	22^{d}	22^{d}
	Dry weight of tillers (g/pot)							
0	4.1^{e}	3.8^{e}	3.9^{e}	3.7^{e}	6.8^{c}	10.8^{b}	10.9^{ab}	11.1^{a}
60	2.2^{f}	2.5^{f}	2.3^{f}	2.1^{f}	3.4^{e}	6.0^{cd}	5.4^{d}	5.8^{d}

Different letters represent statistical groups ($p<0.05$) according to the Duncan's New Multiple Range Test

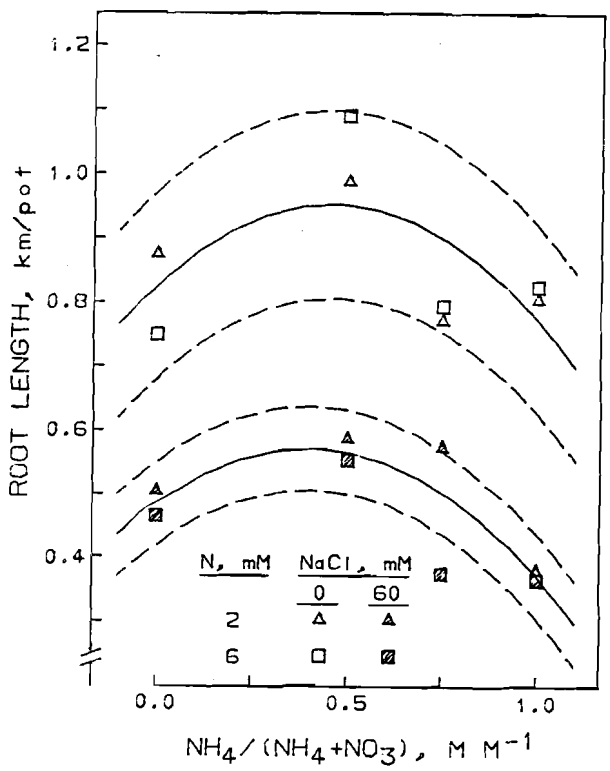

Figure 10: Root length of wheat plants grown in sand culture and irrigated with water of two salinity levels and different concentrations and ratios of NH_4/NO_3 nitrogen (the dashed lines represent confidence interval of 0.95).

Discussion

Salt reduced dry matter in the shoot of wheat plants in all the nitrogen treatments, but the extent of this inhibition was larger in 6 mM than in 2 mM nitrogen (Fig. 9). Furthermore, the increase of NH_4^+ proportion in the 6 mM concentration increased the yield either with or without NaCl. The extent of growth inhibition by NaCl was higher in the ammonium than in the nitrate treated plants. Yield reduction due to salinity is therefore relatively, but not absolutly, is more more pronounced when nutritional conditions are more favorable to the plant.

Nitrogen concentration affected shoot growth but not root growth. Ammonium grown plants seem to allocate a larger proportion of assimilates to the shoot than to the roots. This allocation pattern is not observed in nitrate fed plants. These assimilate allocation patterns are presently being studied in our laboratory.

(2b) Effect of nitrate or ammonium nitrogen to aliviate salinity damage. II. Reproductive growth

Introduction

The correlation between the number of tillers (number of spikes) and shoot dry matter (Fig. 9 and table 13) suggests that larger plants have also a greater potential to produce grains. These relationships between yield components were studied in this section of the project.

Materials and methods

The fourth replication of the previous experiment (section 2a) was allowed to grow to maturity. The spikes of each pot were collected into one butch and stored in the greenhouse until air dryness. The grains of each spike were counted and weighed separately.

Results and discussion

Grain weight distribution and frequency of the different treatments are presented in figures 11a and 11b. Nitrate fed plants produced less tillers and spikes (table 13) and their grains were noticably larger in plants receiving 6 mM nitrogen (table 14). This grain weight compensation mechanism was effective in plants irrigated with 60 mM NaCl. The means of grain weight distribution presented in Table 14 were very close to the calculated medians which indicates that the distributions may be treated as normal distributions.

Table 14: Means of grain weight distributions of wheat grown with different water salinities, concentrations of K and N, and different NH_4^+/NO_5 nitrogen ratios.

	N concentration							
	2 mM				6 mM			
NH_4/NO_3	0	0.5	0.75	1.00	0	0.5	0.75	1.00
mM NaCl	0.5 mM K^+							
0	47^{a-c}	52^{a}	50^{ab}	45^{a-d}	26^{i-k}	29^{hi}	31^{g-i}	33^{f-i}
60	48^{a-c}	38^{d-g}	43^{a-d}	38^{d-g}	35^{e-h}	28^{h-j}	31^{g-i}	29^{hi}
	5 mM K^+							
0	49^{ab}	46^{a-c}	47^{a-c}	48^{a-c}	30^{g-i}	24^{i-k}	24^{i-k}	26^{i-k}
60	40^{c-f}	47^{a-c}	44^{a-d}	42^{b-e}	37^{d-g}	20^{i-k}	19^{k}	19^{k}

Different letters represent statistical groups ($p<0.05$) according to the Duncan's New Multiple Range Test

Ammonium fed plants were more sensitive to salt than nitrate fed plants, with a larger salt induced inhibition of number of tillers and spikes as well as total grain yield (Fig. 12). Unlike ammonium grown plants, nitrate-fed plants grown in 60 mM NaCl produced larger grains than plants not exposed to NaCl. The overall grain yield of nitrate-fed plants (in 6 mM) was essentially unaffected by salinity due to the compensation on grain weight.

Ammonium fed plants were more efficient than nitrate-fed plants in the production of shoot dry matter. They also had more tillers and spikes although they failed to increase proportionally assimilate transfer into the filling grains. The same amount of assimilates was distributed in a larger number of spikes and grains, resulting in lower mean grain weight. Ammonium-fed plants were more susceptible to NaCl.

Nitrate-fed plants had a smaller number of tillers and spikes but their total grain yield was barely affected due to the increased weight of single seeds in the presence of NaCl. Therefore, vegetative growth in the presence of NaCl is less sensitive in nitrate than in ammonium-fed plants.

Figure 11a: Distribution of grain weight and frequency of wheat plants grown in 0.5 mM K^+ and 6 mM nitrogen (NH_4^+ or NO_3^-), with or without 60 mM NaCl.

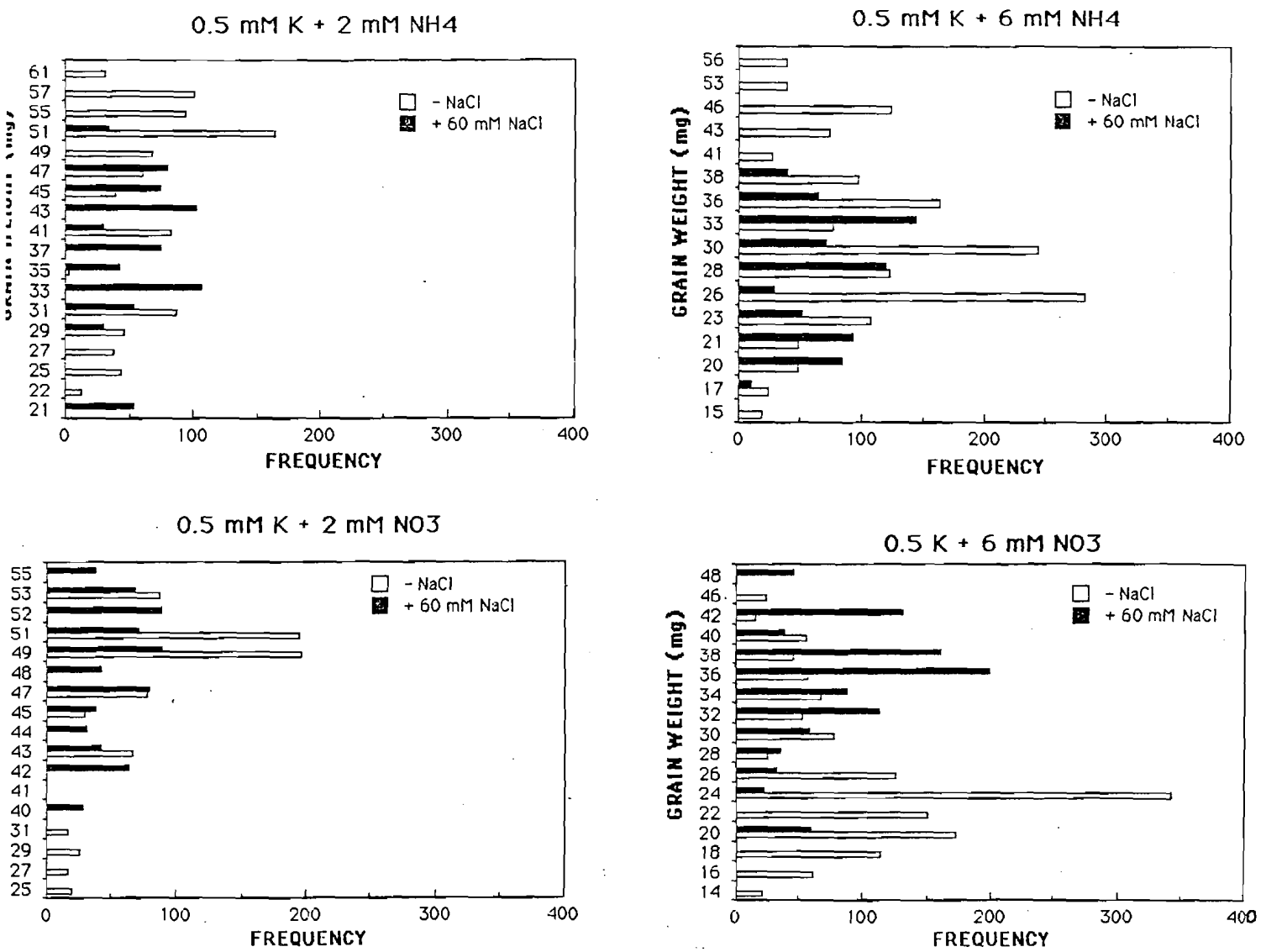

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Figure 11b: Distribution of grain weight and frequency of wheat plants grown in 5 mM K^+ and 6 mM nitrogen (NH_4^+ or NO_3^-), with or without 60 mM NaCl.

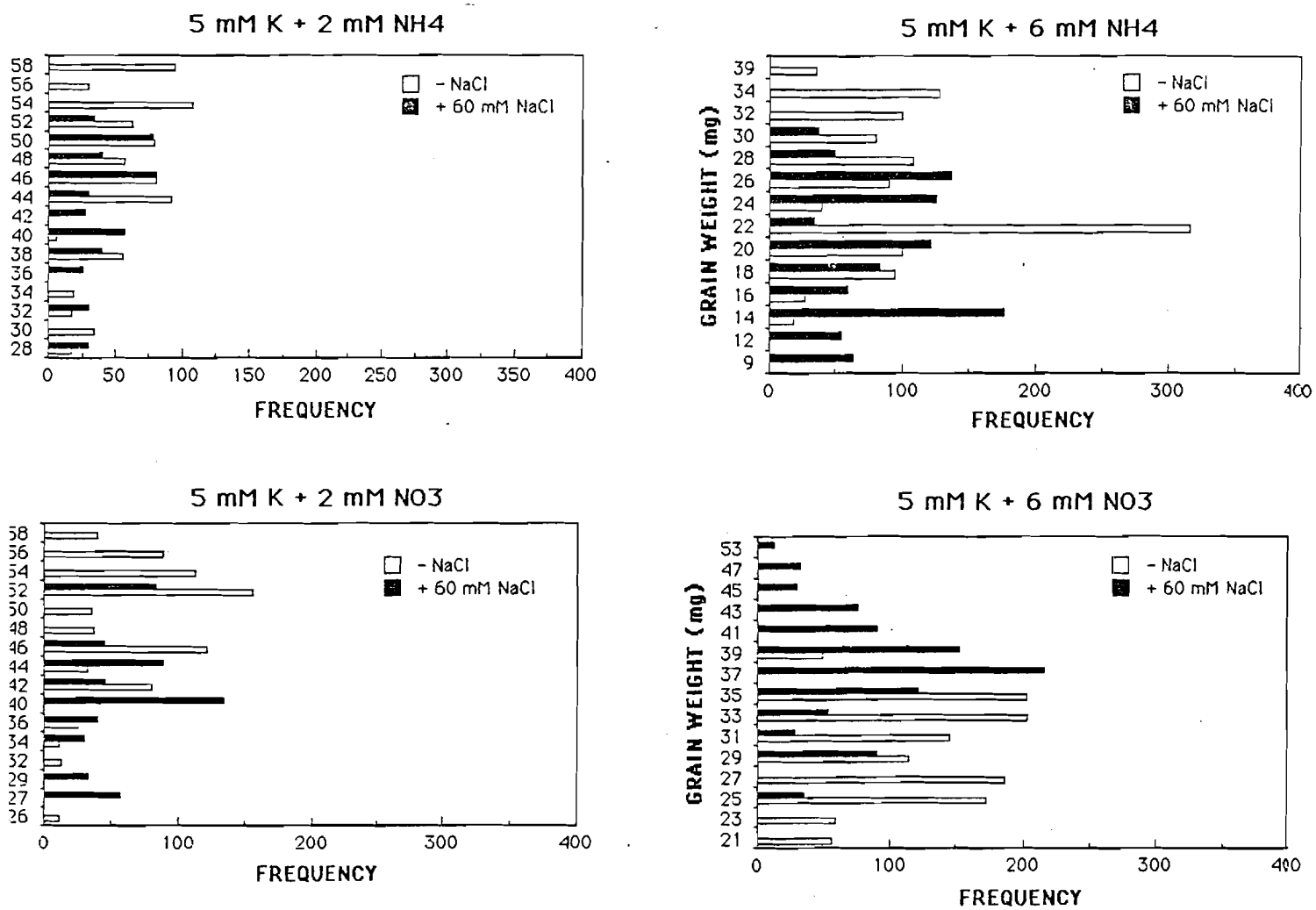

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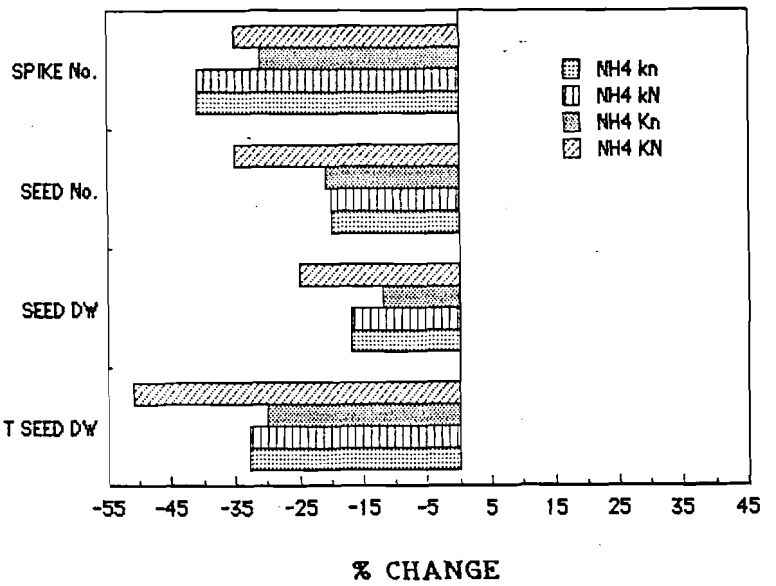
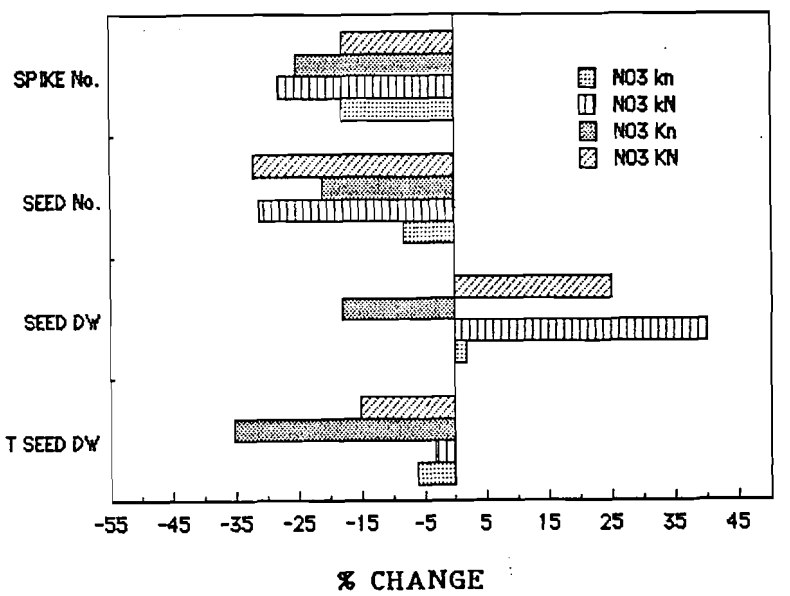
Figure 12: The relative effect of 60 mM NaCl on different parameters of the reproductive growth of wheat fed different concentrations of nitrogen and potassium. Nitrogen was applied either as ammonium or as nitrate ions.



AMMONIUM



NITRATE

(3) MAIZE

Introduction

This was a preliminary field experiment to study characteristics of maize production for seeds on sand dunes and irrigated with brackish water. Maize seemed an interesting crop due to its extreme sensitivity to salinity. We also studied the response of maize irrigated with brackish water to fertilization with different inorganic forms of nitrogen.

Materials and methods

The experimental site was located at the Ramat Negev Regional Experimantal Station close to Ashalim. The following treatments were studied:

Salinity level: 1 dS/m (tap water) and 6.5 dS/m (local brackish water well)
Nitrogen levels in irrigation water: 2 and 6 mM.
Nitrogen forms: NH_4^+, NO_3^- and NH_4NO_3.

Fertilizer was introduced into the irrigation drip system as concentrated solutions of $(NH_4)_2SO_4$, $Ca(NO_3)_2$ and NH_4NO_3 using and hydraulic fertilizer pump. KCl was added to all treatments to obtain a final concentration of 1.5 mM. Posphoric acid, Fe-EDDHA and microelements were added in equal amounts to all treatments.

Each experimental plot consisted of 4 rows, each of them 10 m long, at 1 m distance from each other. The experiment was carried out with 6 blocks, half of each of them irrigated with tap water, the other half with brackish water. Plants were irrigated daily with 2 l/h drippers, one every 0.5 m. The amount of water supplied to all treatments was equal, as determined by an evaporation pan (type A), at changing rates as recommended by the Agronomical Service for the Negev area.

Maize was sown on June 6, 1986, and was irrigated with both types of water for 10 days until after germination. Tap water was supplied to all treatments for the following 10 days. Both types of water were then used for irrigation until the end of the irrigation period. Samples of water were taken throughout the entire irrigation period to determine salinity, ammonium, nitrate and K^+.

About two month later (August 6, 1986), when the cobs started to develop, samples of leaves of every treatment were collected. Leaf samples were washed with detergent, 1 mM HCl and destilled water and then oven-dried at 60 C for two days. The dry matter was then ground, extracted and analyzed.

On September 18, 1986, irrigation was stopped. After the plants dried in the field, corn cobs were collected from 5 running meters from the center of each treatment. Cobs were peeled and weighed and then seeds were separated.

Results

Analysis of variants of the experimental parameters tested are summarized in Table 15. Statistical analysis was based on split-plots. The principal plots contained the salinity treatments, while secondary plots carried treatments based on quantity and form of nitrogen supplied. Most of the parameters tested showed significant effects of salinity and nitrogen concentration in the irrigation water. The type of nitrogen fertilizer (ammonium or nitrate) affected only P and Cl content of plants.

Table 15: Analysis of variance of various measured parameters of maize grown in the field with different water salinities (Salt), nitrogen concentrations (N-conc) and NH_4^+/NO_3^- ratio (N-form)

SOURCE	DEGREES FREEDOM	F-values						
		KERNELS	GRAINS	N	P	K	Na	Cl
Blocks	5	0.33	0.21	1.2	0.27	1.56	0.04	0.19
Salt	1	27.65*	24.16*	13.40*	0.05	9.93^	20.76*	4.6
Error 1	5							
N-conc (NC)	1	34.91•	30.64•	200.46•	31.59•	0.41	5.74^	82.98•
N-form (NF)	2	0.95	0.95	0.09	4.25^	0.71	1.24	6.10*
NC X NF	2	0.54	1.51	4.21^	2.1	0.69	7.64^	2.34
NC X Salt	1	5.23^	7.73^	21.55•	14.64•	0.39	0.13	9.92*
NF X Salt	2	0.75	1.16	7.47^	1.03	0.05	0.13	7.49*
Error 2	52							

^,*,• - 0.95, 0.99 and 0.999 level of significance, respectively

Irrigation with saline water, as compared to tap water, reduced to a large extent the yield of maize (Table 16). Enhanced nitrogen fertilization increased yields only to treatments irrigated with tap water. Additional nitrogen fertilization had only a marginal (non-significant) effect in treatments with the higher salinity.

Table 16: Yield of kernels and grains of maize grown in the field in two water salinities at different concentrations and NH_4^+/NO_3^- ratios.

EC25	Nitrogen	N-form	Yield	
			Kernels	Grains
dS/m	mM		<----Kg/Ha----->	
1.2	2	NH4	8887bl	7510bc
		NH4NO3	8397b	7030c
		NO3	9007b	7665bc
	6	NH4	12085a	10723a
		NH4NO3	12458a	10922a
		NO3	11677a	10215ab
6.5	2	NH4	1765cd	1222d
		NH4NO3	3950cd	3135d
		NO3	1512d	1050d
	6	NH4	4400c	3495d
		NH4NO3	3665cd	2872d
		NO3	3552cd	2853d

Different letters represent statistical groups (P<0.05) according to Duncan's New Multiple Range Teste

Use of ammonium or ammonium-nitrate as the source of nitrogen increased yields as compared to the effect of nitrogen fertilization as nitrate. Nitrogen content of the plants generally increased with added nitrogen fertilizer (Table 17) and decreased with increased salinity in the irrigation water. The increase of Na^+ in the leaves at low levels of nitrogen fertilization, is much higher than at high levels of nitrogen fertilization.

Table 17: Mineral content of maize leaves

EC25	Nitrogen	N-form	N	P	K	Na	Cl
dS/m	mM		<----------mmoles/Kg dw---------->				
1.2	2	NH4	1424bc1	91.7e	435cd	16.5e	84.1cd
		NH4NO3	1335cd	91.9e	466b-d	17.6e	80.4d
		NO3	1419bc	93.1e	431cd	20.0d	84.7cd
	6	NH4	1826a	129.5ab	425d	92.7cd	92.7cd
		NH4NO3	1716a	137.1a	432cd	121.8b	121.8b
		NO3	1716a	108.2b-e	473a-d	103.1b-d	103.1b-d
6.5	2	NH4	1198e	93.7de	488a-d	94.3cd	94.3cd
		NH4NO3	1403bc	116.7a-d	533a	103.5b-d	103.5b-d
		NO3	1278de	100.7c-e	531a	86.6cd	86.6cd
	6	NH4	1482b	111.8b-e	504a-d	160.6a	160.6a
		NH4NO3	1437bc	122.7a-c	498ab	147.2a	147.2a
		NO3	1507b	107.8b-e	482a-c	111.8bc	111.8bc

Different letters represent statistical groups ($P<0.05$) according to Duncan's New Multiple Range Teste

We conclude that the sensitivity of maize to salinity is so large, that this crop may be suffering from salt-induced damages beyond the inhibition of nutrient uptake. Therefore, we adopted the line-source technique for the summer of 1987 which will provide the entire gradient between 1.2 to 6.5 dS m^{-1}, and from 0 to 10 mM nitrogen (applied as 5 mM NH_4NO_3. This experiment is presently carried out in the field and its results will be included in our next report.

Research in the Philippines

(4) Field experiment

The studies to be carried out in the Pilippines consist of field experiments and greenhouse experiments using a local variety of peanut and rice as test plants. The field experiment will be conducted at the experimental farm of the National Institute of Science and Technology located in Molino, Bacoor, Cavite province. The greenhouse experiment will be set up at the Institute of Biological Sciences

4a - Experimental site

Site description

The field experiment will be set up at the NIST farm which is about 65 km from UPLB. The topography of the farm is generally flat with a slope of 0-2%. The farm is presently cultivated for vegetable crops. The soil is heavy clay with a pH of about 6 - 6.5. Soil analysis is not available but will be completed before planting.

Land preparation

Although the target date of planting will be January 1988, to coincide with the start of the dry season, the field will be thoroughly cultivated and prepared for planting before this time. To keep the soil loose, a periodig passage of a light tractor with disc plow will be required. On the day of planting, furrows will be drawn in the field by passing through a tractor.

4b - Irrigation equipment

At the onset of the dry season in January the field will be furrowed at a distance of 75 cm between furrows. This will be followed with the installation of drip irrigation lines and laterals with drippers at 50 cm intervals or one dripper between two hills. An early trial run will be carried out to determine whether all systems performs correctly.

4c - Experimental plan

Experimental treatment and layout

A 3 x 4 factorial experiment consisting of 3 levels of salinity and 4 levels of potassium nitrate fertilizer will be laid out in a split plot design in which salinity is the main plot and fertilizer is the sub-plot. The design is seen in figure 1. The levels of salinity will be 2, 4 and 8 mmhos/cm electrical conductivity. KNO_3 levels will be 0, 75, 150 and 300 kg/ha. Each plot will be labeled properly for proper identification.

Planting

A local variety of peanut will be planted at the rate of 2 seeds per hill and at a distance of 25 cm between hills. With distance of planting two hills will be irrigated by one dripper with a discharge rate of 4 l/h.

Treatment application

Throughout the growing period peanut will be irrigated with saline water containing NaCl at various concentrations. The rate of irrigation will be determined by the standard pan evaporation rate using a certain factor. For this purpose, a standard USDA pan evaporimeter and collecting raingauge will be installed at the farm.

Fertilizer in the form of KNO_3 will be applied in solution together with irrigation water throughout the vegetative stage. The timing of irrigation and fertilizer application will be programmed with the supplier of drip irrigation equipment (Netafim, Israel).

Measuring parameters

Growth rate
Yield and yield components
Photosynthetic rate (leaf and canopy)
Tissue analysis (shoot and root) for N, P, K, Na, Ca, Mg, Cl.
Soil analysis before planting: total N, extractable P, K, Na, Ca, Mg, Cl.
Soil analysis just before harvest of samples taken from various depth: total N, extractable P, K, Na, Ca, Mg, Cl.
Soil moisture at various depth
Estimation of costs and returns

(5) Greenhouse experiments

The purpose of the greenhouse experiment is to find the response of other crops like rice plant with varying tolerance to salinity stress. Salt tolerant and sensitive rice varieties will be grown in clay pots containing soil of heavy texture and irrigated with saline water. Growth, photosynthetic rate and leaf water potential will be monitored during the growing period and at harvest, the yield and yield components will be determined.

Peanut will also be grown in clay pots to study in detail the morphological changes that occur in the plant when grown in saline conditions.

5a - Response of rice (IR-28) and peanut (UPL Pn2) to varying levels of water salinity and potassium nitrate.
(Jose F. Reano, Dr. Bonifacio Mercado and Dr. Enrique P. Pacardo)

Pot experiments were conducted to study the growth responses and mineral composition of rice (var. IR-28) and peanut (var. UPL Pn2) at varying levels of water salinity and KNO_3. Different dilutions of sea water (EC 32 mmhos/cm) and tap water (EC 0.6 mmhos/cm) were prepared to get the desired salinity levels of 0.6, 5.6 and 10.6 mmhos/cm. The saline water previously mixed with KNO_3 with various concentrations of 0, 60 and 600 ppm was applied as irrigation water starting from 6 weeks up to 11 weeks after seed sowing.

Singnificant interaction between water salinity and KNO_3 was observed in almost all growth parameters such as shoot length, root length, dry and fresh weights of shoots and roots of rice and peanuts. Similar observations were also noted on the different mineral composition such as percentage total nitrogen, calcium, potassium, sodium, chloride and magnedium of shoots and roots of both crops.

Correlations analysis showed that increasing salinity level was inversely related with shoot length, fresh and dry weights of shoot and roots and % total N in shoots. These results were consistently obtained in both crops except for root length in peanut which was found to be positively correlated with salinity. Only percentage chloride in rice shoot was observed to be negatively correlated with KNO_3. On the other hand, significant positive correlation was obtained on % Cl, % Na, % Total N and % Mg in shoots of both crops.

The results generally revealed that rice is relatively more tolerant than peanut. This observation was substantiated by Na/K and Na/Ca ratios of shoot and roots of both crops. Furthermore, data also indicate the apparently favorable effects of KNO_3 on plants growing in saline environment. In these experiments, 60 ppm and 600 ppm KNO_3 were seemingly sufficient to counteract the toxic effect of water salinities at 5.6 and 10.6 mmhos/cm, respectively.

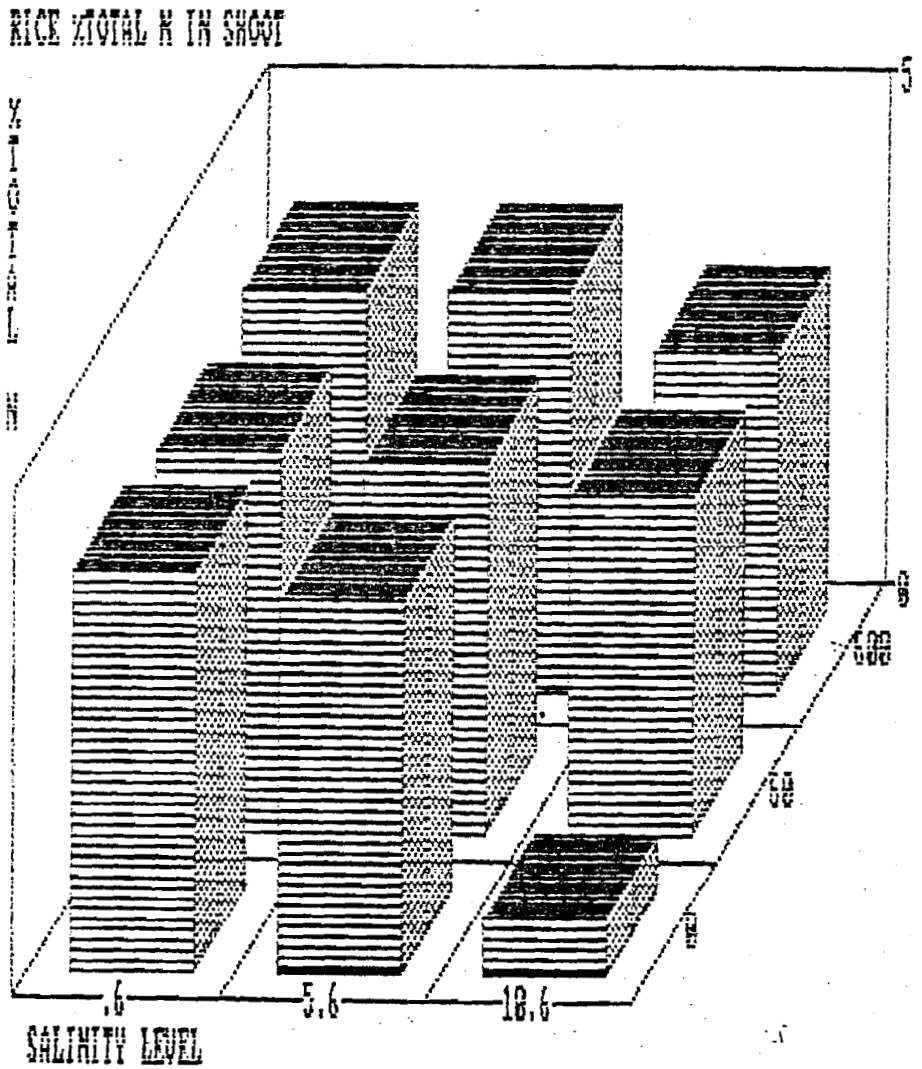


Figure 13: % total N in shoots of rice as affected by varying levels of salinity and KNO_3.

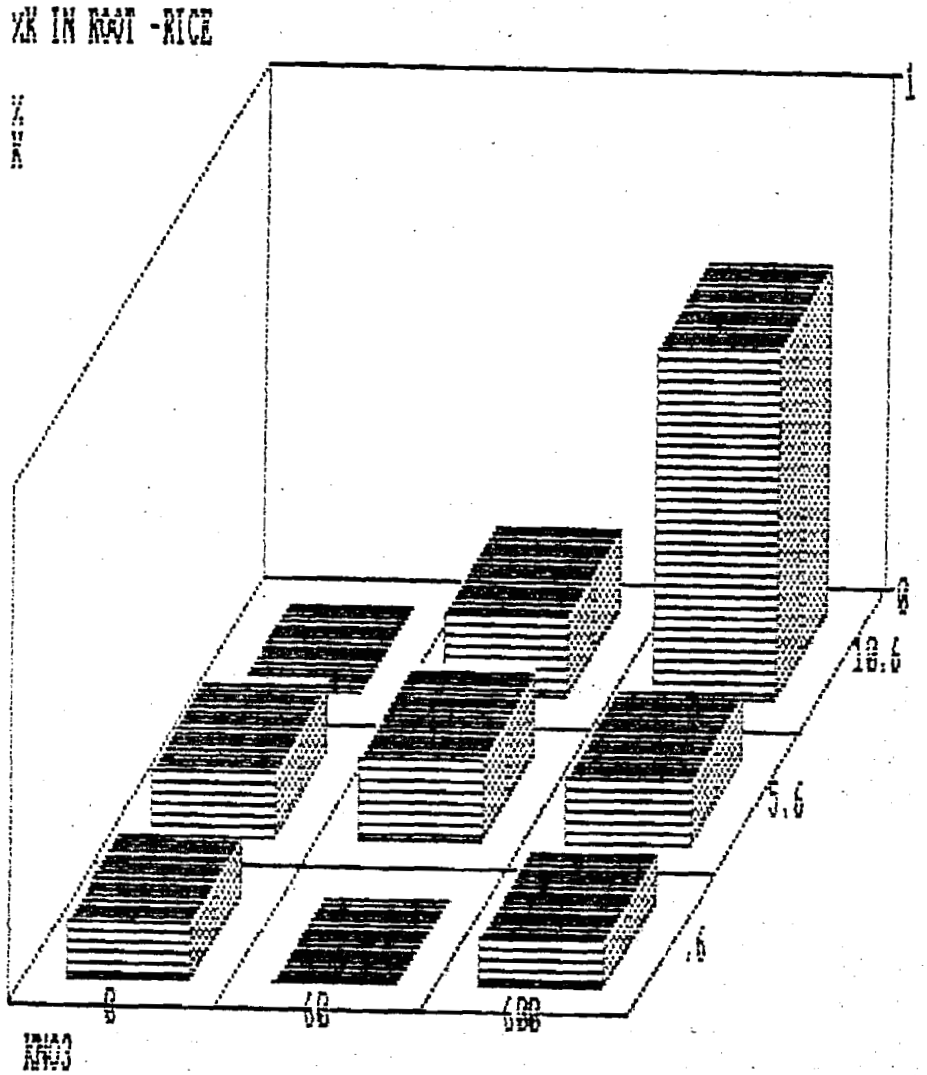


Figure 14: % K in roots of rice as affected by varying levels of salinity and KNO_3.

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CONCLUSIONS

The experiments described in this report support the hypothesis that increased supply of potassium and nitrogen fertilizers may, under defined conditions, enhance the productivity of agricultural crops irrigated with saline water (4 - 6 dS m^{-1}).

Alleviation of salinity damage to crops by added fertilizer is possible up to a certain limit (Fig. 15). Plants can easily adapt to osmotic stresses caused by the equivalent of 40 to 60 mM NaCl. The inhibition of growth of salt-sensitive plants under these conditions is due, to a large extent, to salt-induced difficulties of the plant to obtain the mineral nutrients it requires for its optimal development. Enhanced fertilization, under these conditions may, therefore, allow salt-sensitive plants to grow well and produce adequate crops.

Above these levels of salinity, other stress conditions become prevalent causing metabolic adjustments which result in growth stunting or even death of the plants. Under these conditions, added fertilizer is not only useless, but may even agravate salinity damage.

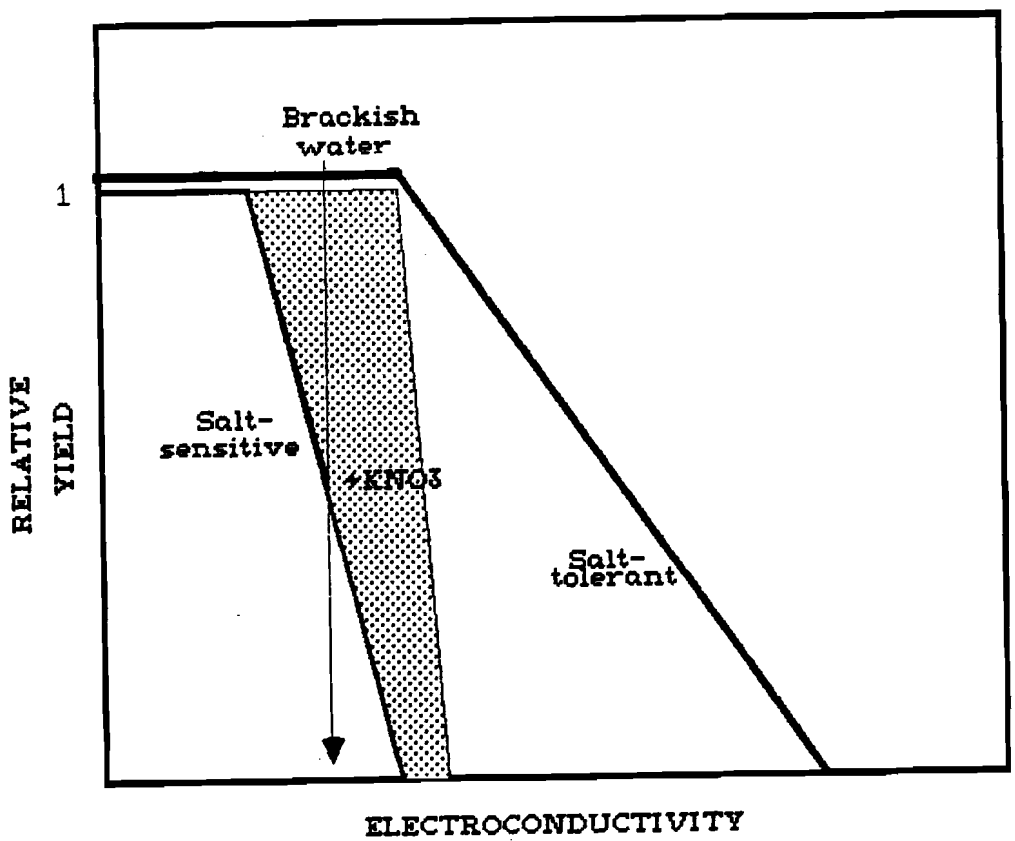

Figure 15: The limits of fertilizer enhancement of salt-tolerance of agricultural crops.

Enhanced selective fertilization may consequently increase salt-tolerance of agricultural crops exposed to electrocunductivities of up to 8 dS m^{-1} but not above it. Enhanced fertilization may be an adequate answer for allowing the use of this water in areas where water resources of better quality are not available.

Several environmental and genetic factors may affect the positive response of crops irrigated with saline water to enhanced fertilization:

(1) Salinity damage and type of inorganic nitrogen fertilization

It appears from our experiments with wheat that plants under saline conditions respond better to ammonium during the vegetative growth stage and to nitrate during the reproductive stage. The response to ammonium-N depends on the level of applied ammonium. The inorganic form of nitrogen enters the root system, by passive diffusion. If not immediately assimilated into organic nitrogen compounds (amino acids and amides), ammonium ions may be toxic to the plant cells. Assimilation of ammonium ions is essentially an event which takes place in the roots, followed by the entrance of the ions into the plant cells and depending on an adequate supply of carbohydrates, imported to the roots from the photosynthesizing shoot.

Plants seems to prefer ammonium-N during the vegetative growth and nitrate-N during the reproductive stage. We are presently carrying out a greenhouse experiment in which wheat plants irrigated with saline water are grown in ammonium-N and transferred to nitrate-N at different stages of their development. This experiment will tell us at which stage of plant development preference changes from ammonium to nitrate nitrogen take place.

(2) Grain filling in cereals as affected by salinity and nitrate

The effect of nitrate on grain filling of wheat irrigated with saline water (60 mM NaCl) is an enhancement of grain size compensating for the decrease in grain number. The final result is that salinity causes only a slight effect on the dry mass of grain produced by plants grown in the presence of nitrate, but not of ammonium. The reasons for the compensation mechanism which leads to production of grains larger than usual should be studied further. According to these results, nitrate seems to be an essential element to withstand salinity inhibition of grain filling.

We will therefore follow the formation of proteins during vegetative growth by gell electrophoresis, as well as the hydrolysis and mobilization of these protein-nitrogen during the reproductive stage. These studies will be carried out in parallel with wheat and rice (see bellow) grown in ammonium and nitrate-nitrogen, with and without 60 mM NaCl in the nutrient solutions supplied to the plants.

(3) Salinity damage as affected by pH of nutrient media

The contradictory effects of KNO_3 on the alleviation of salinity damage of plants grown in hydroponics and in soil should be further studied. One of the explanations for the discrepancies observed is that plants grown in KNO_3 cause an increase of pH around the root, due to a preferential uptake of NO_3^- over K^+. If this is the case, than liquid nutrient media may be a more efficient buffer than soils, preventing alkaline pH conditions around the plant roots. Soils cannot prevent alalinization of the root tip area as the plants absorbs an excess of nitrate over potassium ions.

We will grow plants under hydroponics conditions in 60 mM NaCl, with either ammonium or nitrate nitrogen under different pH level. This experiment will enable us to study the sensitivity of these plants to salinity and nitrogen sources under different pH conditions.

(4) Effect of salinity on flowering

Our experiments show that adding nitrogen to peanut plants irrigated with saline water allows these plants to develop normal (even enhanced) shoots. The sensitivity of gynophores to salt accumulation in the soil may be overcome by supplying water in a form different than trickle irrigation. We consider the effect of salinity on the number of flowers produced by peanut shoots to be an interesting new characteristic worth taking into consideration. This response of peanut plants may be the basis for doubling peanut production if conditions will be insured for allowing development of the increased number of gynophores induced by salinity.

Two experiments have been planned in Israel to persue this idea: (a) a greenhouse experiment for studying optimal irrigation conditions to allow gynophore development in plants irrigated with brackish water; (b) a field experiment for testing the timing of irrigation with brackish and non-saline water as well as several irrigation methods to minimize salt accumulation in the upper layer of soil at the time of gynophore development.

(5) Rice production as affected by salinity

Rice seems to be a plant which responds very well to KNO_3 under saline conditions. A full report on the results of these experiments as conducted by J. Reano, B. Mercado and E. Pacardo in Los Banos (Philippines) will be given in our next joint report.

Jose Reano is already growing rice in Sede Boqer (Israel) where he will study the effect of salinity and different nitrogen sources on the capacity of these plants to transport assimilates from the leaves to the seeds. J. Reano will also study the mobilization of leaf organic nitrogen (mainly proteins) for filling grains as affected by salinity and nitrogen fertilizers.

(6) Maize production under saline conditions

Preliminary studies on the effects of salinity and nitrogen on the growth of maize have shown that the extreme sensitivity of the variety used may be beyond the limits of fertilizer alleviation (see Fig. 15). The use of trickle irrigation in sand may be inadequate since the narrow wetting zone near the emiters tends to generate high concentrations of salt close to the plants. Further work will be carried out under field conditions using different irrigation methods. A method to create gradients of salinity and nitrogen fertilizer under field conditions has been developed for this purpose (details in next report).