Use of saline irrigation water for production of some legumes and tuber plants

Gadalla A.M., Hamdy A., Galal Y.G.M.

in

Lamaddalena N. (ed.), Bogliotti C. (ed.), Todorovic M. (ed.), Scardigno A. (ed.).
Water saving in Mediterranean agriculture and future research needs [Vol. 2]

Bari : CIHEAM
Options Méditerranéennes : Série B. Etudes et Recherches; n. 56 Vol.II

2007
pages 85-97

To cite this article / Pour citer cet article

Gadalla A.M., Hamdy A., Galal Y.G.M. **Use of saline irrigation water for production of some legumes and tuber plants.** In : Lamaddalena N. (ed.), Bogliotti C. (ed.), Todorovic M. (ed.), Scardigno A. (ed.). *Water saving in Mediterranean agriculture and future research needs [Vol. 2].* Bari : CIHEAM, 2007. p. 85-97 (Options Méditerranéennes : Série B. Etudes et Recherches; n. 56 Vol.II)

USE OF SALINE IRRIGATION WATER FOR PRODUCTION OF SOME LEGUMES AND TUBER PLANTS

A. M. Gadalla ** A. Hamdy *, and Y. G. M. Galal **
* IAM-Bari, Italy
**Atomic Energy Authority, Nuclear Research Center, Soil and Water Research Department,
Abou-Zaabl, 13759, EGYPT.

SUMMARY - Effect of irrigation water salinity on growth and production of some legumes, i.e. faba bean, chickpea, and lentil as well as tuber plants like sugar beet and potatoes was investigated in lysimeter system under green house controlled conditions using drip irrigation system. Chickpea was frequently affected by saline water. Number of pods was decreased gradually with increasing water salinity levels. High levels of salinity negatively affected shoot, root dry matter, seed yield and N accumulated in shoots and roots. A slight difference in seed N was noticed between fresh water and 9 dS/m treatments. Results showed that high levels of salinity negatively affected seed yield and N accumulated in tissue of faba bean. Similar trend was noticed with dry matter of lentil. While, shoot-N was increased at 6 and 9 dS/m. Both leguminous crops were mainly dependent on N_2 fixation as an important source of nitrogen nutrition. Under adverse conditions of salinity, the plants gained some of their N requirements from the other two N sources (Ndff and Ndfs). Application of the suitable *Rhizobium* bacteria strains could be beneficial for both the plant growth and soil fertility via N_2 fixation. Sugar percentage in sugar beet tubers was increased with increasing saline irrigation water under different nitrogen strategies. It was slightly increased when N applied at full dose than the splitting one. Addition 75% of water requirements also resulted in high percentage of sugar at all levels of saline irrigation water either N added full dose or splitting doses. Exposure of two varieties of potato to different water salinity levels indicated that total yield, on the base of fresh weight, of Spunta or Nicola tubers was slightly increased by increasing water salinity level up to 6 dS/m. In general, the overall means showed the superiority of Nicola variety over Spunta variety. Also, addition of organic compost in different rates has some significant effects on starch content in tubers. In this respect, gradual increase of tuber starch with increasing salinity levels was noticed with addition of 2.6 kg/m^2 organic matter. In general, Spunta variety showed some superiority in tuber starch over those of Nicola variety tuber.

Key words: Drip irrigation, Legumes, N management, Organic amendment, Saline water, Tubers, Water regime, Yield

INTRODUCTION

Salinity is currently one of the most severe abiotic factors limiting agricultural production. In addition, water demand was increased due to increasing the population and improvement of living standards (Paranychianakisa and Chartzoulakis, 2004). In regions affected by water scarcity such as the Mediterranean basin, water supplies are already degraded, or subjected to degradation processes, which worsen the shortage of water (Chartzoulakis, et al., 2001; Attard, et al., 1996). Therefore, attention had been paid on reusing the low quality water resources in irrigation. In this respect, types of salinity, categories of salt-affected soils, water quality and water classification has been excellently reviewed by Aly (2004).

At high substrate salinity, growth depression may originate from inhibited nutrient uptake, transport and utilization in the plant (Lauchli and Epstein, 1990). Legumes have the capacity to derive a considerable proportion of their nitrogen requirement from the atmosphere through symbiosis with *Rhizobium*. The amount of N_2-fixed by legumes-rhizobia symbiosis is greatly influenced by many environmental factors such as temperature, water, soil pH, oxygen content or soil nutrient status (Kvien and Ham, 1985). Saline habitats are N-poor, therefore the N input is very important in these environments (Zahran, 1997). One of the sources of N input in saline soils is N_2-fixation (Whitting and Morris, 1986). Higher rates of N_2-fixation in saline environment compared to non-saline and agricultural soils were reported (Wollenweber and Zechmeister-Boltenstern, 1989). The low oxygen tension in saline soils may favour the process of N_2-fixation, but the diffusion of gases may be impaired at a higher density and water regime in saline soil, an effect that might reduce N_2-fixation (Rice and Paul 1971).

Sugar beets are salt resistance owing to osmotic adjustment. Physiological adjustments enable the plant in a saline environment to maintain the turgor potential at a similar level as under non-saline conditions. Moisture stress reduced the rate of sucrose concentration to a greater extent in the low-N plants than in the high-N plants (Loomis and Jr. Worker, 1963). Water stress several weeks before harvest of fall-planted beets reduced root yields but increased sucrose percentage. Limited moisture stress to increase sucrose concentration without reducing gross sugar yield can be a profitable practice.

Nitrogen (N) management plays an important role in sugar beet production. However, in sugar beets, managing N for a high-yielding and high-quality crop can be difficult. Sugar beet growers can further improve the efficiency of N applications by applying N in multiple applications.

Potato (*Solanum tuberosum L.*) is one of the most important vegetable crops in Egypt, which lie on the head of Egyptian exports menu and one of the national income resources. In the past, it was believed that potato could only be planted in loam soil cultivated, but recent studies showed that there is a possibility of potato production under sandy soil conditions, with high tubers quality (Abou-Hussein, 1995). Regarding salinity tolerance of potatoes grown in sandy soils, Gong *et al.* (1996) indicated that irrigating potato plants once a day with saline water reduced plant growth as compared with 3 or 6 irrigations a day.

This context mainly focused on the effect of irrigation water salinity on growth and nutritional factors and physiological impacts that limiting the development of different leguminous and tuber crops.

MATERIALS AND METHODS

Different crops either leguminous, i.e. chickpea, faba bean and lentil or tubers such as sugar beet or potatoes were cultivated under greenhouse conditions. PVC Lysemeter with volume 0.103 m^3 (diameter 0.54 m and depth 0.45 m) was used.

A clay textured soil with pH, 8.11; EC, 0.542 dS/m; OM, 2.67%; available water 9.7%, field capacity, 29.7% was used.

Experimental layout

Leguminous crops

Chickpea seeds (*Cicer aeritinum* cv. Giza 1) were planted and treatments were randomly arranged in 16 containers, with additional batch of treatments were carried out with wheat plant (16 containers), used as a reference crop for quantifying the potential of N_2-fixation through the application of isotopic dilution technique. Four salinity levels of irrigation water were used in the experiment namely 1.0 dS/m (freshwater as a control) and three levels of saline water 3, 6 and 9 dS/m. Peat-based inocula of *Rhizobium leguminosarum* biovar vicea, ICARDA 36 was used for inoculation of the tested crop. The inoculum has $8x10^9$ cells g^{-1} peat. ^{15}N-labelled ammonium sulfate, $(^{15}NH_4)_2SO_4$ 5 % atom excess, as N-fertilizer was applied at rate of 20 kg N ha^{-1}.

Similarly, the seeds of faba bean (*Vicia faba* cv. Giza 388) and Lentil (*Lens culinaris* cv. Giza 15) were cultivated under the abovementioned 4 levels of saline water. ^{15}N-labelled ammonium sulfate, $(^{15}NH_4)_2SO_4$ 10 % atom excess, as N-fertilizer was applied at rate of 20 kg N ha^{-1}. Wheat crop (*Triticum aestivum* L. Sakha 69) was used as a reference crop for quantifying N derived from air by the two leguminous crops. This reference crop was fertilized with 100 kg N as $(^{15}NH_4)_2SO_4$ (1% ^{15}N a.e.). Peat-based inocula of *Rhizobium leguminosarum* biovar vicea, ARC 207 F (Faba bean) and

ARC 203 L (Lentil) were used for inoculation of the tested crops. The inoculum has 8 x 10^{-9} cells g^{-1} peat.

Tuber crops

- Sugar beet

An experiment was conducted under greenhouse conditions. The set-up consists of 64 lysimeters (4 saline irrigation water treatments, 2 water regimes, i.e. W_I=100% and W_{II}=75% from field capacity, 2 nitrogen, i.e. N_I=one dose and N_{II}= split doses, and 4 replicates).

Sugar Beet (*Beta vulgaris L.*), Variety GIADA, provided by the International Agronomic Mediterranean Institute, Valenzano, Bari – Italy, from KWS Company, was used as indicator plant. Four qualities of irrigation water were used in the experiment: 0.98 dS/m (Fresh water as a control), and three saline irrigation water treatments 4, 8 and 12 dS/m. Labeled $(^{15}NH_4)_2SO_4$ (5 % a.e.) was added to all lysimeters of Sugar Beet crop at rate of 150 kg N ha^{-1}. Nitrogen fertilizer was divided into two treatments, the first applied as single dose, 112.5 Kg N/ha, while the second treatment is split into two equal doses of 56.25 Kg N/ha.

- Potatoes

The set-up consists of 90 Lysemeter (3 saline irrigation water treatments, 3 organic matter, 2 varieties of potatoes (Spunta and Nicola), and 5 replicates. The saline water was prepared by mixing fresh water (0.91dS/m) with seawater (46dS/m) at certain ratios. The electrical conductivity (EC) values of saline water were 0.91dS/m (fresh water control), 3 and 6 dS/m.

Three rates of organic matter have been used, OM_1, OM_2 and OM_3 with quantities of 0, 600 and 1200g equivalent to 0, 2.6 and 5.2 kg/m^2, respectively. The chemical analysis of organic matter is: Organic C, 35%; Organic N, 1,2 %; C/N ratio, 29; HA+FA, 8%; Zinc, 80 ppm; salinity, 20 dS/m.

Potato *(Solanum tuberosum)*, with two varieties (Spunta & Nicola), provided by the International Agronomic Mediterranean Institute, Valenzano, Bari – Italy, from HZPC Company was cultivated. The cultivated varieties were fertilized with nitrogen which applied at a rate of 200 kg N /ha as ordinary urea (NH_2CONH_2) and labeled urea (10% a.e.).

All leguminous and tuber crops were also fertilized with the recommended doses of phosphorus and potassium fertilizers. The standard methods were used for soil and plant analyses according to Page et al., (1982). Isotope dilution concept was applied for quantification of different portions of nitrogen used by plants (Hardarson et al., 1991).

Statistical analysis

All data were subjected to ANOVA analysis followed by Duncan's multiple range test (DMRT) according to SAS software program (1987).

RESULTS AND DISCUSSION

Legume crops

Chickpea

Yield and growth components of chickpea as influenced by salt stress are listed in *Table 1.* It is clear that the number of pods decreased gradually with increasing salinity of irrigation water. Raising salinity level resulted in a relative reduction in the number of pods by 10 %, 24% and 31% for 3, 6 and 9 dS/m, respectively. Shoot and root dry matter yield showed a remarkable decrease with increasing salinity level up to 9 dS/m as compared to the fresh water control, but it doesn’t vary so much. Concerning the seed yield, the data show that the total seed yield sharply decreased with increasing salinity levels. For instance, the relative reduction was by 67% caused by rising up to 3 dS/m. The highest reduction was noticed with the high EC unit of 9 dS/m, where 89% of the total seed yield of fresh water treatment was reduced. A similar trend, but to a lesser extent, was recorded with the weight of 100-seed yield. Summation of dry weight (total seed yield + shoot + root) of chickpea plants indicates a gradual reduction with gradual increase in water salinity, by about 36%, 45% and 56% for 3, 6 and 9 dS/m. From the above-mentioned results, we can conclude that the growth and yield components of chickpea plants were adversely affected by salinity stress.

Table 1. Number of pods and dry weight of different parts of chickpea plants as affected by the salinity level of irrigation water

Salinity (EC)	No. Of pods		Dry weight (g/Li)				D.W. Sum.	R.D. (%)
	No./Li	R.D. (%)	Seeds		Shoot	Root		
			Total	100 seed				
F.W	309 a	-	182 a	24.2 a	147.2 a	50.0 a	379.2	-
3 dS/m	277 b	10	59.8 b	21.4 a	142.8 a	41.8 ab	244.4	35.5
6 dS/m	236 c	24	35.2 c	9.8 b	136.4 a	35.6 b	207.2	45.4
9 dS/m	212 d	31	19.2 d	5.8 c	113.3 b	35.0 b	167.5	55.8
Average	258.5	22	74.1	15.3	135.0	40.6	249.6	45.6

Means in the same column followed by the same letter are not significantly different at $P \geq 0.05$.

It is documented earlier (Singh and Saxena 1999) that salinity causes nutritional imbalances and restricts water availability to plants and causes physiological drought, adversely affecting seed yield. Saxena and Rewari (1992) found that the increases in salt concentration not only adversely affected the percentage germination of seeds of chickpea cultivars but also delayed their germination at lower levels of salinity, whereas at higher concentrations the percentage germination and radical length were reduced. The mean tolerance index (MTI) estimated for chickpea cultivars grown under EC of 2, 4, 6 and 8 dS/m (Field study, Dua, 1992) indicates that although the germination percentage in chickpea was not affected up to EC of 8 dS/m, sensitivity to salinity increased as the plants grew. Other authors have also reported that chickpea was less sensitive to salinity at germination than at later growth stages (Sharma et al., 1982). Considering seed yield, Dua (1992) verified that the adverse effect of salinity on seed yield/plant results mainly from a reduction in the number of pods/plant and the number of seeds/plant rather than in 100-seed weight. Thus, this indicated that plants were more sensitive to salinity at seed setting (flowering) than at the maturity stage.

Faba bean

As presented in *Table 2*, the salinity levels did not affect the number of pods of faba bean significantly. The data show a relative increase in the number of pods by 8% and 13% when saline water of 3 dS/m and 6 dS/m, respectively, was used. This result may give evidence that faba bean is somewhat tolerant to experimental salinity levels of water. At the higher level (EC 9 dS/m), the number of pods tended to decrease as compared to other salinity levels, but is still identical to that of the fresh water control. In other words, the production of pods is not affected by increasing salinity of irrigation water. In contrast, high EC units negatively affected the total and 100-seed yield. It means that high EC units affected faba bean. It seems also that faba bean plants is not affected by the lower level of salinity, whereas the seed yield was identical in fresh water and 3 dS/m. A similar trend was noticed with either shoot or root dry weight, indicating the inhibition of growth by increasing water salinity. The overall average of relative reduction of faba bean total dry weight (seeds + shoot + root) resulted in 15% and 22% reduction, as affected by 6 and 9 dS/m salinity, respectively.

Table 2. Number of pods and dry matter accumulated in different parts of faba bean plants irrigated with saline water

Salinity (EC)	No. of pods		Dry weight (g/Li)				D.W. Sum.	R.D. (%)
	No./Li	R.D. (%)	Seeds		Shoot	Root		
			Total	100 seed				
F.W	40 a	-	98.4 a	87.4	175.2 ab	44.2 a	317.8	-
3 dS/m	43 a	+ 8	98.9 a	86.4	183.5 a	38.2 a	320.6	+ 0.88
6 dS/m	45 a	+ 13	87.2 a	77.0	151.0 bc	31.0 a	269.2	- 15.3
9 dS/m	40 a	-	79.2 a	82.2	138.4 c	30.1 a	247.7	- 22.1
Average	42	7	90.9	83.3	162.0	35.9	288.8	- 12.2

Means in the same column followed by the same letter are not significantly different at $P \geq 0.05$.

In a greenhouse experiment, faba bean was found to be sensitive to the high level of NaCl (1000 ppm) were its dry weight of shoot and root was decreased (El-Fouly et al., 2001). Hajji et al., (2001) explained that growth inhibition of bean was associated with excess accumulation of Na$^+$ in leaves and attributed to depletion of K$^+$ and Ca^{++} in this organ. This suggests that Cl in the medium inhibited the adsorption of essential nutrients. Thus, it appears that these elements were limiting for growth in the presence of NaCl because salinity probably inhibited the transport of K$^+$ and Ca^{++} from roots to shoots. In short, under saline conditions, growth is primarily limited by osmotic not by excessive Na$^+$ accumulation. The results obtained in our study show that despite the particular/notable increase in the number of pods with increasing salinity level, the overall average of dry matter accumulation tended to decrease. This finding was confirmed by the reduction in life cycle long of faba bean plants with salinity level (Fig.1).

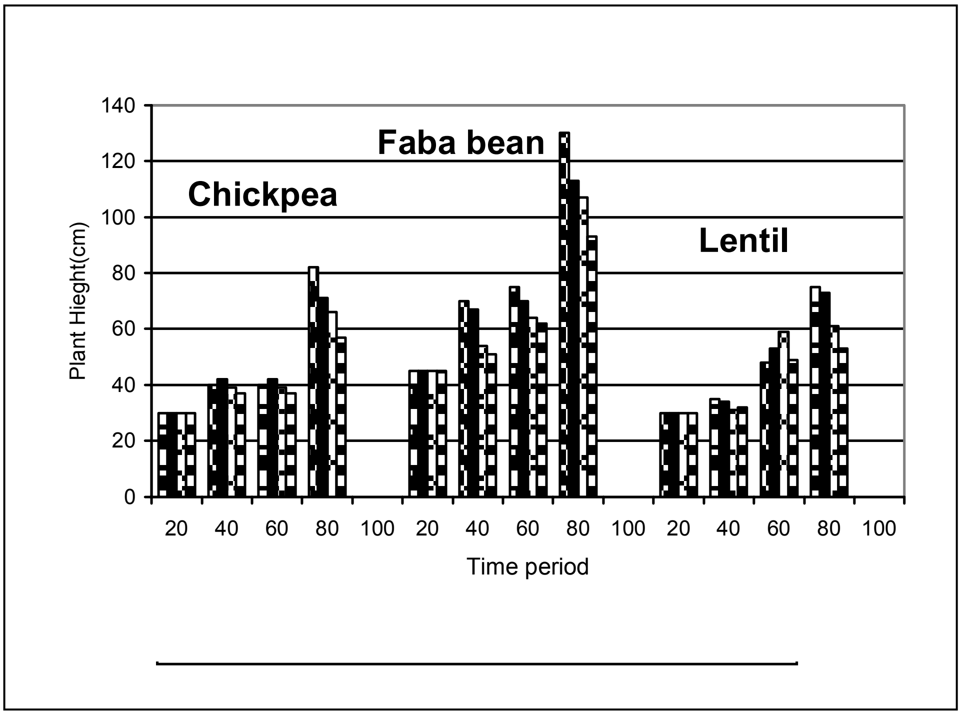

Fig. 1. Changes in plants height with times as affected by salinity levels of irrigation water

Lentil

Lentil is known to be sensitive or moderately tolerant to salt stress. The effect of EC units of irrigation water on growth components is reported in *Table 3*. Dry weight of pods revealed the sensitivity of lentil plants to salinity. The decline in pod dry weight was recorded even with the lowest salinity level (3 dS/m). The increase in salinity was followed by decreasing dry weight of pods by 21%, 41% and 54% for 3, 6 and 9 dS/m, respectively, as compared to the fresh water treatment. A similar trend was observed with shoot and root dry weight and seed yield of lentil plants. The summation of plant dry weight (shoot + root + seed) indicated a sharp decrease with increasing salinity up to 9 dS/m, by 32% from those recorded with fresh water treatment. Our results are in accordance with those reported by Yasin and Zahid (2000) who found that lentil crop was sensitive even at low level of salinity. Similarly, they found a linear decrease in shoot biomass, of 55% and 85%, respectively, at 4 and 8 dS/m salinity levels. Under greenhouse conditions, lentil dry weight was higher at 3.1 dS/m than at 4.3 and 6 dS/m salinity levels (IAEA, 1995). In a two-year field experiment conducted under Bangladesh conditions, lake water of an EC ranging from 1.5 to 4.5 dS/m was used for irrigation of lentil crop. The yield of lentil irrigated with lake saline water was found to be lower as compared to average national yield recorded under Bangladesh conditions (Rahman, IAEA 1995). Result of screening experiments of lentil conducted in greenhouse conditions showed that lentil varieties can with stand various levels of soil and/or water salinity from 0.63 to 6.0 dS/m (IAEA, 1995).

Table 3. Effect of changes in EC units on pod weight, dry matter accumulation in different lentil parts

Salinity (EC)	W. Of pods		Dry weight (g/Li)				D.W. Sum.	R.D. (%)
			Seeds					
	(g/Li)	R.D. (%)	Total	100 seed	Shoot	Root		
F.W	54 a	-	51.5 a	3.0 a	68.0 a	26.6 b	146.1	-
3 dS/m	43 b	-20.8	38.0 b	2.6 b	67.9 a	33.6 a	139.5	-4.5
6 dS/m	32 c	-41.4	24.4 c	2.0 c	68.1 a	17.2 c	109.7	-24.9
9 dS/m	25 d	-54.4	15.0 d	1.6 d	68.5 a	16.0 c	99.5	-31.9
Average	39	-38.9	32.2	2.3	68.1	23.4	123.7	-20.4

Means in the same column followed by the same letter are not significantly different at $P \geq 0.05$.

Portions of Nitrogen Derived from Different N-sources

Chickpea

In this part of the present study, we aimed at applying the stable heavy isotope of nitrogen N-15 to distinguish the different sources of nitrogen derived to the chickpea plants and to estimate exactly how much N could be compensated by the different sources. In this respect, the portions of N derived from air, fertilizer and soil are presented in *Table 4*.

The obtained data showed a slight variation in ^{15}N atom excess of chickpea straw with salinity levels. A remarkable decrease in the percent of ^{15}N atom excess was noticed in the case of chickpea seeds as affected by gradient/gradual increase in salinity levels. These percentages of ^{15}N a.e., were significantly lower than those recorded with wheat as a reference crop used for quantifying the biological nitrogen fixation (BNF) when applying the isotope dilution (A-value) technique.

The calculation of the percentage and absolute values of N derived from chemical fertilizer added, showed slight increase with 3, 6 and 9 dS/m treatments, while they were notably higher than the fresh water control, when straw-N was considered. In contrast, seed-N derived from fertilizer tended to decrease with increasing water salinity levels. These results indicate that most of the fertilizer N yield was accumulated in straw of chickpea than seeds. Generally, the portion of N derived from fertilizer to either straw or seeds doesn't exceed 12 % of the total N uptake.

The opposite was observed with the fraction of N derived from fixation, whereas more than 80% and 70% of the nitrogen accumulated by straw and seeds, respectively derived from air. Portion of N_2-fixed in straw of chick-pea decreased with the level of 3 dS/m as compared to the fresh water control, then it tended to increase with both 6 and 9 dS/m treatments but is still lower than fresh water. Considering the N_2-fixation by seeds, the data indicate stability of % Ndfa with increasing salinity, except the treatment of 6 dS/m where it decreased with respect to other treatments and even the control. Absolute figures of N fixation revealed that the relationship of *Rhizobium leguminosarum* – chickpea symbiosis is obviously affected by the adverse conditions of saline water used. In this respect, Saxena and Rewari (1992) explained that symbiotic performance in saline soil depends on the salt-tolerance of both the host and the micro-symbiont. We agree with this conclusion since our results indicated a good performance of chickpea, *Rhizobium symbiosis*, under salinity conditions given. The reduction in the quantities of N_2-fixation with increasing salinity seems to be related to the reduction in plant growth (Kumar and Promila, 1983), disturbed metabolism, and imbalanced nutrient acquisition (Kawasaki, et al., 1983).

Soil-N came to the next as a fraction of nitrogen demand. It increased with increasing water salinity levels. This fraction may compensate the reduced quantities of N_2 derived from air under high level of salinity. In other terms, under adverse conditions, which may reduce the potential of N_2 fixation, the plant turned to depend on other N fractions like the Ndf soil.

From the above-mentioned data, it may be concluded that chick-pea plants were dependent on the different N sources in the following order:

Ndfa > Ndfs > Ndff

Also, it may be stated that the unsuitable abiotic conditions that inhibited P_{fix} could push the grown plant to profit from other N sources to avoid N-nutrition disorders.

Table 4. Nitrogen derived from air (Ndfa), fertilizer (Ndff) and soil (Ndfs) in chickpea straw and seeds as affected by salinity conditions

Treatment	Nitrogen sources						
	^{15}N a.e.	Ndff		Ndfa		Ndfs	
		%	g/Li	%	g/Li	%	g/Li
Straw							
F.W.	0.581	5.62	**0.17**	82.1	**2.53**	12.33	**0.38**
3 dS/m	0.590	11.8	**0.28**	62.8	**1.49**	25.41	**0.60**
6 dS/m	0.596	11.92	**0.35**	70.5	**2.09**	17.60	**0.52**
9 dS/m	0.598	11.96	**0.31**	72.24	**1.87**	15.80	**0.41**
Seeds							
F.W.	0.431	8.62	**0.14**	71.28	**1.18**	20.1	**0.33**
3 dS/m	0.402	8.04	**0.16**	71.0	**1.46**	20.96	**0.43**
6 dS/m	0.386	7.72	**0.08**	67.1	**0.70**	25.18	**0.26**
9 dS/m	0.310	6.20	**0.04**	72.87	**0.48**	20.93	**0.14**
Reference crop **Straw**							
F.W.	0.695	69.5	**0.82**	-	**-**	30.5	**0.36**
3 dS/m	0.699	69.9	**0.52**	-	**-**	30.1	**0.22**
6 dS/m	0.772	77.2	**0.86**	-	**-**	22.8	**0.26**
9 dS/m	0.791	79.1	**1.09**	-	**-**	20.9	**0.29**
Seeds							
F.W.	0.682	68.2	**1.81**	-	**-**	31.8	**0.85**
3 dS/m	0.657	65.7	**1.62**	-	**-**	34.3	**0.85**
6 dS/m	0.605	60.5	**1.86**	-	**-**	39.5	**1.21**
9 dS/m	0.597	59.7	**1.57**	-	**-**	40.3	**1.06**

Faba bean

The data of N derived from the different sources and taken up by faba bean straw and seeds, (*Table 5)* show a trend similar to that observed with chickpea plants-N derived from fertilizer was negatively affected by increasing salinity levels. % Ndff didn't vary so much as in straw but drastically decreased in seeds at the highest (6 and 9 dS/m) levels of water salinity. In the same time, faba bean plants take up a reasonable amount of nitrogen from soil. This component was higher under low levels of salinity than under the highest ones. More Ndfs was found in seeds as compared to straw-N.

Nitrogen derived from air (Ndfa) seems to be the main source of N utilized by both straw and seed organs. This source of N nutrition compensated about 70% and more than 80% of the N needed for faba bean demand. Also, N_2-fixation by seeds was higher, to some extent, than by straw. This fraction reflects that faba bean was tolerant to levels of 3 and 6 dS/m when N_2-fixed by seed was considered.

Table 5. Nitrogen derived from air (Ndfa), fertilizer (Ndff) and soil (Ndfs) in faba bean straw and seeds as affected by salinity conditions

Treatment	Nitrogen sources						
	^{15}N a.e.	Ndff		Ndfa		Ndfs	
		%	g/Li	%	g/Li	%	g/Li
			Straw				
F.W.	0.611	12.22	**0.45**	60.97	**2.22**	26.81	**0.98**
3 dS/m	0.621	12.42	**0.49**	60.84	**2.39**	26.74	**1.05**
6 dS/m	0.631	12.62	**0.33**	68.74	**1.83**	18.64	**0.49**
9 dS/m	0.640	12.80	**0.41**	70.29	**2.27**	16.91	**0.55**
			Seeds				
F.W.	0.605	12.1	**0.61**	59.69	**2.99**	28.21	**1.41**
3 dS/m	0.501	10.02	**0.50**	63.82	**3.21**	26.16	**1.31**
6 dS/m	0.298	5.96	**0.25**	74.52	**3.10**	19.52	**0.81**
9 dS/m	0.210	4.20	**0.11**	81.62	**2.00**	14.18	**0.35**

In this respect, Cordovilla et al. (1995) stated that the host tolerance appeared to be a major requisite for nodulation and N_2 fixation of faba bean cultivars grown under salt stress. They also found that some cultivars have the ability to sustain nitrogen fixation under saline conditions (salt tolerant genotype). The absolute value of N_2 fixed by faba bean seeds was higher than those recorded for chickpea plant suggesting the specific *Rhizobium*-host relationship. In conclusion, faba bean as well chickpea are mainly dependent on N derived from fixation for offering/meeting its nitrogen requirements. Nitrogen derived from soil came next and followed by nitrogen derived from fertilizer. Also, from the obtained data of ^{15}N analysis, it is clear that N_2 fixation potential should take place (should be part of) in the program of integrated plant nutrition systems and soil fertility improvement especially under adverse conditions of salinity stress. Similarly, may I have the chance to advise the properly selection of both *Rhizobium* bacteria strains and the suitable host plant tolerant to salinity stress.

Lentil

The data in *Table 6* present the effect of salt stress on nitrogen derived from fertilizer, air and soil and taken up by straw and seeds of lentil plants. The effect of water salinity on fertilizer-N derived to straw was unclear. In contrast, the decrease in the amount of N derived from fertilizer and assimilated by lentil seeds was noticeable. Our results, to some extent, are in agreement with those reported by Rahman (1995) who found that the percentage of N derived from fertilizer to lentil seeds does not exceed 12% under irrigation with normal water, but tended to decrease when lake saline water (10 dS/m) was applied. Soil-N derived to lentil plants ranged from 6% to 28% as affected by salinity levels. The highest percentage of soil-N was obtained with 3 dS/m and 6 dS/m for straw and seeds, respectively. It seems that lentil plants grown under salinity stress was more dependent on soil-N than fertilizer-N.

Concerning the N_2-fixation by straw and seeds of lentil, the data show a negative response to gradient increase in water salinity, especially in seed-N. Seeds were mainly dependent on N derived from air since it accounted for 87% and tended to decrease with increasing salinity levels. The portion of N_2 fixed obtained in the present study is in agreement with the value reported earlier by Rahman (1995). It is clear, that the improvement of lentil growth, in general, is attributable to fixation of atmospheric N_2 by lentil due to the application of the appropriate *Rhizobium* strains. As mentioned above, we also advise the application of inoculation technology to improve both the soil fertility and plant growth especially under the adverse saline conditions.

Table 6. Nitrogen derived from air (Ndfa), fertilizer (Ndff) and soil (Ndfs) in lentil straw and seeds as affected by salinity conditions

Treatment	^{15}N a.e.	Nitrogen sources					
		Ndff		Ndfa		Ndfs	
		%	g/Li	%	g/Li	%	g/Li
			Straw				
F.W.	0.591	11.82	**0.16**	0.16	**62.24**	25.94	**0.34**
3 dS/m	0.651	13.02	**0.17**	0.17	**58.4**	28.04	**0.37**
6 dS/m	0.663	13.26	**0.22**	0.22	**67.16**	19.58	**0.32**
9 dS/m	0.671	13.42	**0.20**	0.20	**68.85**	17.73	**0.26**
			Seeds				
F.W.	0.342	6.84	**0.16**	0.16	**87.47**	5.69	**0.16**
3 dS/m	0.310	6.20	**0.11**	0.11	**77.62**	16.18	**0.29**
6 dS/m	0.287	5.74	**0.05**	0.05	**75.52**	18.74	**0.18**
9 dS/m	0.285	5.70	**0.03**	0.03	**73.06**	21.24	**0.12**

Sugar beet

Sugar % and yield (kg/h)

Sugar % and yield (kg/h) as affected by different water salinity, N as added at one time or splitting and irrigation water percent (100 or 75% of field capacity) were presented in *Table 7*. Generally, the data indicate that sugar % increased with increasing salinity levels of irrigation water under both N_I and N_{II} treatments. It seems that sugar% was higher in case of N_I than N_{II} under different salinity levels, when W_I was concerned. Opposite direction was noticed with W_{II} water treatment.

Data recorded in *Table 7* show that sugar yield (kg/ha) increased by increasing water salinity. The increment of sugar yield was (8.3 and 7.7%) under application of N as one time and irrigation by saline water (4 and 12 dS/m), respectively, comparing with FW, under W_I treatment. While in case of N_{II} the rate of increase was (13.2, 11.5 and 33.1 %) for (4, 8 and 12 dS/m), respectively compared to fresh water treatment. At the same time, irrigating sugar beet plants with 75% of water field capacity also lead to a remarkable increase in sugar yield either under N_I or N_{II} where the increment of sugar yield in case of N_I was (24.7, 52 and 39%) for (4, 8 and 12 dS/m of water salinity), respectively comparing to FW treatment. The same trend was noticed in case of N_{II} but to somewhat higher extent. Significant variation between treatments was presented in *Table 8.*

Our results are in harmony with those obtained by El-Hawary (1990) who found a significant increase in sugar yield per plant due to nitrogen application. He added that, the N application at rate of 90 kg N/feddan after 40 days from sowing date (N_3-treatment) gave the highest average of sugar yield per plant. These results might be attributed to the favorable effect of nitrogen on root volume and fresh weight of root / plant.

Wiesler et al. (2002) reported that increasing fertilizer N rates reduce sucrose concentration and sugar yield. Although, we did not apply different doses of N fertilizer but only split the recommended dose, we believe that this technique has the advantage to save N-fertilizer and in the same time offers preferable conditions, in combination with water regime, to remarkable production of sugar.

Table 7. Effect of salinity levels, N doses and water percent on sugar yield (% and kg/ha) of sugar beet plants

Salinity levels	W_I				W_{II}			
	(%)		kg/ha		(%)		kg/ha	
	N_I	N_{II}	N_I	N_{II}	N_I	N_{II}	N_I	N_{II}
FW	16.0	14.0	5886.1	5192.2	13.7	15.7	4753.4	6366.0
4 dS/m	17.4	16.3	6375.3	5878.6	15.3	18.2	5928.1	6745.1
8 dS/m	19.0	17.8	5788.1	5787.9	18.8	20.5	7226.0	7604.4
12 dS/m	21.2	20.4	6340.2	6912.2	19.6	23.3	6607.5	7717.2
Average	18.4	17.1	6097.4	5942.7	16.9	19.4	6128.7	7108.2

Table 8. Summary of ANOVA –Significance of sources of variation and variance of error of studied characters for plant root

Sources of variation	D.F.	Sugar content %	Sugar yield (t/ha)
Water treatments (W)	1	ns	*
Water salinity level (S)	3	**	*
Nitrogen (N)	1	Ns	ns
Interaction W * S	3	Ns	*
Interaction W * N	1	**	**
Interaction N * S	3	Ns	*
Interaction W * N * S	3	ns	**
Error	60	0.8166	0.1348

Potatoes

- Total yield of tuber on the base of fresh weight (t/ha)

As presented in *Table 9*, the total yield of Spunta tubers was slightly increased by increasing water salinity level up to 6 dS/m. Similar trend was noticed when organic addition rate concerned. Nicola tubers showed similar trend as those of Spunta variety, but the increments affect by salinity and decrements caused by addition of organic matter were much remarkable than in case of Spunta variety. In general, the overall means showed the superiority of Nicola variety over Spunta variety.

Table 9. Effect of water salinity and organic matter levels on total yields tuber fresh weight (t/ha) of Spunta and Nicola potatoes varieties.

Organic Matter Level (kg/m^2)	**Water salinity level (dS/m)**			
	F.W	**3**	**6**	**Mean**
		Spunta		
0	40.0	42.2	42.9	41.7
2.6	41.4	41.8	44.2	42.5
5.2	39.8	40.7	42.7	41.1
Mean	40.4	41.6	43.3	
		Nicola		
0	47.6	50.8	52.4	50.3
2.6	44.8	45.6	46.3	45.6
5.2	42.4	44.9	46.1	44.4
Mean	44.9	47.1	48.2	

Concerning the yield and tuber size distribution, Porter et al. (1999) reported that, the yield increases in response to the amended treatments (green manure) may be due to increased availability and/or changes in soil bulk density, water stable aggregates or other soil physical properties. The soil amendment treatments increased soil nutrient concentrations and aggregation. Also supplemental irrigation increases tuber size during the drier growing season. Maintaining soil water after tuber initiation increased the percentage yield of tuber than 5.7cm in diameter. Soil amendment treatments (green manure) significantly increased tuber size. These results are sometimes on line with our results of tuber distribution.

Iqbal et al. (1999) studied the yield response of potato to planned water stress; the results obtained showed that, the timing of water stress influenced the tuber yield. The stress imposed at ripening stage caused the lowest reduction in yield whereas that imposed at early development caused the greatest yield reduction followed by the tuber formation stage.

- Starch content (g/100g FW)

Increasing water salinity level up to 3 and 6 dS/m induced relative decrease in Spunta starch under 0 organic matter by about 11.5 and 14.1%, respectively *(Table 10)*. Addition of 2.6 kg/m^2 organic matter had decreased the tuber starch, except the treatment of 5.2 kg/m^2 organic matter under 6 dS/m level where the starch was vigorously increased. Starch in Nicola tuber under no-organic amendment, was decreased with increasing salinity level up to 3 dS/m, and then increased with increasing salinity to 6 dS/m. Similar trend was noticed with 5.2 kg/m^2 organic matter level. Gradual increase of tuber starch with increasing salinity levels was noticed with addition of 2.6 kg/m^2 organic matter. In general, Spunta variety showed some superiority in tuber starch over those of Nicola variety tuber.

Our results of starch are in agreement with those obtained by Silva et al. (2001). Starch level in two potatoes (*S.tuberosum and S.curtilobum*) was constant with salinity levels (0, 25, 50, 75 and 100 mmoll^{-1} NaCl). The starch levels in both varieties of potatoes (*S.tuberosum and S.curtilobum*) remained constant under all salt levels. Also, organic solutes such as soluble carbohydrates have been suggested to play an important role as osmoprotectants counteracting the toxic effects of Na$^+$ and Cl$^-$ in the shoots under salt stress (Evers et al., 1997).

Table 10. Effect of water salinity and organic matter levels on starch (g/100g FW) of Spunta and Nicola potatoes varieties

Organic Matter Level (kg/m^2)	**Water salinity level (dS/m)** **F.W**	**3**	**6**	**Mean**
	Spunta			
0	17.6	14.9	14.3	15.6
2.6	15.4	15.4	13.9	14.9
5.2	14.7	13.6	16.0	14.8
Mean	15.9	14.6	14.7	
	Nicola			
0	13.8	11.3	14.9	13.3
2.6	10.7	12.8	14.6	12.7
5.2	15.4	12.6	14.9	14.3
Mean	13.3	12.2	14.8	

CONCLUSION

Results obtained in this study confirm the reuse of low quality irrigation water mainly saline one, which may overcome the gab between water charge and requirements for agricultural practices. As shown above, the use of saline water in irrigation of some salt-tolerant plants may result in economical production of such economical legumes and/or tuber crops. The application of stable isotope in such studies may help us to understand the physiological impacts of plants imposed to salt stress and gave us a clear picture about its response to such adverse conditions.

REFERENCES

Abou-Hussein, S.D. (1995) Studies on potato fertigation in newly reclaimed lands. Ph.D Thesis, Faculty of Agriculture, Ain Shams University, Cairo, Egypt.

Aly, A.Z.S. (2004) Sugar beet production and nitrogen fertilizer efficiency under different irrigation regimes with saline water, using ^{15}N tracer technique. M. Sc., Thesis IAM-Bari, CHEIAM, Italy.

Attard, D.J., Axiak, V., Borg, S., Cachia, J., de Bono, G., Lanfranco, E., Micallef, R.E., Mifsud, J. (1996) Implications of expected climatic changes for Malta. In: Jeftic, L., Keckes, S., Pernetta, J. (Eds.), Climate Change and the Mediterranean, vol. 2. Arnold, UK, pp. 322–430.

Chartzoulakis, K.S., Paranychianakis, N.V., Angelakis, A.N. (2001) Water Policy 3, 193-205.

Cordovilla, M.P.; Ligero, F. and Lluch, C. (1995) Influence of host genotypes on growth, symbiotic performance and nitrogen assimilation in faba bean (*Vicia faba* L.) under salt stress. Plant and Soil, 172: 289-297.

Dua, R.P. (1992) Differential response of chickpea (*Cicer arietinum*) genotypes to salinity. J. Agric. Sci., Camb. 119: 367-371.

El-Fouly, M.M.; Zeinab, M.M and Zeinab, A.S. (2001) Micronutrient sprays as a tool too increase tolerance if faba bean and wheat plants to salinity. *In*: W.J. Horst et al., (eds), Plant Nutrition, Food Security and sustainability of agroecosystems, P. 422-423. Kluwer, Academic publishers, the Netherlands.

El-Hawary, M, A. M. (1990) Effect of soil salinity and nitrogen fertilization on sugar beet. Ph.D Thesis. Fac. of Agric. Al-Azhar University.

Evers, D., Schmit C., Mailliet Y. and Hausman I.F. (1997) Growth characteristics and biochemical changes of poplar shoots in vitro under sodium chloride stress. J. Plant Physiology.151, 748-753.

Gong, JiaDong, Pasternak D., Demalach Y. and Gong J.D. (1996) Acta Pedologica Sinica. 33:4, 405-413.

Hardarson G, Danso SKA, Zapata F and Reichardt K. (1991) Plant and Soil 131: 161-168.

Hajji, M. Lachaat, M., Soltani, A. and Grignon, C. (2001) Large accumulation of sodium in leaves may be compatible with normal growth. *In*: W.J. Horst et al., (eds), Plant Nutrition, Food Security and sustainability of agroecosystems, 416-417 Kluwer, Academic publishers, The Netherlands.

IAEA, (1995) Management strategies to utilize salt affected soil. Isotopic and conventional research methods. IAEA-TECDOC-814. Vienna, Austria.

Iqbal, M.M., Shah S.M., Mohammed W. and Nawaz H. (1999) Field response of potato subjected to water stress at different growth stages. In: Kirda, C., Moutonnet P.; Hera, C. and Nielsen, D.R (Eds), crop yield response to deficient irrigation. Kluwer Academic Publishers, the Netherlands, pp. 213-223.

Kawasaki, T.; Akiba, T. and Maritsuge, M. (1983) Effect of high concentration of sodium chloride and polyethylene glycol on the growth and ion absorption in plants: I. Water culture experiments in a green-house. Plant and Soil, 75: 75-85.

Kumar, S. and Promila, K. (1983) Effect of chloride and sulphate types of salinization and desalinization on nodulation and nitrogen fixationin chickpea. Indian J. Plant Physiol. 26: 396-401.

Kvien, C.S. and Ham, G.E. (1985) Agron. J. 77, 484-489.

Lauchli, A. and Epstein, E. (1990) Plant responses to saline and sodic conditions. In: Agric. Salinity Assissment and Management K. Tani (ed) Am. Soc. Of Civil Eng. P. 113-137.

Loomis, R.S. and Jr. Worker, G.F. (1963) Agrono,y J. 22: 509-515.

Page *et al*., (1982) Methods of soil analysis, Part: 2. Chemical and Microbiological Properties, 2nd ed. ASA; SSSA, Madison, Wisconsin, USA. pp. 595-624.

Paranychianakisa, N.V., and Chartzoulakis, K.S. (2004) Agriculture Ecosystems & Environment (in press).

Porter, G.A., Opena G.B., Bradbury W.B., McBurnie J.C. and Sisson J.A. (1999 Soil management and supplemental irrigation effects on potato; 1. soil properties, tuber yield and quality. Agron. J.91: 416-425.

Rahman, S.M. (1995) Irrigation with saline water. *In*: Management strategies to utilize salt affected soils. IAEA-TECDOC- 814, pp. 54-57.

Rice, W. D. and Paul, E.A., (1971) Can J. Microbial 17: 1049-1056.

SAS, (1987) Statistical Analysis system. User’s Guide, Version 5, Cary, C.N.

Saxena, A.K. and Rewari, R.B. (1992) Differential responses of chickpea (*Cicer arietinum* L.) - Rhizobium combinations to saline soil conditions. Biol. Fertil. Soils. 13: 31-34.

Sharma, S.K., Manchanda, H.R. and Singh, J.P. (1982) Note on the performance of some chickpea varieties grown on chloride – dominated saline soils. Indian J. Agric. Sci., 52: 405-407.

Silva, J.A.B., Otoni W.C., Martinez C.A., Dias L.M. and Silva M.A.P. (2001) Microtuberization of Andean Potato Species (*Solanum spp.*) as affected by salinity. Scientio Hort.89: 91-101.

Singh, K.B. and Saxena, M.C. (1999) Chickpeas. The Tropical Agriculturalist services. Mac Millan and ICARDA, MacMillan Education Ltd.

Whitting, G.I. and Morris, I.T. (1986) Soil Biol. Biochem. 18, 515-521.

Wiesler, F; Baure, M.; Kamh, M., Engles, T. and Reusch, S. J. (2002) Plant Nut. Soil Sci. , 165, 93 – 99.

Wollenweber, B. and Zechmeister-Boltenstern, S. (1989) Botanical Acta 102: 96-105.

Yasin, M. and Ashraf Zahid, M. (2000) Genotypic behavior of lentil cultivars towards salinity. Book of Abstract on ispsa, April 10-12, 2000, Islamabad, Pakistan.

Zahran, H.H. (1997) Biol. Fertil. Soils 25, 211-223.