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The effects of salinity on growth and ion content of chickpea (*Cicer arietinum* L.), eggfruit (*Solanum melongena* L.) and red pepper (*Capsicum annuum* L.) varieties

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Abstract

The effects of salinity on yield and ion concentrations of chickpea (*Cicer arietinum*) varieties from Syria and eggfruit (*Solanum melongena*) and red pepper (*Capsicum annuum*) varieties from Palestina were studied in pot experiments in a greenhouse. The yield of all plants was reduced by increasing salinity from 0 to 8 dSm^{-1} in the saturation extract. Emergence as well as shoot and grain yield of all chickpea varieties was inhibited from 4 dSm^{-1} onwards, while root growth was reduced from as low as 2 dSm^{-1}. As a consequence of salinity treatment, chickpea variety Ghab 2 showed the best root and shoot growth, and Ghab 1 the highest grain yield. For chickpea, a high yield in spite of salinity corresponded with a low Na and Cl concentration in the tissue. Chickpea is an excluder plant, trying to protect its tissue against the harmful salt. The yield of eggfruit and red pepper was diminished for the two sensitive varieties Balady and Battiri already at 1.46 dSm^{-1}, but the varieties Turshy and Shatta were much more tolerant. Turshy showed the highest salt tolerance: its slope of yield reduction was not as steep as that of the other varieties. Compared to chickpea, eggfruit and red pepper seem to be includer plants. They can accumulate the salt which can be useful for osmotic adjustment against water stress due to salinity.

1 Introduction

In the arid and semi-arid regions of the world, soil salinisation is a very serious threat to agriculture. A content of salt which is too high, especially of NaCl, in the soil solution hinders germination, vegetative growth, yield and quality of crops (RHOADES, 1990). In many areas, this is the case in rainfed agriculture due to a higher evapotranspiration than rainfall, e.g. in the Mediterranean areas for crops like chickpea, as well as for irrigated crops, as, e. g., eggfruit and red pepper.

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Many leguminous crops are very sensitive to salinity, especially to chloride which is transported into the shoot in these plants more than in other plant species (MARSCHNER, 1995). In addition, NaCl inhibits the growth of chickpea by effecting the N accumulation of specific strains of *Rhizobium* (LAUTER et al., 1981). Ashraf and Waheed (1992) and Mamo et al. (1996) reported about varietal differences between several chickpea varieties from Pakistan and India, and from Ethiopia, respectively. As chickpea is a crop widely cultivated in the Mediterranean areas, e.g. in Syria, it seemed valuable to study the salt tolerance of the four most important Syrian chickpea varieties.

Salt tolerance of the vegetable crops eggfruit and red pepper is described by Maas (1986): These plants are moderately sensitive, e.g. red pepper, showing a threshold (maximum salinity that does not reduce yield) of 1.5 dSm^{-1} in the saturation extract of the soil and a slope (yield reduction per dSm^{-1} beyond threshold) of 14 %. These two figures indicate a relative high sensitivity, compared to other crops. Savvas and Lenz (1994) showed yield reduction of *Solanum melongena* from 4.1 dSm^{-1} onwards, which was their lowest salt treatment. It seemed interesting to test whether there exist differences between eggfruit varieties and to compare them with a red pepper variety which nowadays is cultivated often in practical agriculture by the farmers together with eggfruit in a mixed culture system in Palestina as well as in many other Mediterranean areas. We chose eggfruit and red pepper varieties cultivated in the Gaza strip in Palestina, because at the moment in this region salinity is a serious problem in agriculture. In the region of Gaza, the chloride concentration in drinking water and irrigation water has become dangerously high (KUHAIL and ZOAROB, 1995).

Our study was conducted in order to test the salt tolerance of different crop species and varieties of the Mediterranean area, especially of four Syrian chickpea varieties and of three eggfruit varieties compared with one red pepper variety from Palestina. However, our aim was not only to classify the varieties as to their salt tolerance, but also to try to explain salt tolerance by different adaptation possibilities as a consequence of different ion uptake and transport processes in various parts of the plant. As an example for this, Schubert and Läuchli (1990 and 1995) showed that sodium exclusion can contribute to salt tolerance of maize plants. Red pepper, on the contrary, seems to be more an includer plant type, which accumulates not only Na^+ and Cl^- but also proline in order to overcome the water stress caused by salinity (GÜNES et al., 1996).

2 Materials and methods

All experiments (one experiment with chickpea, and one experiment with eggfruit and red pepper) were conducted as a randomized block design in a greenhouse with a day/night temperature of 20/20°C, 60% r.h. and a light intensity of 20,000 lux for 12 h d^{-1}.

Experiment with chickpea

Samples of different chickpea (*Cicer arietinum* L.) varieties were obtained from the government center for seed production in Aleppo/Syria. The four varieties were Marakesh, Ghab 1, Ghab 2, and Ghab 3. All these varieties are planted by farmers in Northern Syria.

The soil used for the chickpea trials was a loam from Hebenshausen, Germany, with a pH (0.02 n $CaCl_2$) of 6.8, 0.5 % $CaCO_3$, 0.14 % N_t, and 2 % organic matter. As 6.6 mg P and 15 mg K were found by the CAL-method and 9 mg Mg by the $CaCl_2$-method, these nutrients were sufficient for optimal plant growth. The content of exchangeable Na (7.4 mg $100g^{-1}$) and the EC of the experimental soil (0.32 dSm^{-1} at 25°C in the saturation extract) were low.

The levels of NaCl were 0, 0.58, 1.16, 2.31, 4.63, and 9.27g NaCl per pot with 3.75 kg of soil, corresponding to an EC of 0, 0.5, 1, 2, 4, and 8 dSm^{-1} at 25°C in the saturation extract. The salt was dissolved in 200 ml of distilled water, half of it was given to the soil before planting and the other half 3 days after planting. 12 seeds were sown in each pot. After 10 days, the percentage of emergence was determined, and the plants were reduced to 8 per pot. The chickpea plants were harvested 68 d after planting at grain maturity.

Experiment with eggfruit and red pepper

Eggfruit (*Solanum melongena* L.) and red pepper (*Capsicum annuum* L.) seeds were obtained from a seed grower in Gaza. They were precultivated in a soil provided with all nutrients. At the age of 37 days, the roots were washed with distilled water, and the plants were planted in pots with 5.5 kg of pure, washed sand. They were irrigated every third day, once with tap water and the next time (after 3 days) with the following nutrient solution (mM l^{-1}): 20 $Ca(NO_3)_2 \cdot 4\,H_2O$, 10 KH_2PO_4, 7.5 $MgSO_4 \cdot 7\,H_2O$, and mg l^{-1}: 25 sequestrene with 6% Fe, 0.25 $MnSO_4 \cdot H_2O$, 0.08 $CuSO_4 \cdot 5\,H_2O$, 0.2 $ZnSO_4 \cdot 7\,H_2O$, 0.14 H_3BO_3 and 0.12 $(NH_4)_6Mo_7O_{24} \cdot 4\,H_2O$. The EC at 25°C of this nutrient solution was 1.4 dSm^{-1}. The NaCl concentrations added to the nutrient solution for the different treatments were 0, 25, 50, 100, and 150 mM l^{-1}, corresponding to an EC at 25°C of 0, 1.46, 2.92, 5.84, and 8.76 dSm^{-1}. The eggfruit and red pepper plants were harvested 153 days after sowing.

After harvest, the roots of chickpea, eggfruit and red pepper were washed carefully with distilled water in order to remove adhering sand and soil. The plants were separated in roots, shoots and fruits, oven dried at 70°C, weighed and ground <1mm. For the Na and K determination, 1g of the dry and ground plant material was ashed at 550°C for 5 h and the ash was dissolved in conc. HCl. Na and K were read by flame photometry. For chloride analysis, 0.5 - 1.0 g of the dry and ground plant material was shaken for 30 min with 50 ml of boiled water and filtered after addition of one teaspoon of activated charcoal into the filter. To 2 ml of the filtrate which were transfered into a 25 ml flasc, 5 ml of solution C were added. Solution C was prepared from 75 ml of stock sulution A (4g mercure thiocyanate / l methanol) and 150 ml of stock solution B (150 g $Fe(NO_3)_3 \cdot 9 H_2O$ + 30 ml conc. HNO_3/ l dest.water), and Cl^- was read by spectrophotometry at the wave length of 483 nm.

All the data were statistically analysed. Analysis of variance of both experiments was done. Treatment means were compared by the least significant difference (LSD) test and the Duncan test.

3 Results

Experiment with chickpea

a) Emergence

The emergence 10 d after sowing is shown in Fig.1. There was no reduction of emergence up to a salinity of 2 dSm^{-1}, but at 4 dSm^{-1} a severe reduction could be observed. At the time of emergence, there existed no differences in the salt tolerance between the four tested chickpea varieties.

b) Roots

The root dry weight after the harvest of the four chickpea varieties is shown in Fig. 2. From 2 dSm^{-1} onwards, the root dry matter yield was influenced by the salt treatment for Marakesh, the other varieties showed a slightly higher tolerance and a diminished root growth from 4 dSm^{-1} onwards. At 8 dSm^{-1}, no roots could grow any more. At all salt levels, Ghab 2 showed the best growth of all tested chickpea varieties.

Fig. 2 also shows the Na and Cl concentrations of the roots. Ghab 2 which showed the highest dry matter yield of all varieties, had the lowest Na content in the roots at the first 4 salt levels and the second lowest at 4 dSm^{-1}, which indicates that a diminished sodium uptake can be a reason for salt tolerance. The chloride concentration (Fig. 2) did not correspond to the yield of the different chickpea roots. The chloride content was much higher than the sodium content. This can be observed often in leguminous plants (MARSCHNER, 1995): Their high chloride content may even be the most important reason for salt injury, even more important than the sodium content.

c) Shoots

While root growth was influenced already from 2 dSm^{-1} onwards, shoot dry matter yield was reduced only above 4 dSm^{-1} (Fig. 3). Ghab 2, which had the best root growth, showed the second best shoot growth at most of the salt steps and was the best one at 2

dSm^{-1}. As can be seen from Fig. 3, the high yield of Ghab 2 corresponded with the lowest sodium and chloride content.

d) Grains

In contrast to the root and shoot weight, the grain weight of variety Ghab 1 was the best one of all tested chickpea varieties (Fig. 4), and its sodium concentration in the grains was the lowest of all varieties in the salt steps from 0 to 2 dSm^{-1} and the second lowest in the salt treatment of 4 dSm^{-1}. However, a low Cl^- concentration in the grains (Fig. 4) did not correspond to the high yield of Ghab 1.

There were no differences in the potassium and phosphorus contents of roots, shoots and grains.

Experiment with eggfruit and red pepper

a) Yield

Table 1 shows the dry matter yield of roots and shoots of the four tested eggfruit and red pepper varieties. The eggfruit variety Turshy and the red pepper variety were very tolerant, a yield depression in the roots could not be observed, even not at 150 mM, and a yield depression in the shoots occured only from 100mM onwards. The two other eggfruit varieties (Balady and Battiri) were much more sensitive: Their shoot yield was diminished by the salt already at 25 mM. The most salt tolerant variety was the eggfruit variety Turshy. As can be seen from Figs 5 and 6, the slope of the linear regression of the natural logarithm of root and shoot yield on salinity was not as steep for Turshy as for the other varieties. This shows that Turshy was the most salt tolerant variety.

b) Na and Cl concentrations

Table 2 shows that one reason for Turshy's relatively high salt tolerance may have been that, compared to the other varieties, in most cases only little Na and Cl was accumulated in the roots. However, the Na and Cl transport into the shoots was not less but in most cases even more than in the other varieties; especially Na was transported in large amounts into the shoots of Turshy.

4 Discussion

In all the tested chickpea varieties there was no difference in salinity tolerance during emergence, but differences became apparent during later stages of development. While Ghab 2 showed the best root and shoot growth in spite of salinity, Ghab 1 had the highest grain yield. For all varieties, emergence, shoot and grain yield were diminished from 4 dSm^{-1} onwards. However, their root weight was already diminished at 2 dSm^{-1}

compared with the no salt (control) treatment. In most cases, a high yield corresponded to a low sodium and chloride content in the chickpea plants. Therefore, chickpea belongs to the excluder type of plants, being able to protect its tissue against the harmful salt. Generally, excluder plants are very salt sensitive, as they suffer from water stress easily because of the lack of osmotic substances. A solution would have to produce organic compounds (amino acids, sugars, etc.) for osmotic adjustment (GORHAM et al., 1985). Compared to other leguminous plants, e.g., soybean, *Glycine max* and lablab bean, *Lablab purpureus* (unpublished data) and also compared to other chickpea varieties (MAMO et al., 1996), the chickpea varieties tested here were more salt tolerant (as they tolerated a salinity of 4 dSm^{-1}, and the "very salt resistant" variety Ghab 2 tolerated even more than that). The reason may be that these chickpea varieties are adapted to the dry climate of Syria.

Of the tested eggfruit varieties, we found that Turshy was more salt tolerant than the others. The red pepper variety was also very tolerant. The salt sensitive eggfruit varieties Balady and Battiri showed a yield depression already at 25 mM. This result corresponds exactly with that one of Chartzoulakis and Loupassaki (1997). As our results show, the slope (log yield vs. salinity) of the eggfruit variety Turshy was not as steep as

Table 1: Influence of salinity on root and shoot yield (dry weight) of 3 different eggfruit (*Solanum melongena*, Balady, Turshy, Battiri) and one red pepper (*Capsicum annuum*, Shatta) varieties. Means in columns with the same letter are not significantly different at $P<0.05$ (Duncan test).

Variety	Salt Level (mM NaCl/l)	Dry Weight (g)	
		root	shoot
Balady	0	6.48a	17.63 a
	25	4.91 b	14.86 b
	50	4.58 bc	10.12 cde
	100	3.59 bcd	8.87 defg
	150	3.58 bcd	7.37 efgh
Turshy	0	4.62 bc	12.24 bc
	25	4.41 bc	10.04 cdef
	50	3.96 bcd	9.53 cdef
	100	3.82 bcd	7.18 fgh
	150	3.78 bcd	7.14 fgh
Battiri	0	4.96 b	17.63 a
	25	4.66 bc	14.52 b
	50	3.97 bcd	10.72 cd
	100	2.99 cde	7.58 efgh
	150	3.03 cde	6.39 ghi
Shatta	0	2.28 def	6.03 ghi
	25	1.91 ef	5.35 hij
	50	1.87 ef	4.20 ij
	100	0.98 f	2.97 j
	150	0.88 f	2.90 j

that of the other three varieties. The salt tolerant variety Turshy absorbed less sodium and chloride in the roots, but transported more Na into the leaves than the other varieties. In comparison to chickpea, eggfruit and red pepper seem to be more includer than excluder plants. They absorb a lot of sodium. This high quantity of sodium may be accumulated in parts of the plant where it is not so harmful for plant metabolism, e. g. it may be transported into the old instead of the young leaves (BLITS AND GALLAGHER,1990), or the salt may be accumulated more in the leaf sheaths and in the epidermal cells of the blades in order to protect the mesophyll (HUANG AND VAN STEVENINCK, 1989). Such mechanisms of adaptation to high salinity also may have been important in our eggfruit and red pepper plants.

Acknowledgement

The advice given by Dr. H. -P. PIEPHO on statistical analyses and computation procedures in the conduct of this study is highly appreciated.

Table 2: Influence of salinity on Na and Cl concentration in roots and shoots of 3 different eggfruit (*Solanum melongena*, Balady, Turshy, Battiri) and one red pepper (*Capsicum annuum*, Shatta) varieties. Means in columns with the same letter are not significantly different at $P < 0.05$ (Duncan test).

Variety	Salt Level (mM NaCl/l)	Na (mg/g)		Cl (mg/g)	
		root	shoot	root	shoot
Balady	0	2,3j	0,30 h	1,2 f	3,4 g
	25	12,0 defg	10,2 fg	21,6 de	38,7 f
	50	12,1 def	19,7 de	28,9 cd	52,8 e
	100	15,6 bcd	27,6 bc	35,9 ab	62,5 cde
	150	17,8 ab	32,9 ab	39,2 abc	73,9 abc
Turshy	0	2,9 j	0,72 h	2,6 f	6,9 g
	25	8,6 fgh	12,3 f	16,4 e	30,9 f
	50	9,7 efgh	24,1 cd	17,8 e	52,8 e
	100	12,9 def	32,1 ab	29,1 cd	66,6 bcd
	150	14,7 bcd	37,2 a	34,7 abc	79,1 a
Battiri	0	3,6 ij	0,29 h	1,2 f	3,9 g
	25	13,3 cde	10,4 fg	20,8 de	39,6 f
	50	17,4 abc	15,5 ef	32,5 bc	55,8 de
	100	18,6 ab	26,4 bc	39,5 ab	70,9 abc
	150	20,1 a	32,1 ab	44,9 a	75,9 ab
Shatta	0	1,5 j	0,32 h	3,8 f	3,8 g
	25	7,1 hi	4,7 gh	15,2 e	29,2 f
	50	7,7 hi	14,5 ef	17,9 e	54,0 e
	100	12,0 defg	28,4 bc	29,2 bc	68,1 abc
	150	17,5 abc	38,3 a	37,8 abc	79,0 a

5 Zusammenfassung

Einfluß von Bodenversalzung auf das Wachstum und den Ionengehalt verschiedener Sorten von Kichererbsen (*Cicer arietinum* L.), Auberginen (*Solanum melongena* L.) und Paprika (*Capsicum annuum* L.).

Der Einfluß der Bodenversalzung auf den Ertrag und die Ionenkonzentrationen verschiedener Sorten von Kichererbsen (*Cicer arietinum* L.), Auberginen (*Solanum melongena* L.) und Paprika (*Capsicum annuum* L.) aus Syrien und Palästina wurde in Topfversuchen im Gewächshaus geprüft. Der Ertrag aller Pflanzen wurde durch steigende NaCl-Versalzung von 0 bis 8 dSm^{-1} im Sättigungsextrakt des Bodens vermindert. Keimung, Sproß- und Kornertrag der Kichererbsen wurden ab 4 dSm^{-1} verringert, das Wurzelwachstum sogar schon ab 2 dSm^{-1}. Die Kichererbsensorte Ghab 2 hatte trotz Versalzung den höchsten Wurzel- und Sproßertrag, Ghab 1 dagegen den höchsten Kornertrag. Bei Kichererbse, einer typischen Salz-Excluder-Pflanze, die sich durch Ausschließung von Salz zu schützen versucht, korrellierte eine hohe Salztoleranz mit geringen Na- und Cl-Gehalten im Gewebe. Bei Aubergine und Paprika wurde der Ertrag der empfindlichen Sorten Balady und Battiri ab 1,46 dSm^{-1} vermindert, während die Sorten Turshy und Shatta wesentlich toleranter waren. Turshy zeigte die höchste Salztoleranz: Das Gefälle der Ertragsreduktionskurve war hier nicht so steil wie das der anderen Sorten. Nach unseren Ergebnissen scheinen Aubergine und Paprika im Vergleich zu Kichererbsen mehr Salz-Includer-Pflanzen zu sein. Sie können mehr Salz akkumulieren, was dann infolge osmotischer Regulation einem durch die Versalzung verursachten Wasserstreß der Pflanzen entgegenwirkt.

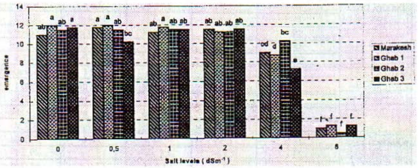

Fig. 1: Emergence (plants per pot) of 12 sown seeds of four different *Cicer arietinum* varieties. Means with the same letter are not significantly different at $P < 0.05$ (LSD test).

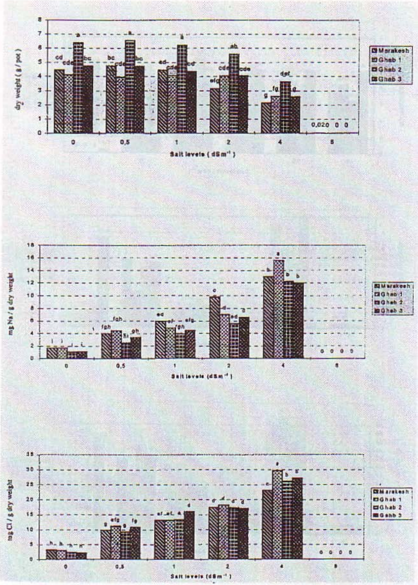

Fig. 2: Root dry weight (g/pot) and Na and Cl concentration (mg/g dry weight) of four *Cicer arietinum* varieties. Means with the same letter are not significantly different at $P < 0.05$ (LSD test).

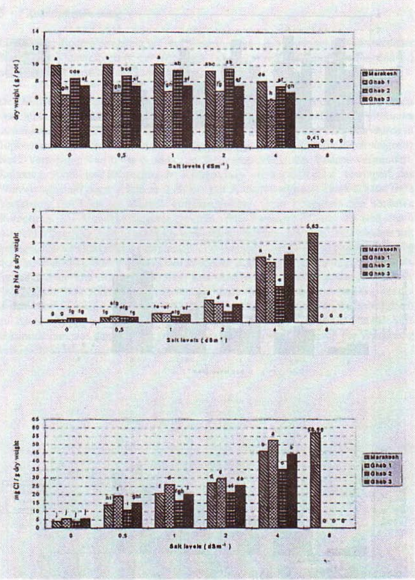

Fig. 3: Shoot dry weight (g/pot) and Na and Cl concentration (mg/g dry weight) of four *Cicer arietinum* varieties. Means with the same letter are not significantly different at $P < 0.05$ (LSD test).

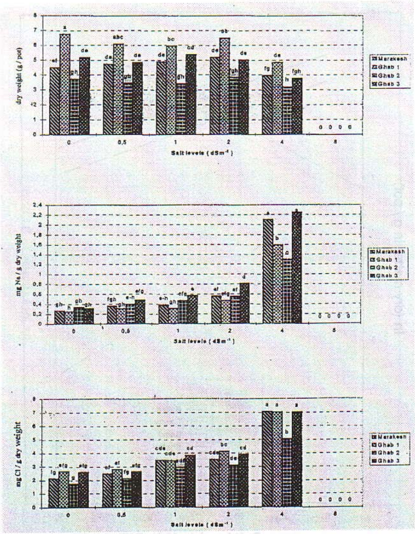

Fig. 4: Grain dry weight (g/pot) and Na and Cl concentration (mg/g dry weight) of four *Cicer arietinum* varieties. Means with the same letter are not significantly different at $P < 0.05$ (LSD test).

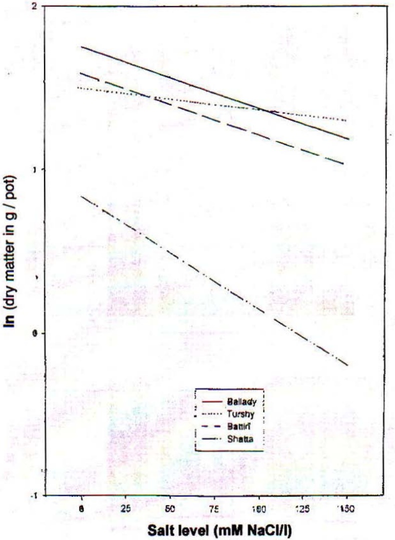

Fig. 5: Slope of the linear regression (ln, natural logarithm) of the root dry weight of eggfruit (*Solanum melongena*) and red pepper (*Capsicum annuum*) as affected by salinity.

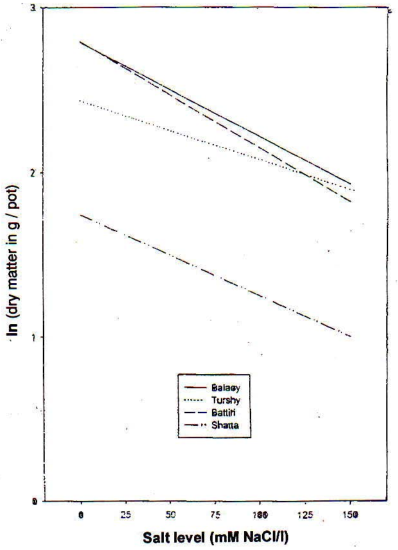

Fig. 6: Slope of the linear regression (ln, natural logarithm) of the shoot dry weight of eggfruit (*Solanum melongena*) and red pepper (*Capsicum annuum*) as affected by salinity.

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