SZENT ISTVÁN UNIVERSITY

SALT TOLERANCE OF SWEET PEPPER

Thesis of PhD work

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Introduction

High salt content of the soil and of the irrigation water causes many troubles all over the world. Unfortunately, Hungary is not exempt, especially vegetable forcing is in a difficult position in this respect. The structures used for protected growing are stationary and production has been practised in the traditional areas of vegetable forcing often on the same soil since several ten years. In addition, the irrigation water is unsuitable for watering because of its high salt content on every fourth farm in the main forcing districts. Improving the water quality of the dug wells is very expensive either by deepening or by desalting.

Besides diseases and pests, soil tiredness is caused chiefly by the increased salt content of the soil, owing to the cheap and nasty irrigation system (i.e. the wetting through of the root zone only, and merely in the growing season, with poor quality irrigation water), to unconsidered fertilization and to careless soil cultivation (formation of a compact soil layer). More and more growers have chosen isolated growing (most frequently soilless cultivation) for avoiding the harmful effects of high soil salt content or they have made use of pricy grafted transplants tolerating high salt content. These facts indicate that the problem cannot be solved any more by working high quantities of organic material into the soil.

In order to get a deeper knowledge on the life processes and on the environmental requirements of the plants, more and more investigations have been aimed at the study of the salt tolerance of the different species. Many papers have given evidence on the sensitivity to high salt content in the majority of vegetable crops. Besides experimental results, vegetable growers often observe the differences in salt sensitivity shown by cultivar types or even by cultivars of the same species.

This is especially true for the different sweet pepper varieties. According to the production volume of sweet pepper varieties on world scale, trials have been made in most cases with Lamuyo, Blocky and pointed green types all over the world.

These types are differing from the Hungarian ones. Several home investigations and practical observations have shown that the sweet pepper type of white, conical fruits (stuffing pepper) regarded as “Hungaricum” is more salt sensitive than the types mentioned above.

In the present work, I have investigated the salt sensitivity of the typical Hungarian white fruited sweet pepper varieties in different phases of development. Changes in a great number of parameters have been studied in order to known the plant properties and the

analytical methods suitable for characterizing salt tolerance in the different phases of plant development.

Material and methods

Seed germination tests were made in the laboratory, transplant raising tests in heated plastic houses and forcing experiments in unheated plastic houses with the aim of examining the salt tolerance of several pepper varieties.

The choice of the varieties to be studied has been based on the type. From the primarily studied conical type of white fruit colour a determinate growing synthetic variety (Fehérözön) and two indeterminate varieties (HRF F_1 and Syn. Cecei) have been chosen. In addition, a white variety of blunt, infolded apex (Boni) has been examined, too. The control varieties have been the following: Titán F_1 of hot, pointed type, the tomato-shaped Pritavit F_1 and – in several germination tests and transplant raising trials – the red pepper (seasoning paprika) Kalocsai merevszárú 622 (K. m. 622).In the germination test and in several transplant raising trials one variety of tomato (Heinz 1350 and Marmande, respectively) one of lettuce (Május királya) and one of kohlrabi (Gigant) were tested, too.

Laboratory germination tests were made with three white fruited varieties and with one spice pepper (Seasoning paprika) variety on 20-22°C in filter paper rolls wetted with KCl solutions of different concentration (EC 0-40 mS/cm). Parallel tests were conducted with the species listed above in order to compare the salt tolerance of sweet pepper with that of other vegetable crops. The tests were continued till the terms given in the standard MSZ 6354-3. The dynamics of germination, the appearance of the cotyledon, the diseases and the length of the seedlings in the cotyledonous stage were recorded.

During ***transplant raising***, the effects of the different doses of fertilizers added to the soil mixture and the effects of KCl containing irrigation water were studied.

For studying **the effect of different fertilizer doses** the seed was sown into uniform propagation mixture. In the cotyledonous stage, the seedlings were pricked into a 1:1 mixture of peat and sand containing PG-MIX™ (15+10+20). Choosing the ferilizer doses, 1,5 kg/m^3 has been taken as middle value (treatment III) as recommended by the producer for 6 week transplant raising. The other treatments contained the half, the double, the quadruple of that, respectively, and an soil mixture containing no fertilizer has been used, too. Transplant raising was finished when the plants of treatment III reached the size suitable for setting. At that time,

the root and the top weight, the stem diameter, the dry substance, nitrogen, phosphorus and potassium content of the top were measured.

The effect of KCl has been studied in glasshouse, on plants grown in soil mixture and in rockwool, respectively, on transplants raised from seed germinated in rockwool and pricked into soil mixture.

For the experiments in nursery soil, seed was sown directly into 176 mesh KITE trays. As starter nutrient, PG-MIX™ was added to the peat-sand mixture. The plots were treated with KCl solutions of different EC (0, 3, 6, 9 and 12 mS/cm), respectively. From the 20th day after sowing on, the solutions were completed by Volldünger. During the 20 days period after sowing the number of the embryos appeared and that of the healthy ones were recorded. The height, stem diameter and the dry matter content of the plants were measured. Like in laboratory tests, the same trials were performed with other species, too.

In the trials in rockwool, seed of six sweet pepper varieties was shown into Grodan® seedling cubes. The four different solution concentrations (0, 3, 6, 9 and 12 mS/cm) were set with pharmacopeal KCl in two experiments and by the fertilizer Multi K Standard (potassium nitrate: 13,0% N, 46,0% K) in the third experiment. Deionized water was used. The plots were made of seedling cubes covered with white plastic film from outside and arranged after the scheme 5x2. Till the beginning of germination, the trays were screened in order to reduce drying out. The trials were conducted over 20 days. During this period, the substrate was wetted once or twice daily. Plant development was recorded every second day. The healthy embryos as well as the browned ones were counted, the dates of cotyledon and true leaf appearance were recorded.

The salt tolerance of rockwool grown seedlings in soil mixture. On the 20th day of the experiment with KCl treated rockwool, the most developed plants of the control (0 mS/cm) and of the 3 mS/cm treatment were pricked out into plastic cups of 20 cm^3, filled with 1:1 peat:sand mixture. 3 plants were raised forth from each variety and from both treatments with 5 different level KCl concentration. Like in the KITE tray experiments, the KCl solutions of 0, 3, 6, 9 and 12 mS/cm EC were completed by 2‰ Volldünger (2,61, 5,27, 8,16, 11,0, 13,67 mS/cm). These solutions were used for every irrigation. The dead plants were recorded daily and conclusion on salt tolerance was drawn from the length of life. On the last day, the height of the plants and the number of the leaves bigger than 1 cm were noted and the dry matter content was determined. Evaluating the results, we tried to state if the treatments with salt solutions of 3 mS/cm over 20 days had any positive or negative effect on the later treatments.

In 1999 and 2000, production trials with different sweet pepper varieties were conducted in unheated plastic houses at the Experimental Farm Soroksár of our University, in order to know the salt sensitivity of the different types in forcing. Solutions of different NaCl content (0,3 l/plant) were given twice every week. The nutrient solution containing 0,25% Volldünger Linz complex fertilizer (14% N, 7% P_2O_5, 21% K_2O, 1% MgO, 1% microelements) was completed by pharmacopeal NaCl. The control nutrient solution (4,4 mS/cm) contained Volldünger only. Besides furnishing nutrient solutions, irrigations were made with pure water (EC 0,6 mS/cm) when necessary. The plants were cultivated in containers, isolated from the soil.The planting density was 7,2 plants/m^2 in both years.

The parameters studied were the following:

– Vegetative parts: stem diameter, height, totalleaf area, dry material content and N, P, K, Ca, Cl content of the leaves, cuticular recretion, peroxidase enzyme activity.

– Generative parts: yield (early and total yield), daily yield increase, number of fruit set and number of marketable fruits per square meter, fruit length, fruit diameter (measured at the peduncle), fruit weight, fruit volume, number of deformed and diseased fruits, dry matter content, N, P, K, Ca, Cl content, flavour, seed yield, 1000 seed weight, germinative ability.

Results

Laboratory germination test

Statistically significant protraction of the germination and diminution of the germ length have been observed under the influence of high salt concentration. The solutions of low salt concent, however, haven't impaired germination, on the contrary, they have slightly accelerated it. From the four sweet pepper varieties tested, Syn. Cecei seemed to be the most sensitive. It was even more responsive to the salt treatments than lettuce, a crop regarded expressly salt-sensitive by several authors. Fehérözön and K.M.622 showed the least sensitivity among sweet pepper varieties.

The sweet pepper varieties (except Syn. Cecei) started to germinate even in solutions of EC higher than 20 mS/cm. Lettuce proved to be unable to germinate above 15 mS/cm and tomato above 20 mS/cm. This experience, however, doesn't prove that tomato is more sensitive than sweet pepper since a much higher percentage of diseased seedlings occurred in sweet pepper than in tomato. The number of healthy cotyledonous seedlings registered on the last day of the experiment proved, too, that tomato tolerates higher salt concentrations than sweet pepper.

In all the parameters tested, kohlrabi turned out to tolerate salt better than all other species tested.

Experiments in transplant raising

Trials with soil mixtures containing different doses of fertilizer

Studying the effects of soil mixtures containing different doses of fertilizer we have found that neither double nor fourfold doses of the recommended quantity of PG-MIX™ fertilizer have caused any damage in the sweet pepper transplants.

The high EC value of the watery extract of the soil mixture (4,08 mS/cm in the case of the highest fertilizer dose tested) hasn't caused any stress effect, in spite of 5,1-6,2% organic matter content by the method of Tiurin. Thus, the humus content may be regarded as medium. In vegetable forcing, the EC value mentioned above is very high. This may be due to the fact that the fertilizer granules dissolved by the preparation of the watery extract don't solve instantly in the soil solution but gradually with the diminution of the soil solution's concentration.

Transplant raising in soil mixture

Under glasshouse conditions, irrigation with KCl solution of 3 mS/cm EC hasn't significantly impaired the germination in a number of varieties in soil mixture. Higher doses have considerably hindered the germination of sweet pepper varieties and of tomato in the second series. Germination was 70% with the solution of 6 mS/cm, 35% with 9 mS/cm and below 20% with 12 mS/cm EC in every variety on the 20^{th} day. In these species, similary to the findeings in the laboratory tests, the slowing down of germination has been observed. Among sweet pepper varieties, Titán F_1 and HRF F_1 have better tolerated high salt concentration in both series and Pritavit F_1 has better tolerated high salt concentration in the second trial than the other varieties. However, decline has been found in these varieties, too, and germination was very poor with the highest salt concentration (12 mS/cm) in both series.

In lettuce, only the treatment 12 mS/cm has significantly diminished germination percentage to 45-47%. This seems to be inconsistent with the results of the laboratory trials and with publications on the sensitivity of the species. One has to bear in mind, however, the quick germination of lettuce seed. During the short germination period, much less salt gets into the soil by irrigation than in the course of the germination of sweet pepper and tomato seed. Thus, the results in lettuce mustn't be compared with the results in sweet pepper and in tomato. It is clear, however, that the quick germination of lettuce helps the crop to tolerate salty irrigation water in the early phase of development.

Kohlrabi has shown high salt tolerance of germination, in accordance with publications on the subject and with the results of our laboratory trials.

Plant height and stem diameter diminished with salt treatment in both series, particularly in the second one. Here, the nutrient solution with Volldünger, of 11,0 mS/cm EC (KCl EC=9 mS/cm), reduced plant height by 56,7-72% and stem diameter by 31,6-64,8%. In the treatment of EC higher than mentioned, none of the seedlings survived. In the first series, diminution hasn't been observed with the solution containing the lowest dose of KCl. In most cases, superior dry matter content of the top was found with increased salt concentration. This experience agrees with reports on other species.

Germination in rockwool

In rockwool, the 3 mS/cm treatment had no negative effect on germination tested on the 8th day after seeding, it was even helpful in several varieties (especially in Fehérözön and in Syn. Cecei). on the 14th day, however, such effect was found only in the first experiment.

On the 20th day (the most important day in cultivation practice as pricking is usually done at that time), even the lowest salt concentration proved to be harmful in several varieties. In these varieties, decline was above 20 per cent in several cases. In the first trial series and in the second one, the white, conical varieties showed the highest sensitivity. In the third series, each of the varieties was highly responsive to the treatments.

Soil mixture salt content tolerance of seedlings precultivated in rockwool

When the sweet pepper seedlings cultivated in rockwool till the 20^{th} day after sowing with solutions of 0 and 3 mS/cm EC were transplanted into soil mixture and irrigated with nutrient solutions of different KCl content, it was found that the vitality of the seedlings of the white conical fruited varieties precultivated with salt solutions-seemingly as developed and healthy as the seedlings pregrown with pure water - show poorer vitality following salt treatment in general than the latter ones. In the majority of the cases, the plants pretreated with salt solutions were less high than the seedlings precultivated with deionized water. The dry matter content increased in the treatments with salt (by 11,1 to 33,2%) but no close relation to salt quantity was found in every variety. In general, the pretreatment with salt resulted in lower dry matter content than the pretreatment with pure water (the differences were above 10% in several cases).

Experiments in forcing

Analysis of the vegetative parts

The diameter of the stem above the root neck hasn't shown explicit correlation with the treatments. As compared to the control treatment, stem diameter was bigger on medium salt

level at several dates of measurement, especially in the determinate growing variety Fehérözön. Diminution in stem diameter (1 to 12%) has been found merely in the treatment of the highest salt level (6,194g NaCl, EC 18 mS/cm). Thus, the stem diameter didn't indicate the phenomenon of becoming thin, regarded characteristic for salt damage in vegetable growing practice and in technical literature, too.

In 1999, the results of measurement of the **total leaf area** in the different treatments showed great dispersion in the series (repetitions) in most cases. The increasing salt concentrations have produced fluctuating changes in the averages of every single treatment. The application of the solution of medium salt content increased the leaf area of the Syn. Cecei variety by 19,2% as compared to the control. The leaf area of the plants decreased with higher salt concentrations but the varieties responded differently (10,8-30,7%).

The average length of the main stem diminished because of the salt treatment in almost every case (by 13,2 to 22,4% in two treatments of the highest salt level) according to the measurements in 2000. However, no significant differences have been observed.

There haven't been found changes in the **dry matter, nitrogen, phosphorus and potassium content of the leaves**.

The calcium and chlorine content in the leaves of the variety Fehérözön increased by the salt treatments. The increase in chlorine content was very high (107,0-280,3%).

In the course of the examination of **cuticular recretion** we have observed the dissolution of sodium and chlorine from the leaves. This may be especially important in field growing where the rainwater may wash out a part of the excreted sodium and chlorine.

The activity of peroxidase enzyme measurable in the leaves was different in the varieties. The varietal differences were noticeable in the control treatment, too. The varieties Fehérözön and HRF F1 responded with increased enzyme activity to 0,582 g/l and 2,123 g/l NaCl content of the nutrient solution, respectively (140,3-102,2% increase). This reaction indicates salt stress. The decrease of enzyme activity found in the following treatment may be explained, in our opinion, by tolerance resulting from stress effect. In the subsequent treatments, the peroxidase activity found in the leaves of the variety Fehérözön increased again, indicating the absence of tolerance of heavier salt effects. In the hot, pointed variety Titán F_1, the enzyme activity increased to a lesser degree (by 31,5% with the highest salt concentration applied). In the samples taken at later dates, the peroxidase activity, related to the protein content of the leaves, was lower than in the control treatment. Probably, other stress effects (temperature, temporary water shortage a.s.o.) have had part in this tendency. Relying upon these findings, other stress effects influencing peroxidase activity (temperature,

insolation, air humidity, moisture content of soil and plant) must be continuously controlled in the period before sample taking. The determination of the dry matter content of the samples and the reduction of the result to dry matter would be another solution.

Analysis of the generative parts

The treatments of high salt level have reduced the early and the total yield as well as the average daily weight increase of the fruits. 18 mS/cm reduced early yield by 13,0-40,4%, total yield by 16,3-33,4%, average daily fruit weight increase by 13,0-37,0%. The decrease was on 95-99% level statistically significant in numerous cases. The results measured in the intermediate treatments have shown differences according to varieties. Especially in the variety Fehérözön, these treatments didn't lag behind the control, moreover, they surpassed it in one of the years. The pointed, hot Titán F_1 and the tomato shaped Pritavit F_1 responded to the salt treatments like the white varieties.

The average number of fruit set per square meter as well as the number of the fruits that have reached market ripeness, diminished in general in the treatments of high sodium level (at the highest level by 20% in several cases but statistically not proved because of the great dispersion of the data). However, these parameters showed an improvement in the varieties Fehérözön and Syn. Cecei with the nutrient solution of 0,582 g NaCl content in the second year of the experiment.

The average length of the berries diminished with the higher salt doses (by 2,4-12,6%) but the diminution hasn't been statistically probable. The treatments of medium salt level caused in some cases a slight elongation of the fruit (by 0,6-4,7%).

The salt treatment hadn't any effect on **fruit diameter** (measured at the fruit shoulder). Statistically significant decrease in the length/diameter ratio was found only in the variety Titán F_1 (11%) in the first year of the trial.

Reduction in the **average fruit weight**, like in yield and in fruit length - was found in the higher salt treatments (in several cases statistically provable). Small fruit mass increase was observed in several varieties with the solution containing less NaCl.

The number of deformed and diseased fruits hasn't increased in every treatment. Several plots have shown considerable dispersion. In some varieties, deformed and diseased fruits were found in the control plots, while none were found in several treatments of high salt level. The very probable conclusion can be drawn that the symptoms may be produced by other environmental effects and not by salt treatment.

The dry matter content has increased in almost each of the treatments. There hasn't been found any significant change in the nitrogen, phosphorus and potassium content of the fruits

because of the salt treatment. **The calcium content** however, has shown an increase of 15-17% as compared to the control in the variety Fehérözön and there hasn't been any difference between the treatments of 10 and 18 mS/cm EC. In the variety Titán F1 a small increase of 9% was measured in only one of the samplings. **Chlorine content** of Fehérözön fruits was 90 to 125 per cent higher in the treatment 18 mS/cm than in the control.

In **sensory analysis**, the jury preferred in HRF F_1 the fruits of the plants treated with a solution of 14 mS/cm EC, however, the fruits of the control plants haven't much behind. From the other varieties, the control plants were held best, but in Syn. Cecei practically no difference was found between the first and the second level of treatment.

The **seed yield** of the fruits picked at full ripeness hasn't shown explicit correlation to the salt content of the nutrient solution. The laboratory tested germinating ability of the seed has been unchanged, indicating that the salt treatment didn't impair the proliferation of the plants. The thousand seed weight was significantly lower in the salt treatments than in the control, with the exception of the variety Boni. The decrease didn't coincide with the increase in salt content. It was of different rate (in several cases insignificant, but in some varieties higher than 20%).

On the basis of the observations made in the sweet pepper forcing experiment it can be stated that the treatments with NaCl, higher than 10 g/m^2:

- have reduced the leaf area, the height of the plants, the total and the early yield, the fruit set number per square meter, the average weight of the fruit (and, in some measure, fruit length, too), the taste and the thousand seed weight.
- They have increased the calcium and the chlorine content of the leaves and fruits and the dry matter content of the fruits and the peroxidase enzyme activity in the leaves.
- They haven't affected the dry matter content of the leaves, the nitrogen, phosphorus and potassium content of the leaves and fruits and the germinating ability of the seed.
- The effect on stem diameter and on seed production per fruit has been contradictory in some cases.

The effects of the intermediate treatments haven't been explicit in several cases.

The hot, pointed variety and the tomato shaped sweet pepper haven't shown expressly higher salt tolerance than the varieties of white fruit colour.

New scientific results

1. The salt sensitivity of sweet pepper manifests itself in the days following germination in the decay of seedlings, as opposed to tomato where germination doesn't start at all when EC value is unfavourable for the species.
2. The EC values measured in the watery extract of soil filled up with retarded fertilizers don't reflect the actual salt conditions prevailing in the soil.
3. When the irrigation water is of high salt content, good germinating vigour of the seed is highly advantageous for the emergence of the crop.
4. The seedlings irrigated with poor quality water (of high salt content) till the cotyledonous stage will show increased sensitivity to water quality in the later stages of their development.
5. The sweet pepper plant responds more sensitively to irrigation water of poor quality (of poor quality (of high salt content) at germination and the cotyledonous stage than in the later phenological phases.
6. NaCl given with the irrigation water in doses higher than 10 g/m2 weekly, affects adversely the development of sweet pepper in forcing.
7. Peroxidase activity in the leaves of the sweet pepper plant accurately reflects the physiological disorders resulting from unfavourable salt effects, thus, it can be regarded as a perspective method of predicting salt stress.