**Nodulation, Nodule Growth and Proton Release by Soybean Plants Cultivated in Hydroaeroponic System as Affected by Salinity and *Bradyrhizobium japonicum* Strains**

Mohamed A.N. Mohamed¹, El-Sayed M. El-Tantawy²

¹Soil and Water Department, ²Plant Production Department,
Faculty of Environmental Agricultural Sciences, Suez Canal University, El-Arish, Egypt

**ABSTRACT**

The present study aims to investigate the nodulation and nodule growth and proton release by soybean plants, Essor, inoculated with two strains of *Bradyrhizobium japonicum*, G49 and USDA122, tested for their salinity tolerance. The plants were cultivated in aerated saline solutions from the germination or 21 day after transplanting. By increasing salt concentrations, the strains were slowly grown. This effect was more obvious for strain USDA122 than G49 indicating that strain USDA122 was more sensitive to salts than the other one. Salt decreases the different parameters of plant growth. However, its effect was more pronounced in plants with early exposure to saline solutions. The nodule dry weight was the most affected. Nodule number was systematically less affected by salt than nodule mass. Plants inoculated with strain, G49 seem to be more tolerant than those inoculated with USDA122, especially for plants continuously growing in the high saline solution treatment. Salinity application significantly decreased the total proton release, whatever the strain used for inoculation. However, plants inoculated with strain G49 released more protons than those inoculated with the other bacterial strain. Increasing both of salinity concentration and time of application caused an increase in the values of specific proton release.

**Key words:** *Bradyrhizobium japonicum*, hydroaeroponic system, nodulation, salinity, soybean plants, proton.

**INTRODUCTION**

The vegetative production was highly limited by dinitrogen in saline zones. In the condition of limited available dinitrogen, the leguminous plants can grow better than the other plants since they can fix the atmospheric dinitrogen. Increasing salt concentrations limit and affect the dinitrogen symbiotic fixation (Lauter et al., 1981; Tu, 1981; Singleton and Bohlool, 1983, Abdel-Wahab et al., 2002).

The initiation of nodules was particularly sensitive to salinity. Survival and multiplication of rhizobia in the rhizosphere do not seem to limit the nodulation in saline medium. In fact, the majority of studied nodulating bacteria seem to be tolerant to salts rather than hosts plants. However, dinitrogen fixation by nodulated legumes which resulting from a molecular dialog between the micro and macrosymbiont and lead to nodules formation appears to be sensitive to salinity stress (Tu, 1981; Ikada, 1994).

The inhibition of infection may be related to a decrease of potential sites of infection which resulting from an inhibition either of root development (Ikada, 1994; Souissi, 2000) or elongation and curling of these organs (Lakashmi-Kumari et al., 1974; Tu, 1981; Zahran and Spret, 1986; Ikada, 1994). Saline culture media limit the plant nutrition by calcium which leads to an inhibition in root emergence and growth (Zahran and Spret, 1986; Zahran, 1999).

The inhibition of infection by salts seems to be due to the sensitivity of host plant rather than the direct effect on the microsymbiont (Singleton et al., 1982; Hafeez et al., 1988). However, other studies showed that salt effect occurs in late stages of the recognition plant host-bacteria. In white clover, the penetration of bacteria to root hair was inhibited by salts (Ikada, 1994). The ramification of infection filament and its migration through the root cortex is affected by salt stress (Bauer, 1981). Independent of its mode of action, the effect of salinity on nodulation was translated by a reduction in nodule number observed in several legumes, *Glycine max* (James et al., 1993; Abd-Alla et al., 1998); *Cicer arietinum* (Lauter et al., 1981; Ram et al., 1989; Elsheikh and Wood, 1990; Soussi et al., 1999); *Vigna radiata* (Hafeez et al., 1988); *Phaseolus vulgaris* (Saadallah et al., 2001). However, stimulation in nodulation was observed in some legumes grown under salt stress: faba bean (Yousef and Sprent, 1983) and some varieties of chick-pea (Soussi et al., 1999).

Increased acidification of the rhizosphere by roots is a widespread response to the nitrogen (N) nutrition of the plant, as related to the balance of cations over anions taken up and, also, to the source of N taken up. Indeed, N can be positively charged (ammonium) and favor large proton release, negatively charged (nitrate) and favor hydroxyl release, or uncharged in the case of legumes depending on N₂ fixation (Raven and Smith, 1976; Hinsinger et al., 2003). In the latter case, proton release and, hence rhizosphere acidification is expected to occur because of legumes reliant on N₂ fixation take up more cations than anions (Raven et al., 1990; Tang et al., 2001a, b). The effect of N sources and rhizobial strains inoculation on proton release in legumes were reported before (Fan et al., 2002; Hinsinger et al., 2003). However the intrinsic rhizobial strains effect on the proton release by soybean plants under salinity stress need more studies.

* Corresponding author: nasr_dana@yahoo.com
The majority of studies conducted on the interaction symbiotic dinitrogen fixation/salinity showed a decrease in nodule dry weight under salinity conditions. However, this behavior translates the simultaneous effects of salinity on either the nodules initiation or the growth of these organs. This study aims to determine: (1) the salinity tolerance of two *Bradyrhizium japonicum* strains, (2) the respective part of the two previous mentioned components (nodule initiation and growth) in the reduction of nodule dry matter in the soybean plants cultivated at different levels of salinity and (3) to which extent the salinity and the two rhizobial strains enhance proton release.

**MATERIALS AND METHODS**

**Tolerance of *Bradyrhizium japonicum* strains, G49 and USDA122 to salinity stress**

The two *B. japonicum*, strains G49 and USDA122 were tested for their salinity tolerance by analyzing the growth curve parameters. Strains were pre-cultured in 96-well microplates in YEM medium without agar. The growth of strains was monitored using a Microplate Reader (Thermomax, Molecular Device, USA). Each well was filled with 150 µl of liquid medium, containing 0 (S0), 1500 (S1500), 3000 (S3000) and 5000 (S5000) mg NaCl l−1 and inoculated with 10 µl of the strain pre-cultures (Mohamed, 2004). Each treatment was replicated for 4 times. Plates were incubated at 20 °C for 192 h. Optical density (Asiaa) was measured at 0, 24, 48, 72, 96, 120, 144, 168, 192 hours. Analyzed data were: (1) maximum growth (growth yield) estimated by the maximum optical density, (2) maximum growth rate estimated by the maximum increase in optical density per unit of time, and (3) apparent lag phase estimated by the time required to observe an increase in optical density (Mohamed et al., 2005). Variance analysis for maximal growth yield and maximal growth rate of each strain were performed using StatView Version 5 (SAS Institute Inc., USA) with the Fisher’s PLSD test at the probability level of 5%.

**Hydroaeroponic culture**

Plants were grown in nutrient solution. Soybean seeds (*Glycine max* L. Merril) Essor, were sterilized in Ca hypochlorite solution (70% active chlorine) for 20 min, rinsed several times with sterile water. Seeds were germinated for 5 d in the dark on fly screens covered with paper towels above an aerated nutrient solution containing 800 µM CaCl2 and 4 µM H3BO3. One seedling was transplanted (day 0) to 1 l bottle containing nutrient solution of the following composition (µM): KH2PO4, 250; K2SO4, 700; MgSO4, 500; CaCl2, 800; H3BO3, 4; Na2MoO4, 0.1; ZnSO4, 1; MnCl2, 2; CoCl2, 0.2; CuCl2, 1; and FeNaEDTA (ferric monosodium salt of ethylenediamine tetraacetic acid), 10 (Vadez and Drevon, 2001). Solution pH was adjusted every two days with KOH (0.01 M) to 7 during 0-42 day after transplanting (DAT) (Hinsinger et al., 2003). The bottles were wrapped with aluminum foil to keep the rooting environment in dark and to prevent the growth of algae. The roots were gently passed through the hole of a rubber stopper on the bottle neck, and cotton wool was fitted at the hypocotyl level. A dense water suspension of *B. japonicum*, strains G49 or USDA122 was added to the solution at a rate of approx 104 cells l−1. This solution was unchanged for 7 d and then renewed with added rhizobia. Seven days later, plants were placed in solutions without added rhizobia; solutions were then changed every week. Urea (0.2 mM N) was added for the first 14 days after transplantation (DAT). Thereafter, the plants did not receive any external source of N. This low N supply did not prevent the formation of nodules (Saadallah et al., 2001).

The seedlings were distributed in 5 treatments from the first day of transplanting. In the 1st treatment, seedlings were grown in control nutrient solution described above. In the 2nd and 3rd treatments, NaCl was added to distilled water in order to raise the salinity levels to 1500 (S1500), 3000 (S3000) ppm, respectively. The salts of nutrient solution were added to these saline solution at the same concentrations described above. The addition of NaCl to the seedlings in the 4th (BS1500) and 5th (BS3000) treatments were at the same salinity levels of treatments 2 and 3, respectively, but it’s application was delayed 21 DAT. Each treatment was repeated for four times.

The number of nodules was counted on intact plants 42 DAT and plants in the bottles were harvested. Plants were separated into shoots, roots and nodules. All plant tissues were oven-dried at 70 °C for 48 h. The dry nodules were split up into three classes by sieving. First correspond to nodules which have diameter superior than 1mm, second contains nodules of diameter ranged between 0.5 and 1 mm and the third contains the nodules less than 0.5 mm in diameter.

Total amounts of protons released by plants were determined by summing up the amounts of KOH used for pH adjustment during plant growth and for titrating the used solution after plant growth to the initial pH. Specific H+ release was expressed as the amount of H+ released per unit root biomass.

Variance analysis for total and specific proton release were performed using StatView Version 5 (SAS Institute Inc., USA) with the Fisher’s PSLD test at the probability level of 5%.

**RESULTS**

**Tolerance of *B. japonicum* G49 and USDA122 to salinity stress**

Growth curves at different salinity levels are shown in Figure (1A & 1B). The two strains exhibit the same rate of growth in the control media. By increasing salt
concentrations, the strains were slowly grown with an indication of longer lag times. This effect was more obvious for strain USDA122 than G49. During the period ranged between 72-144h, all strains at the different salinity concentrations were in the exponential phase of growth; afterwards the cultures entered the stationary phase. For each strain, maximum growth rate was not significantly different between the salinity treatments indicating that the increased salt concentration had no effect on this parameter. However, the maximum growth was significantly affected by salinity for each strain with a probability less than 0.0001. The values of the maximum OD_{590nm} ranged between 0.670-0.853 and 0.759-0.857 for USDA122 and G49 strain, respectively, indicating again that the strain USDA122 was more sensitive to the high salinity concentrations than the other one.

**Plant growth**

In the control nutrient solution, plants inoculated with the two rhizobial strains noticeably produced, in average, the same quantity of dry matter, a little more than 3.3 g plant\(^{-1}\) (Fig. 2). By increasing the salinity levels, the growth of plants decreased. In order to estimate the difference between plants inoculated with each strain, the index of saline sensitivity (SI) was used. This parameter corresponds to the difference between the dry matter production in saline solutions and those produced in control solution, expressed in a percentage of the latest. The values of this parameter were less than \(-35\%\) for plants inoculated with the two strains in the S\(^{1500}\) treatment. Plants express approx. the same sensitivity at this level of salinity. However, plants inoculated with \textit{B. japonicum}. G49 seem to be more tolerant than those inoculated with USDA122 at the S\(^{3000}\) since the SI was \(-42\%\) for the first and \(-49\%\) for the second.

The delayed salinity treatments also reduced the growth of plants. However, its effect was less pronounced than when salinity treatments were applied at the germination. The values of SI for plants growing at the belated S\(^{1500}\) and S\(^{3000}\) treatments ranged between 17-25 \%.

Values of the ratio root/shoot dry matters (R/S) were presented in Table (1). For plants inoculated with the two strains, this ratio tends to decrease in S\(^{1500}\) treatment as compared with control. This result seems to be related to the higher sensitivity of root than shoot at this level of salinity. However, R/S ratio in the S\(^{3000}\) treatment slightly increased as compared with S\(^{1500}\) treatment indicating that the shoot parts were more affected at this level of salinity than the roots. For the plants growing at the postponed salinities, the values of R/S ratio were more close to those of plants in control solutions than those growing in continual saline solutions. The plants presented the same variations of R/S ratio. However, the roots of plants inoculated with the strain \textit{B. japonicum B. japonicum} USDA122 were slightly more affected by saline solutions than those inoculated with \textit{B. japonicum} G49, especially for plants growing in continual saline solutions.

**Nodule initiation and developments**

In the control solution, plants inoculated with the strain \textit{B. japonicum} G49 slightly produce more nodule dry matter than those inoculated with the strain
USDA122 (Fig. 3A). The application of saline solution from the germination highly reduced nodule dry weight in plants inoculated with the two strains (plants inoculated with the strain G49 were less affected than those inoculated with the other one, especially at S1500 treatment). The delayed salt treatment caused also a decrease in nodule dry matter. However, its effect was less marked. Values of the ratio nodule/shoot dry matters (N/S) were presented in Table (1). For plants growing in control solution, the nodule dry matter represents approx 5-6 % of the shoot dry matter. This result showed a good nodule growth for plants inoculated with the two strains in the absence of salts. Increasing salinity from germination caused a high reduction of this ratio suggesting a particular sensitivity of nodules comparing with shoot parts. However, when the application of saline solution belated, the dry matter of the two organs reduced by the same manner.

The reduction of nodule dry weight results from either a decrease in nodule number, a reduction in the volume of these organs or as a result of these two parameters. The data shown in Figure (3B) demonstrate that the depressive action of salinity on nodule number was only obvious in plants growing continually in S3000 treatment. The delayed application of salinity does not seem to negatively affect the nodulation.

The reduction in nodule dry matter and number for plants growing in saline solutions are presented in Table (2). The decrease in nodule dry weight varied between -18 to -86.5 % according to salinity or strain treatments. Nodule number was less affected. Moreover, a slight stimulation in nodule number was observed for plants in belated salinity treatments. It seems that the reduction in nodule mass in these treatments is suggested to be due to the decrease in nodule growth more than the nodule initiation inhibition.

For the difference between plants inoculated with the two strains, it’s noted that at S1500 treatment, nodule dry weight and nodule number were more affected for plants inoculated with strain USDA122 than strain G49. This leads us to suggest that the nodulation and nodule growth were more sensitive to salinity for plants inoculated with the first than the second strain. At S3000 treatment, plants inoculated with G49 do not seem to maintain its superiority, especially at the level of nodulation.

The distribution of dried nodules according to their sizes showed that, for plants in control solution, the nodules of big and medium sizes were predominant and represented more than 90 %, in average, of whole nodules (Fig. 4). For plants growing in saline solutions, the nodules of big sizes became minorities. This effect was less marked when saline solutions treatments were belated. This schema of distribution was identical for plants inoculated with the two strains.

Table (1): Variation of dry matter ratios R/S, N/S and N/R as a function of salinity concentrations and its application time for soybean plants inoculated with Bradyrhizobium japonicum strains, G49 and USDA122.

<table>
<thead>
<tr>
<th>Plants inoculated with B. japonicum strain G49</th>
<th>Control</th>
<th>S1500</th>
<th>S3000</th>
<th>BS1500</th>
<th>BS3000</th>
</tr>
</thead>
<tbody>
<tr>
<td>R/S</td>
<td>0.26</td>
<td>0.22</td>
<td>0.23</td>
<td>0.24</td>
<td>0.24</td>
</tr>
<tr>
<td>N/S</td>
<td>0.06</td>
<td>0.03</td>
<td>0.01</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>N/R</td>
<td>0.25</td>
<td>0.16</td>
<td>0.06</td>
<td>0.21</td>
<td>0.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plants inoculated with B. japonicum strain USDA122</th>
<th>Control</th>
<th>S1500</th>
<th>S3000</th>
<th>BS1500</th>
<th>BS3000</th>
</tr>
</thead>
<tbody>
<tr>
<td>R/S</td>
<td>0.29</td>
<td>0.22</td>
<td>0.25</td>
<td>0.31</td>
<td>0.30</td>
</tr>
<tr>
<td>N/S</td>
<td>0.05</td>
<td>0.01</td>
<td>0.01</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>N/R</td>
<td>0.18</td>
<td>0.06</td>
<td>0.05</td>
<td>0.19</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Proton release
There was a net proton release by plants relying on N2-fixation. The amounts of total proton released by N2 fixing plants (15-42 DAT) as measured by pH-meter are shown in Table (3). Growing plants released protons and decreased the solution pH. Salinity application significantly decreased the total proton release, whatever the strain used for inoculation. However, plants inoculated with the strain G49 released more proton than those inoculated with the other strain.
The amounts of specific proton release (i.e., protons released per unit root biomass) at different salinity treatments are shown in Table (3). The lowest values of specific proton release were found in plants growing at control nutrient solution. Increasing both the salinity concentration and its time of application caused an increase in the values of this parameter. This effect was more obvious for plants inoculated with the strain G49 than those inoculated with the other one. Regardless of the salinity treatments, plants inoculated with the strain G49 release significantly more protons than the strain USDA122 since they released 1.06 and 1.00 nmol plant\(^{-1}\) s\(^{-1}\), respectively with a probability value of less than 0.0001. However, no significant difference was observed between the values of specific proton release for plants inoculated with strains G49 and USDA122 since the values of this parameter were 2.184 and 1.993 nmol g root DM\(^{-1}\) s\(^{-1}\), respectively, with a probability value of 0.2706.

**DISCUSSION**

The present study aimed to investigate the nodulation and nodule growth of soybean plants inoculated with two strains of *Bradyrhizobium japonicum* tested for their salinity resistant. The plants were cultivated at aerated saline solutions from the germination or at a belated manner after the establishment of the symbiotic organs. In soil system, the effect of salinity on the growth and survival of rhizobia and its distribution in the rhizospheres of plants was reported before (Jenkins et al., 1989; Tate, 1995). However, in the hydroaeroponic system, as rhizobia were only added to the nutrient solution in the first 14 d, the rhizobial population was expected to be very low in the nutrient solution after day 14 (Tang et al., 2001b). It is not

**Table (2): Reduction in nodules dry matter and nodules number as affected by salinity concentrations and its application time for soybean plants inoculated with *Bradyrhizobium japonicum* strains, G49 and USDA122.**

<table>
<thead>
<tr>
<th>Salinity Treatment</th>
<th>Reduction in nodule dry matter*</th>
<th>Reduction in nodule number*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>S(^{1500})</strong></td>
<td>-61.7</td>
<td>-86.5</td>
</tr>
<tr>
<td><strong>S(^{3000})</strong></td>
<td>-55.1</td>
<td>-18</td>
</tr>
<tr>
<td><strong>BS(^{1500})</strong></td>
<td>7.3</td>
<td>3.4</td>
</tr>
<tr>
<td><strong>BS(^{3000})</strong></td>
<td>-10.8</td>
<td>8.2</td>
</tr>
</tbody>
</table>

*The reductions were calculated as a percentage of control treatment.

**Table (3): Proton release by the roots of soybean plants as affected by salinity concentrations and its application time. Plants inoculated with *Bradyrhizobium japonicum* strains, G49 and USDA122.**

<table>
<thead>
<tr>
<th>Salinity treatments</th>
<th>Total proton release (15-42) nmol plant(^{-1}) s(^{-1}) (G49)</th>
<th>Total proton release (15-42) nmol plant(^{-1}) s(^{-1}) (USDA122)</th>
<th>Specific proton release (15-38) nmol g root DM(^{-1}) s(^{-1}) (G49)</th>
<th>Specific proton release (15-38) nmol g root DM(^{-1}) s(^{-1}) (USDA122)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1.112</td>
<td>1.017</td>
<td>1.591</td>
<td>1.326</td>
</tr>
<tr>
<td>S(^{1500})</td>
<td>1.020</td>
<td>0.983</td>
<td>2.507</td>
<td>2.385</td>
</tr>
<tr>
<td>S(^{3000})</td>
<td>1.029</td>
<td>0.995</td>
<td>2.822</td>
<td>2.919</td>
</tr>
<tr>
<td>BS(^{1500})</td>
<td>1.066</td>
<td>1.000</td>
<td>1.949</td>
<td>1.622</td>
</tr>
<tr>
<td>BS(^{3000})</td>
<td>1.071</td>
<td>1.006</td>
<td>2.051</td>
<td>1.715</td>
</tr>
<tr>
<td>Values of probability*</td>
<td>0.0083*</td>
<td>0.0129*</td>
<td>&lt;0.0001*</td>
<td>&lt;0.0001*</td>
</tr>
</tbody>
</table>

*The reductions were calculated as a percentage of control treatment.

\[(G49)\] Plants inoculated with *B. japonicum* strain G49, (USDA122)\[^{2}\] Plants inoculated with *B. japonicum* strain USDA122, * indicates a significant level at P < 0.05.
known whether the high salinity levels affect the nodule formation when the rhizobial population is low. In general, increasing salt concentrations may have a detrimental effect on microbial populations as a result of direct toxicity as well as through osmotic stress (Tate, 1995).

Successful Rhizobium-legume symbioses under salt stress require the selection of salt-tolerant rhizobial strain (Zahran, 1991a) since some legume hosts are less tolerant to salt than are their rhizobia. Although the root nodule-colonizing bacteria of the genera Rhizobium and Bradyrhizobium are more salt tolerant than their legume hosts, they show marked variation in salt tolerance. Growth of a number of rhizobia was inhibited by 100 mM NaCl (Yelton, 1983), whiles some rhizobia, e.g., Rhizobium meliloti, was tolerant to 300 to 700 mM NaCl (Mohammad, 1991; Embalomatís, 1994). The two tested rhizobial strains differed in their salinity tolerance since the strain G49 was more tolerant than the USDA122 strain. Variability in salt tolerance among crop legumes has been reported (Zahran, 1991a; Zahran, 1991b). Some legumes, e.g., Vicia faba, Phaseolus vulgaris, and Glycine max, are more salt tolerant than others, e.g., Pisum sativum (Zahran, 1999).

The legume-Rhizobium symbioses and nodule formation on legumes are more sensitive to salt or osmotic stress than are the rhizobia (El-Shinnawi, 1989). Salt stress inhibits the initial steps of Rhizobium-legume symbioses. Soybean root hairs showed little curling or deformation when inoculated with Bradyrhizobium japonicum in the presence of 170 mM NaCl, and nodulation was completely suppressed by 210 mM NaCl (Tu, 1981). In our experimental conditions, the different parameters of plant growth were affected even at 1500 ppm. This result confirms the particular sensitivity of soybean at this stressed condition. The modification of the dry matter distribution induced by salts between the shoot and root part was estimated by the variations between the ratio of roots/shoots dry matters. The results suggested that a specific inhibition of assimilates transport from shoot to root parts for plants growing at saline concentrations which translated by a decrease in the ratio of roots/shoots dry matters. This particular sensitivity of roots were found at saline conditions with other legumes; Medicago sativa (Brun, 1980; Bauer, 1981) Cicer arietinum, (Śliémi, 1996, Souissi, 2000).

The reduction in root growth was associated with an inhibition of nodulation, estimated by nodule number. This decrease was related to the diminution of potential sites of infection resulted essentially from an inhibition of root hair emergence and its development (Ikada, 1994; Souissi, 2000). Salt presence in culture medium limits the plant nutrition by calcium which leads to an inhibition in root emergence and growth (Zahran and Sprent, 1986).

The diminutions in nodule dry weight were more distinct than those of roots or shoots parts. The values of the ratios N/S or N/R were systematically reduced by salinity for plants inoculated with the two strains. According to Velagaleti and Marsh (1989), the diminution in nodule weights result from a reduction in quantity of photosynthesats which consecutively lead to a decrease in shoots parts development and a partial inhibition of photosynthesats transport to nodules. The results shown in the present study demonstrate that the reduction in nodule mass result from an inhibition of nodule initiation (estimated by nodule number) and/or the growth of these organs (estimated by nodule sizes). This second parameter seems to be more sensitive to salinity than the first one (Saadallah et al., 2001).

An interesting finding in this study is the intrinsic rhizobial strains difference in the relationship between root symbioses and proton release. It was observed that plants inoculated with B. japonicum, strain G49 released more protons than those inoculated with the other strain (Table 3). However, no significant difference was observed between plants inoculated either with strain G49 or USDA122 when released protons expressed per unit root biomass. This indicates that the rhizobia strain had no specific effect on proton release, but an indirect effect via increased N₂ fixation and plant growth. The increased salinity caused a reduction in proton release. This may be explained by the observed reduction in root dry matter as an effect of salinity and by its negative effect on the potential sites of proton release which resulting from an inhibition of root development. Salinity stress in the growing root medium limits the plant nutrition by calcium which leads to an inhibition in root emergence and growth (Zahran and Sprent, 1986).

Several studies showed that the salinity increase the resistance to oxygen diffusion in the nodules (Vance and Heichel, 1991; Drevon et al., 1994; Vadez et al., 1996) which lead to an inhibition of the nitrogenase activity. They showed that the increase in oxygen pressure in the media of nodulated roots permit to eliminate the inhibitor effect of salinity on the acetylene reduction activity.

Generally, the salinity inhibits the N₂ symbiotic fixation, at least by limiting the nodule functioning through a decrease in its conductance of oxygen diffusion. In these conditions, the establishment of high number of small nodules ensures that a bigger contact surface with the exterior media which favors an excellent entrance of oxygen to nodules. This may partially compensate the limitations in oxygen diffusion caused by salinity stress (Sheehy and Thornley, 1988).

REFERENCES


SLEIMI, N. 1996. Utilisation de critères physiologiques pour la recherche de variétés de pois chiche (Cicer arietinum) tolérant le sel. DEA, Tunis.

SOUSSI, A. 2000. Effets du sel sur le comportement physiologique du pois chiche (Cicer arietinum), en
relation avec le mode de nutrition azotée. DEA, Tunis, 2000.


Received July 19, 2008
Accepted February 25, 2009
مدى تأثير التعقيد ونمو العقد والبروتونات المنطقة من نباتات فول الصويا المنزوعة في نظام الزراعة الهوائية المائية بالملوحة والتفقيح بالبرادي ريزوبيا

محمد أحمد نصر محمد 1 و السيد محمد الطنطاوي 2
1 قسم الأراضي والطبيعة، كلية العلوم البيئية والزراعية، جامعة قناة السويس، العريش، مصر
2 قسم الأنتاج النباتي (الخضر)، كلية العلوم البيئية والزراعية، جامعة قناة السويس، العريش، مصر

المملوكت العربي

تم في هذا البحث دراسة تأثير التركيزات المتزايدة من كلوريد الصوديوم في مدى من 1500 إلى 5000 جزء في المليون على نمو سلالتين من براداي ريزوبيم جابوتيك في USDA122 G49. استخدمت هذين السلالتين في تلقيح نباتات فول الصويا (صنف أسسو) المنزوعة بنظام الزراعة الهوائية المائية في محايل ملحية طبقت من بداية الزراعة أو بعد استقرار تكون العقد (21 يوم من بداية الزراعة).

وقد أظهرت النتائج أن نمو النباتات وتكوين العقد الجذري وأخجامها قد تأثرت بزيادة تركيزات الملوحة ومع ذلك فإن هذا التأثير كان أكبر وضوحا على النباتات المنزوعة في المحايل الملحية من بداية الزراعة. وقد وجد أن الأوزان الجافة للعقد الجذرية كانت أكثر تأثيرا من أعداد العقد. كما لوحت أيضا تأثير نمو السلالتين بزيادة تركيزات الملوحة وكان تأثير الملوحة أكبر على USDA122 من USDA122 G49. مما يؤكد أن هذه السالة أكثر حساسية للملوحة من السلالة الأخرى. وقد انعكس هذه الملاحظة على مدى تأثير هذين السلالتين على نمو نباتات فول الصويا في المحايل الملحية. فقد أعطت السالة USDA122 G49 زيادة ملحوظة للقياسات سابقة الذكر عنها للسالة USDA122. خاصة للنباتات المنزوعة في محال ملحية عالية الملوحة. ان زيادة تركيزات الملوحة أدّى إلى انخفاض معنوي في كمية البروتونات الكلية المنطقة من جذور النباتات وذلك عند استخدام أي من السلالتين. وعلى الرغم من ذلك فإن فقد أعطت النباتات المنزوعة بالسالة USDA122 G49 زيادة ملحوظة في كمية البروتونات الكلية المنطقة من جذور النباتات عنها للنباتات المنزوعة بالسلاسل USDA122.