FLUORIDE UPTAKE IN HYDROPONIC CULTURE BY DIFFERENT CLONES OF BASKET WILLOW, SALIX VIMINALIS L.

A Telesiński, a M Śnioszek, a B Smolik, a K Malinowska, b M Mikiciuk, b J Cichocka, a H Zakrzewska a
Szczecin, Poland

SUMMARY: This study was conducted to determine the relationship in Hoagland’s hydroponic culture medium between fluoride at levels of 190, 380, 570, and 950 mg F/L and the ability of different clones of basket willow (Salix viminalis L.: ‘Bjor’, ‘Jorr’, and ‘Tora’) to take up F. After 14 days of exposure to NaF in the medium, the roots and leaves of seedlings of these three varieties of basket willow were collected for F analysis. The results indicated that all three clones have significant F uptake ability, most effectively at the lowest F concentration, and may therefore be useful to remediate F-contaminated soil.

Keywords: Basket willow; Fluoride uptake; Hydroponic culture; Phytoremediation; Salix viminalis L; Soil fluoride remediation.

INTRODUCTION

The increasing levels of soil contamination by environmental pollutants have prompted the search for non-invasive biological methods for their removal. With this end in view, appropriate plant species are being investigated, one of them being a bushy form of basket willow (Salix viminalis L.) with its excellent adaptability and broad ecological niche. Owing to its very dense root system, basket willow fulfills an important stabilization function in light and erosion-threatened soils because of its special predisposition to absorb and bioaccumulate various harmful chemical elements.

Fluoride in the form of HF is widely regarded as the third most important air pollutant after SO₃ and O₃. Most of the F in plants in airborne F polluted areas is taken up through the stomata in the leaves. F also enters soil in precipitation, dry deposition, and through contaminated litter. Under natural conditions the content of F in soil is rather low and is between 10–1500 mg F/kg soil. Nevertheless, human activities often lead to increased local levels of F in soil. HF and particulate F are emitted mainly from mining operations, fertilizers, and various kinds of chemical and metal manufacturing. In places where these activities exist, F pollution can usually be regarded as a local problem. However, soils that have received large doses of phosphate fertilizers are reported to have elevated levels of F as high as 5300 mg F/kg dw. Polluted soil can be a source of F for plants with F being taken up by the roots.

The purpose of this study was to determine the F uptake abilities from hydroponic cultures of three varieties or clones of basket willow, Salix viminalis L.

MATERIALS AND METHODS

In 2009, vegetation experiments by the hydroponic growth method were conducted under controlled conditions in the Department of Plant Physiology at

---

aFor correspondence: Department of Biochemistry, West Pomeranian University of Technology, Słowackiego 17, 71-434 Szczecin, Poland. E-mail: helena.zakrzewska@zut.edu.pl;
bDepartment of Plant Physiology, West Pomeranian University of Technology, Słowackiego 17, 71-434 Szczecin, Poland.
the West Pomeranian University of Technology in Szczecin. A two-factor experiment designed for complete randomization was set up for three replications. The first experimental factor was the F level in the hydroponic culture in the form of solutions of sodium fluoride (NaF). For the study, seedlings were grown in Hoagland’s complete hydroponic culture medium (pH 5.8). The second factor was the genotype of three clones of basket willow, Salix viminalis L.: ‘Bjor’, ‘Jorr’, and ‘Tora’.

Willow seedlings were collected from the plantation of the Department of Plant Physiology, where the maternal material came from Denmark. Willow cuttings (20-cm sections of annual shoots having at least 3–4 buds) were placed in 1-L containers filled with Hoagland’s complete medium. After 14 days, when the cuttings had taken root and the plant shoots were about 10 cm long, NaF was added to the individual containers to provide 10, 20, 30, and 50 mM F/L, corresponding to 190, 380, 570, and 950 mg F ion/L. During the exposure period the hydroponic cultures were aerated and supplemented with Hoagland’s complete medium to maintain constant volume.

After an additional 14 days, roots and leaves were collected. Each sample was oven-dried in paper sacks at 70ºC for at least 48 hr and analyzed for F according to the method of Szymczak and Grajeta. In addition, samples of the culture medium solution were also collected. F concentrations were determined in the presence of TISAB III buffer using the potentiometric method with an Orion Research ion-selective electrode.

**RESULTS AND DISCUSSION**

In the medium treated with 190 and 380 mg F/L, there were no visible signs of toxicity to the basket willow clones. With 570 mg F/L in the medium, toxicity was seen only in the ‘Jorr’ clone. Therefore the ‘Bjor’ and ‘Tora’ clones appear to have the ability to tolerate higher levels of F than the ‘Jorr’ clone, probably by excluding F at the roots or by detoxifying it at cellular levels in the plant. As has been reported, critical concentrations of F are highly dependent on plant species and cultivars. F toxicity in plants is normally manifested by marginal necrosis (tip-burn, scorching, or lesions) on foliage, which begins on the margin or tips of the leaves and moves inward. With 950 mg F/L in the culture medium, visible chlorosis and necrosis occurred in all three basket willow clones.

As seen in the Table, the greatest decrease of F in the culture medium occurred with 190 mg F/L. In pots where the ‘Jorr’ clone were placed, this decrease was the highest (51.30%). In the medium treated with 380–950 mg F/L the decreases were smaller, and varied between 12.39 and 29.71%. From the data, for whatever reason, it also appears that a notable increase in F removal occurred at 570 mg F/L compared to 380 mg F/L, especially with the ‘Bjor’ clone.
As seen in the Figure, the roots of examined clones accumulated more F than their leaves, and the amount of F in roots and leaves of the ‘Jorr’ and ‘Tora’ clones increased linearly with the concentration of F in medium. Similar findings are reported by Arnesen in studies with *Lolium multiflorum* and *Trifolium repens,*6 by Stevens et al. with *Avena sativa* and *Lycopersicon esculentum,*14 and by Gautam and Bhardwa with *Hordeum vulgare.*15 A study by Ruan et al. has also shown that F uptake by *Camelia sinensis* tea plants was linearly correlated to external F concentration and that the F taken up by tea plants was readily transported to the leaves.16 Santoz-Diaz and Zamora-Pedraza noticed that tea plants, *Camelia japonica,* and also *Pittosporum tobira,* and *Saccharum officinarum* are able to remove F from water with some degree of efficiency.17

Uptake of F by roots appears to be passive.18 Higher concentration of F in roots than in leaves is probably due to relatively low permeability through the endodermis.19 In the ‘Bjor’ clone, accumulation of F increased in the leaves but decreased in the roots with increasing concentration of F in the medium. Jha et al. reported that fluoride uptake by *Spinacea oleracea* followed a linear and sigmoid response in both the root and shoot, respectively.12 Additionally, among the three

### Table. The concentration of F in the Hoagland hydroponic culture medium at the beginning and at the end of 14 days of exposure to F

<table>
<thead>
<tr>
<th>Clone</th>
<th>Concentration of F in the culture medium at the beginning of experiment (mg/L)</th>
<th>Concentration of F in the culture medium at the end of experiment (mg/L±SD)</th>
<th>Decrease of F in culture medium (mg/L)</th>
<th>Decrease of F in culture medium (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bjor</td>
<td>190</td>
<td>98.57±3.93</td>
<td>91.43</td>
<td>48.12</td>
</tr>
<tr>
<td></td>
<td>380</td>
<td>294.67±7.64</td>
<td>85.33</td>
<td>22.64</td>
</tr>
<tr>
<td></td>
<td>570</td>
<td>400.67±7.51</td>
<td>169.33</td>
<td>29.71</td>
</tr>
<tr>
<td></td>
<td>950</td>
<td>832.33±8.62</td>
<td>117.67</td>
<td>12.39</td>
</tr>
<tr>
<td>Jorr</td>
<td>190</td>
<td>92.53±0.96</td>
<td>97.47</td>
<td>51.30</td>
</tr>
<tr>
<td></td>
<td>380</td>
<td>307.33±5.51</td>
<td>72.67</td>
<td>19.12</td>
</tr>
<tr>
<td></td>
<td>570</td>
<td>442.33±5.69</td>
<td>127.67</td>
<td>22.40</td>
</tr>
<tr>
<td></td>
<td>950</td>
<td>756.00±10.01</td>
<td>194.00</td>
<td>20.42</td>
</tr>
<tr>
<td>Tora</td>
<td>190</td>
<td>110.20±5.63</td>
<td>79.80</td>
<td>42.00</td>
</tr>
<tr>
<td></td>
<td>380</td>
<td>286.33±2.52</td>
<td>93.67</td>
<td>24.65</td>
</tr>
<tr>
<td></td>
<td>570</td>
<td>421.00±3.61</td>
<td>149.00</td>
<td>26.14</td>
</tr>
<tr>
<td></td>
<td>950</td>
<td>730.00±7.21</td>
<td>220.00</td>
<td>23.16</td>
</tr>
</tbody>
</table>
clones studied here, the highest accumulation of F in roots was in ‘Tora’, and in leaves, it was in ‘Jorr’.

**CONCLUSION**

F uptake from hydroponic culture media by three clones of basket willow was found to be related to the F concentration in the medium and kind of clone. The results indicate that all three clones can probably be useful to remediate F-contaminated soil.

**REFERENCES**


17 Santoz-Diaz MdS, Zamora-Pedraza C. Fluoride removal from water by plant species that are tolerant and highly tolerant to hydrogen fluoride. Fluoride 2010;43(2):150-6.
