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Effect of fulvic and humic organic acids and calcium on growth and chlorophyll content of tree species grown under salt stress

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Abstract: The use of salt to malt ice has definite effects on the environment. Some of these environmental effects are: soil erosion, environmental pollution, changes in mineral nutrition or general destruction of the physiological processes of plants. This use of salt has a negative impact on roadside vegetation and sustainability. The objective of the presented study was to investigate the effects of fulvic and humic organic acids as well as the calcium on growth and chlorophyll content of seven tree species grown under salt stress. Two year old seedlings of – *Acer campestre, Acer platanoides, Acer pseudoplatanus, Acer tataricum* ssp. *ginnala, Ginkgo biloba, Platanus ×hispanica* 'Acerifolia' and *Tilia cordata* were planted to plastic pots (2 dm^3 vol). They were planted outdoors in a growing medium compound which had high sphagnum peat, grainy sand and composted pine bark. Salinity stress was maintained by irrigating plants with tap water containing 3.3 g NaCl/L H_2O. Different organic fertilizers were used to redce the risk of nutritional stress caused by salinity. Salinity in the growing medium limited the growth of two maple species and littleleaf linden. In other species such *A. campestre, A. tataricum* ssp. *ginnala, G. biloba* there were no significant differences when compared to the control group of plants. Severe leaf damage was observed on *A. paltanoides* where leaf burning was seen on up to 30 % of the leaf blade surface. The response to salinity of other species like *A. pseudoplatanus, A. tataricum* ssp. *ginnala*, and *T. cordata* was less evident. Humic organic acids applied alone to the growing medium improved the growth of all the maple species when compared to the control group. A calcium had the best effect on the growth of all tested trees except *A. tataricum* ssp. *ginnala* and *G. biloba*. The chlorophyll content index (CCI) differed according to the growing medium treatment and the species. The total CCI ranged from 9.62 for the control plants *P. ×hispanica* 'Acerifolia' to 52.64 for *G. biloba* which had been treated with a calcium. Application of organic fertilizers to the salt treated growing medium increased the CCI in many species.

Additional key words: chlorophyll content, salinity stress, ornamental trees

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Introduction

In northern hemisphere countries soil salinity is not as great a problem as it is in the semi-drought regions of the world. In Poland, however, like in many other northern countries, tons of salt are used every winter on roads to maintain safe driving conditions. The most often used de-icing agent is sodium chloride. It is frequently mixed with sands and sometimes an anti-caking agent. This salt mixture is applied in solid or liquid form at a rate of 10–40 g m^{-2}, depending on the weather conditions. The use of NaCl results in increased corrosion of both vehicles and road surfaces, damage to roadside vegetation, and the contamination of groundwater and surface waters, 75–90% of the added salt enters the roadside environment via run off or splashing (Green and Cresser 2008). Road side soils and plants, especially trees and shrubs, are exposed for decades to road salt. Woody plants grown near the roads are force-fed by salt and this has a negative effect on their growth and decorative value (Marosz 2004). Salinity dominated by Na+ salt reduces the Ca2+ availability, transport, and mobility to growing regions of the plant. This affects the quality of both vegetative and reproductive organs (Rengel 1992). Higher calcium nutrition for plants grown under salinity stress is valued and could reduce the concentration of Na ions in plants (Kaya et al. 2003; Marosz and Nowak 2008).

The high impacts of Na+ and Cl- on N cycling may be envisaged. There have been few studies to date that focus on such impacts (Green and Cresser 2008; Green et al. 2008). Road salts also may increase organic colloid mobility and alter the structure of the soil (Norrström and Bergstedt 2001). A high exchangeable sodium percentage and low salt solution concentration lead to enhanced dispersal of soil colloids (Shainberg and Letey 1984). Thus it may be further hypothesized that salting will lead to a reduction in the organic matter content of the soil which is adjacent to the roads. Soil aggregate stability deteriorates through the accelerated leaching of calcium and magnesium ions from the soil exchange sites as a result of enhanced competition with sodium ions (Bäckström et al. 2004; Norrström and Bergstedt 2001). This, reduce bonding with the organic matter that aids flocculation and soil structural stability. Green and Cresser (2008) predicted that high sodium inputs lowered organic matter content in soils close to roads.

Chlorophyll content is a direct indication of plant heath and physiological well being. A plant's photosynthetic potential is directly proportional to the quantity of chlorophyll present in the leaf tissue. This parameter is fundamental to understanding a plant's response to the environment in which it resides. Remotely sensed measurements of this parameter could provide information about the status of the plant without the use of destructive tissue sampling (Schepers et al. 1992). Despite the fact that reflectance spectroscopy can provide considerably more data than hand-held Chl absorbance meters, there is no evidence that more is actually better. Biber (2007) found that the chlorophyll content index as measured by the Opti-Sciences CCM-200 was correlated positively with 90% acetone extracted Chl *a* content in three plant species, including one grass (family *Poacae*), one rush (family *Juncaceae*) and one tree (family *Rhizophoraceae*). As he reported the strength of the correlation varied by species. Once more the two species with flat leaves (*S. alterniflora* and *R. mangle*) showed better correlation between the CCI and Chl *a* content, presumably because a flat leaf is better at reflecting and transmitting the LED light to the detector in the CCM-200 (Biber 2007).

This paper examines the effect of some organic component additions to a saline treated growth medium on the growth of seven tree species often used for planting along roads. The chlorophyll content index as a direct indication of a plant's condition was also examined in this study.

Material and methods

Plant material

Two years old seedlings (bare root) of the following seven species of trees were used: *Acer campestre* L. (Field maple), *Acer platanoides* L. (Norway maple), *Acer pseudoplatanus* L. (Sycamore maple), *Acer tataricum* L. ssp. *ginnala* Maxim. (Amur maple), *Ginkgo biloba* L. (Ginkgo), *Platanus* ×*hispanica* (Ait.) Willd. 'Acerifolia' (London planetree), *Tilia cordata* Mill. (Littleleaf linden). The seedlings were obtained from a commercial nursery, in Opoczno, Poland. At the end of April in 2007 and 2008 they were planted to plastic pots (2 dm^3 vol) in a growing medium which contained high sphagnum peat, grainy sand, and composted pine bark (80%:7%:13% by volume). The plants were grown outside. Automatic sprinklers were used and were switched off on the days when the plants were given salt treatment and being fertilized.

Salt treatment and organic fertilizing

One salinity level was maintained by irrigating plants with tap water containing 3.3 g NaCl/L H_2O. This salt dose was previously established on by Marosz and Nowak (2008). Three different organic fertilizers were used for reducing the risk of nutritional stress caused by the high salinity growth medium. These three were: 1) liquid organic fertilizer – rich in fulvic acids (30% by weight – Sollum F30), 2) liquid organic fertilizer with an organic calcium complex (11% CaO by weight – Radix-Cal) and 3) grainy organic fertilizer rich in humic acids (76% humic acids by weight and 4% fulvic acids by weight – Solum H80). Humic acids were applied once only to four tree species. The fertilizer was applied at a dose of 1g per plant under their roots during the planting process. The reason for applying only to four species was the fact that there were a limited number of the three other plant species. Plants were irrigated using: pure water, a sodium chloride solution, a fertilizers solution, fertilizers and a sodium chloride solution. The NaCl dose was the same each time. The electrical conductivity (EC) and pH of water, soil and the fertilizer solutions is presented in Table 1. The highest EC was

Table 1. Electrical conductivity (EC) and pH of water, NaCl solution and fertilizers solutions used for trees irrigation in the experiment (mS cm^{-1})

Parameter	Control (tap water)	NaCL (3.3 g · l^{-2})	Solum F30 (10 ml · l^{-2}	Solum F30 + NaCl	Radix-Cal (10 ml · l^{-2})	Radix-Cal + NaCl	Solum H80 (1 g · l^{-2})	Sollum H80 + NaCl
EC	0.57	6.83	1,13	6.79	6.29	11.4	–	–
pH	6.85	7.11	6.44	6.60	6.21	6.45	–	–

noted in the case of the calcium organic complex and sodium chloride solution (11.4 mS cm^{-1}), the heights pH was in the sodium chloride solution. Saline treatment began thirty days after planting, and started 29.05.2007. The trees were irrigated eight times during the growing season with seven days intervals and 150 ml of solution per plant was added each time. The experiment was repeated during the same months in 2008. Control plants were irrigated with tap water; EC 0.5 mS cm^{-1}.

Measurements

Plant height was evaluated in each September of the experiment. Soil samples for EC and pH determinations were taken every three weeks starting on May 30. Ten samples for each combination were collected from the middle part of the growing medium. EC and pH levels were measured using the multi-parameter analyzer (Eijkelkamp – Agrisearch Equipment, Netherlands). Chlorophyll content index (CCI) was measured using the CCM – 200 Chlorophyll Content Meter (Opti-Sciences Inc. USA), which calculates a chlorophyll content index (CCI) based on absorbance measurements at 660 and 940 nm. The claimed accuracy of the CCM-200 is ± 1.0 CCI units. The CCI was measured on five mature leaves on every plant in the experiment ($n=80$). The Opti-Sciences CCM-200 is marketed as an instrument that provides fast, accurate chlorophyll readings on the intact leaves of plants and crops, without the need for grinding or destructive chlorophyll assays (Biber 2007). At the end of each growing season a visual estimation (according to visual estimation range presented beneath), of leaf appearance of trees grown under salt stress with organic fertilizers, was also made. Visual estimation range: 1 – leaves normal with no side effect; 2 – yellowish and edge burnings not more than 10% of leaf blades; 3 – yellowish and edge burnings on 10–30% of leaf blades; 4 – yellowish and leaf burnings on 30–50% of leaf blades; 5 – yellowish and leaf burnings more than 50% of leaf blades; 6 – leaves dying back and dropping.

Statistical analysis

The experiment took place in 2007 in randomized block design, and there were four replicates with four plants in replicate. The experiment was repeated again in 2008. The data were analyzed statistically with ANOVA and are presented as means for two years. To establish significance of differences between means Duncan's Multiple Range Test was used.

Results

Salinity and pH changes in the growing medium

Electrical conductivity of the growing medium varied the dependence of the solution used for irrigation. According to data from Table 2, EC of the growing medium in the control plants was stable during the seasons. The humic acids (Sollum H80) were also stable. EC of the growing medium of trees irrigated with fulvic acids (Sollum F30) was higher but on the same, quite stable level – about 0.25–0.3 mS cm^{-1}. Radix-Cal had a great effect on increasing electrolitical conductivity of the growing medium with the tested fertilizers. EC of the growing medium of trees grown under

Table 2. Changes in electrical conductivity (mS cm^{-1}) of growing medium with different organic component during the seasons 2007 and 2008 (means of two years)

Date of maesurements	30.05	06.06	20.06	05.07	05.08	28.08
Control	0.164a	0.181a	0.166a	0.172a	0.173a	0.143a
NaCl 3.3g · l^{-1}	0.382d	0.428e	0.592d	0.663d	0.819d	0.891d
Solum F30 10ml · l^{-1}	0.249b	0.348cd	0.255b	0.261b	0.287b	0.259b
Solum F30+ NaCl	0.366cd	0.411de	0.560d	0.603d	0.639c	0.739d
Radix-Cal 10ml · l^{-1}	0.249b	0.248b	0.486c	0.463c	0.394b	0.404c
Radix-Cal + NaCl	0.327c	0.328c	0.635e	0.708d	0.680cd	0.672d
Solum H80 1g · l^{-1}	0.186a	0.201ab	0.167a	0.186a	0.187a	0.162a
Solum H80 + NaCl	0.303b	0.308c	0.543d	0.570c	0.601c	0.587cd

*Note – results within each date of measurements denoted by the same letter do not differ significantly according to Duncan's Multiple Range Test.

Table 3. Changes in pH level of growing medium with different organic component during the seasons 2007 and 2008 (means of two years)

Date of maesurements	30.05	06.06	20.06	05.07	05.08	28.08
Control	6.82ab	7.31b	7.33b	7.19a	7.31a	7.24a
NaCl 3.3g $\cdot l^{-1}$	6.75ab	7.46bc	7.1ab	7.35ab	7.47ab	7.56b
Solum F30 10ml $\cdot l^{-1}$	6.64a	6.91a	6.87a	7.22a	7.37a	7.31a
Solum F30+ NaCl	6.79ab	7.4bc	7.6bc	7.25a	7.44ab	7.25a
Radix-Cal 10ml $\cdot l^{-1}$	6.73ab	7.34b	7.11ab	7.48bc	7.47ab	7.42ab
Radix-Cal + NaCl	6.86ab	7.81c	7.34b	7.56cd	7.57b	7.58b
Solum H80 1g $\cdot l^{-1}$	6.94ab	7.76c	7.43b	7.69d	7.76c	7.79c
Sollum H80 + NaCl	7.1b	7.94.c	7.8c	7.6cd	7.63bc	7.59b

*Note – results within each date of measurements denoted by the same letter do not differ significantly according to Duncan's Multiple Range Test.

high impacts of NaCl constantly grew from 0.38 mS cm^{-1} from the first time of measurements to 0.89 mS cm^{-1} at the end of the experiment. This was the highest in this study. Using fulvic and humic organic acids and calcium to break the negative effect of increasing electrolitical conductivity of the growth medium with high impact of NaCl was disappointing. EC of a growth medium with fulvic acids and organic calcium do not differ significantly from a growing medium with NaCl only. However, application of fulvic acids (Solum H80) distinctly lowered the salinity of the growing medium. The salinity level was much lower than in the sodium chloride combination (Table 2). Changes in the pH of the growing medium are less evident. Soil pH measured after the first saline treatment in the control plants was a little bit higher than in other combinations, except the medium mixed with humic organic acides. This small rise was not statistically important. Data varied from 6.64 when fulvic acids were added to 7.1 with the humic acid application to the growing medium. At the end of the experiment a higher pH level was noted in almost all the cases in which NaCl was used for plant irrigation, excluding the combination where fulvic acids were used (Table 3). Humic acids, in which the pH of the growing medium was the highest in the experiments did not show such a tendency.

Plant growth and leaf damage

The control plants did not receive the saline treatment nor were they fertilizied. After 125 days their yarly growth height varied among the species. Less growth was noted in *A. platanoides*. *P. ×hispanica* 'Acerifolia' showed the most growth. The mean was 6.97 cm and 52.12 cm respectively (Table 4). The salinity level in the growing medium limited the growth of two maple species and of littleleaf linden. In other species such as *A. campestre, A. tataricum* ssp. *ginnala, G. biloba* there were no significant differences compared to the control plants. When only humic organic acids were applied to the growing medium it improved the growth of all maple species compared to the control group. The organic calcium had the best effect on growth tested trees with the exception of. *A platanoides* and *G. biloba* (Table 4). Organic acids and calcium used for improving growth under salt stress worked very well. The most effective was the calcium. It had a very positive effect on growth in the saline treated growing medium for all tested species. This combination proved especially true for *P. ×hispanica* 'Acerifolia' (Table 4). Fulvic acids were less effective as well as humic acids; only *T. cordata* plants grew better compared to the plants grown under salt stress only.

Table 4. The plants height (cm) grown under salinity stress with different organic component in growing media

Species	*Acer campestre*	*Acer platanoides*	*Acer pseudoplatanus*	*Acer tataricum,* ssp. *ginnala*	*Ginkgo biloba*	*Platanus ×hispanica* 'Acerifolia'	*Tilia cordata*
Control	8.38a	6.97b	5.16a	31.3ab	6.44ab	52c12ab	10.28b
NaCl 3.3g $\cdot l^{-1}$	9.92a	4.65a	7.25b	28.62a	5.1a	52c11ab	3.86a
Solum F30 10 ml $\cdot l^{-1}$	15.72b	8.67c	14.98c	41.3c	7.91b	57c77ab	9.25b
Solum F30+ NaCl	14.52b	5.68ab	16.62c	41.2c	6.97ab	55c38ab	11.18.c
Radix-Cal 10ml $\cdot l^{-1}$	14.3b	7.3b	14.62c	34.53b	5.61.ab	61.9c	13.89c
Radix-Cal + NaCl	15.72b	7.73b	12.82c	44.51.c	6.74ab	71.57d	9.4b
Solum H80 1g $\cdot l^{-1}$	–	5.97ab	–	33.0b	6.18ab	48.6a	7.22b
Solum H80 + NaCl	–	4.97a	–	30.62ab	5.81ab	–	8.48b

*Note – results within each species denoted by the same letter do not differ significantly according to Duncan's Multiple Range Test.

Table 5. Visual estimation of leaves appearance of trees grown under salt stress with different organic component in growing media

Species	*Acer campestre*		*Acer platanoides*		*Acer pseudoplatanus*		*Acer tataricum,* ssp. *ginnala*		*Ginkgo biloba*		*Platanus ×hispanica* 'Acerifolia'		*Tilia cordata*	
Date of observation	1.08. 2008	4.09. 2009	1.08. 2008	4.09. 2009	1.08. 2008	4.09. 2009	1.08. 2008	4.09. 2009	1.08. 2008	4.09. 2009	1.08. 2008	4.09. 2009	1.08. 2008	4.09. 2009
Control	1.0a*	1.0a	1.0a	1.0a	1.0a	1.0a	1.0a	1.0a	1.0a	1.0a	1.0a	1.0a	1.0a	1.0a
NaCl 3.3g · l^{-1}	1.9c	2.1c	3.5d	3.6d	2.6d	2.7c	2.2bc	2.5cd	1.3b	2.0c	1.0a	1.7b	2.6b	2.8b
Solum F30 10 ml · l^{-1}	1.1ab	1.5b	1.4ab	1.7b	1.1ab	2.0b	1.6b	1.5ab	1.0a	1.5bc	1.1a	1.1a	1.3a	1.3a
Solum F30+ NaCl	1.3b	1.8bc	3.0c	3.5d	1.6bc	1.9b	1.6b	1.9bc	1.4b	2.1c	1.1a	1.3ab	2.8b	3.1b
Radix-Cal 10ml · l^{-1}	2.0a	2.1.c	1.3ab	1.7b	1.0a	1.1a	2.9c	3.0d	1.0a	1.0a	1.2a	1.1a	1.0a	1.0a
Radix-Cal + NaCl	2.0a	2.4c	2.3bc	2.5c	1.7c	1.9b	2.8c	2.9d	1.0a	1.3ab	2.1b	2.1c	1.0a	1.0a
Solum H80 1g · l^{-1}	–	–	1.4ab	1.9b	–	–	1.4ab	2.0bc	1.0a	1.0a	1.9b	1.9bc	1.0a	1.0a
Solum H80 + NaCl	–	–	2.0b	2.2bc	–	–	1.1a	2.2bc	1.0a	1.0a	–	–	1.0a	1.0a

*Note – results within each species and date of measurements denoted by the same letter do not differ significantly according to Duncan's multiple range test, at p= 0.05

Visual estimation range: 1 – leaves normal with no side effect; 2 – yellowish and edge burnings not more than 10% of leaf blades; 3 – yellowish and edge burnings 10-30% of leaf blades; 4 – yellowish and leaf burnings 30–50% of leaf blades; yellowish and leaf burnings more than 50% of leaf blades; 6 – leaf dying back and dropping.

The visual effect of salt stress was observed on the leaves of almost all trees species except *P. ×hispanica* 'Acerifolia'. However the most severe leaf damage was observed on *A. platanoides* where leaf burnings was seen on up to 30 % of the leaf blades surface (Table 5). The response of other species such as *A. pseudoplatanus*, *A. tataricum* ssp. *ginnala*, and *T. cordata* was less evident. *Acer campestre* and *G. biloba* showed only a little leaf yellowing, as did *P. ×hispanica* 'Acerifolia' during the second observation made on the end of the experiment (Table 5). Application of organic fertilizers improved the appearances of many examined species grown under salt stress. This is well demonstrated on *A. paltanoides,* where overall appearance were improved when organic acids or calcium complex were added to the salinized growing medium. The results from the Table 5, show that the organic calcium was less effective, especially on *A. campestre* and *P. ×hispanica* 'Acerifolia'. These species demonstrated high soil salinity tolerance. The leaves of control the plants were light green in comparison to the leaves of plants grown with organic fertilizing with or without sodium chloride (omitting damages caused by NaCL).

Chlorophyll content index (CCI)

CCI differed according to the growing medium treatment and the species. Total CCI ranged from 9.62 for control plants of *P. ×hispanica* 'Acerifolia' to 52.64 for *G. biloba* treated with the calcium. Generally the highest chlorophyll content was obtained in the leaves of *G. biloba* and the lowest in *P. ×hispanica* 'Acerifolia' irrespective of the medium treatment (Table 6). Only two species *A. platanoides* and *G. biloba* grown under salt stress had a lower CCI than the control one. Two others – *A. campestre* and *T. coradata* – showed a higher CCI than the control plants. *Acer pseudoplatanus, A. t.* ssp. *ginnla* and *P. ×hispanica* 'Acerifolia' had a similar concentration of chlorophyll in the leaves of the trees grown under salt stress as

Table 6. Chlorophyll content index (CCI) in the leaves of trees species grown under salinity stress with different organic component in growing media

Species	*Acer campestre*	*Acer platanoides*	*Acer pseudoplatanus*	*Acer tataricum,* ssp. *ginnala*	*Ginkgo biloba*	*Platanus ×hispanica* 'Acerifolia'	*Tilia cordata*
	Chlorophyll Content Index (CCI)						
Control	23.3a	22.3bc	18.94a	21.83a	34.73b	9.62a	13.91a
Solum F30 10 ml · l^{-1}	26.3b	20.53b	15.58a	27.29b	37.14b	11.95a	17.28b
NaCL 3.3g · l^{-1}	25.5b	17.32a	17.0a	19.97a	26.97a	10.0a	19.82bc
Solum F30+ NaCl	27.2b	23.0bc	16.96a	21.66a	46.91c	11.61a	20.31bc
Radix-Cal 10ml · l^{-1}	23.9a	23.3bc	30.96b	42.92.c	52.64c	19.61b	35.5cd
Radix-Cal + NaCl	27.9b	24.64c	30.55b	43.46c	51.86c	22.3b	30.2d
Solum H80 1g · l^{-1}	–	17.46a	–	20.32a	34.31b	12.58a	13.98a
Solum H80 + NaCl	–	16.9a	–	21.4a	30.2b		16.28b

*Note – results within each species denoted by the same letter do not differ significantly according to Duncan's Multiple Range Test.

well as the control one. Organic fertilizers improved the concentration of chlorophyll in the leaves. Calcium showed very good result. However, no significant differences were observed in the control plants *A. campestre* and *A. platanoides*. Solum F30 rich in fulvic organic acids did not work effectively on *A. pseudoplatanus, G. biloba* and *P. ×hispanica* 'Acerifolia'. Solum H-80 containing humic organic acids ws completely ineffective in raising chlorophyll content in leaves of the tested four trees species. CCI of *A. platanoides* leaves was even higher in control plants than in those treated with humic organic acids (Table 6).

Discussion

A number of woody plants cannot grow well in a saline environment. This is because an excess of soluble salts in the soil cause the osmotic potential increase of the soil solution, making it difficult for the roots to absorb the water. This was the main reason for growth retarding of *Potentilla fruticosa* and *Cotoneaster horizontalis* grown under high salinity stress (12 mS·cm) (Marosz 2004). However in this study the main reason for growth retarding, especially in the control plants, was the poor nutrient status of the medium. No mineral nor organic nutrition had been provided. The control and salt stressed plants of species quite tolerant to salinity stress like *A. campestre*, A. *tataricum* ssp. *ginnala*, *G. biloba*, and *P. ×hispanica* 'Acerifolia' reached similar growth heights in all combinations probably for this reason. In contrast trees that are known to be sensitive to the stress of salinity, for example: *A. platanoisdes*, *A. pseudoplatanus*. *T. cordata* (Marosz and Nowak 2008), were obvisiously smaller under salt stress than the control ones. In addition to growth inhibition high soil salinity often causes strong leaf-damage and defoliation of trees (Loupassaki 2002; Marosz 2004). The most evident leaf-damage was observed on three *Acer* species and *Tlilia cordata* when they were under salt stress. Using an organic component to improve the growing conditions helped to show a positive results and leaf damage on plants was less evident (Table 5).

The hypothesis of the possible influences of humic and fulvic organic acids, and the organic calcium on trees growth under salt stress had been positively noted. Organic matter is mobilized as a result of a high pH desorption process as well as via a loss of soil aggregate stability. This takes place following displacement of calcium and magnesium ions from soil organic matter cation exchange sites by sodium ions (Green and Cresser 2008). Nearly a century-old record reveals amelioration of sodic soils through the provision of a readily available source of calcium (Ca^{2+}) to replace excess Na^+ on the cation exchange complex. The displaced Na^+ being subject to leaching from the root zone through the application of excess irrigation water in the presence of a drainage system (Quadir et al 2007). Most of tested species reacted positively to organic nutrition. Both growth and overall appearance of the trees were better than under salt stress. Sodium has the opposite effect of salinity on soils. The primary physical processes associated with high sodium concentrations are soil dispersion and clay platelet and aggregate swelling. The forces that bind clay particles together are disrupted when too many large sodium ions come between them.

The amount of solar radiation absorbed by a leaf is largely a function of the foliar concentrations of photosynthetic pigments. Therefore low concentrations of chlorophyll can directly limit photosynthetic potential and hence primary production (Curran et al. 1990). Second, much of leaf nitrogen is incorporated in chlorophyll, so quantifying Chl content gives an indirect measure of nutrient status (Moran et al. 2000). Third, pigmentation can be directly related to stress physiology, as concentrations of carotenoids increase and chlorophylls generally decrease under stress and during senescence. Fourth, the relative concentrations of pigments are known to change with abiotic factors such as light (e.g. sun leaves have a higher Chl *a*: Chl *b* ratio; Larcher, 1995). Quantifying these proportions can provide important information about relationships between plants and their environment.

Results from this experiment show that using a Chlorophyll Content Meter (CCM –200) is a fast and efficient method to estimate the state of tree grown under salt stress. However as the Richardson et al. (2002) explain that when light hits a leaf, it can either be reflected from, absorbed by, or transmitted through the leaf. Because the function of Chl pigments is to absorb quanta of incident light, it could be hypothesized that instruments that estimate Chl content by directly measuring the amount of radiation absorbed (like CCM – 200) should be able to give better estimates of Chl content than those relying on reflectance measures. However, the results presented by this author indicate the opposite, namely that relative Chl content is best estimated by reflectance rather than absorbance. Further investigations on this subject are needed and will be continued.

Conclusion

1. Application of fulvic organic acids and a calcium has a positive effect on the growth and appearance of trees grown under salt stress. Chlorophyll content in the leaves measured by CCI was also higher compared to salt stressed plants. The most effective was the calcium.
2. Application of humic organic acids was not effective. Plant growth and chlorophyll content were similar to the salt treated or control plants.

3. The most sensitive to salinity stress was *Acer platanoides* followed by *A. pseudoplatanus*, *Tilia cordata* and *A. tataricum* ssp. *ginnala*. *Platanus* ×*hispanica* ‘Acerifolia’ can be classified as a species highly tolerant of salinity stress and very valuable for street and roadside planting. *Ginkgo biloba* showed quite a good resistance for sodium chloride stress.

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