



## APPLICABILITY OF FERTIGATION IN CULTIVATION OF SELECTED TAXA OF ORNAMENTAL SHRUBS\*

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### ABSTRACT

Fertigation is a measure that combines irrigation and plant nutrition, thus producing a synergistic effect. The aim of this study was to determine the applicability of fertigation in pot culture of selected taxa of ornamental shrubs: barberry (*Berberis xottawensis* var. Superba), juniper (*Juniperus xpfitzeriana* var. Mordigan Gold) and arborvitae (*Thuja occidentalis* var. Smaragd). Plants were grown in peat substrate and were fertigated with differentiated nutrient solution of the following chemical composition (mg dm<sup>-3</sup>): NS-I: N-NH<sub>4</sub> <10; N-NO<sub>3</sub> 120; P 50; K 100; Ca 100; Mg 50; Fe 1.2; Mn 0.3; Zn 0.50; Cu 0.03; B 0.011; pH 5.50; EC 1.60 mS cm<sup>-1</sup>; NS-II: N-NH<sub>4</sub> <10; N-NO<sub>3</sub> 160; P 60; K 130; Ca 110; Mg 60; Fe 1.5; Mn 0.4; Zn 0.50; Cu 0.04; B 0.011; pH 5.50; EC 2.00 mS cm<sup>-1</sup>. The control comprised plants grown using Controlled Release Fertilizer (CRF) Osmocote Exact Standard 5-6 M (2 g dm<sup>-3</sup> substrate). Fertigation with NS-I had a significant effect on the growth parameters of barberry (height, width, length of lateral shoots) and arborvitae (height, plant spread, plant projected area) in relation to the control. In contrast, the effects of fertigation in the case of juniper were multidirectional. The nutrition level significantly modified the chemical composition of plants. Fertigation using NS-I resulted in a significant improvement (in comparison to the control) in P plant nutrition at a simultaneous reduction of Mn and Cu levels (in barberry), and an improved nutrition with N, P, K, Mg and Zn at a simultaneous decrease in Cu content (in arborvitae), an improved nutrition with P, K and Mg (in junipers). In view of biometric parameters, the application of NS-I could be recommended in fertigation of barberry and arborvitae.

**Keywords:** juniperus, berberis, thuja, fertigation, nutrient solution, macroelement, microelement.

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## INTRODUCTION

Cultivation of ornamental plants in containers is widespread over the world, hence it is necessary to find the best solutions to grow them under optimum conditions (GAVAT et al. 2008). The methods for improving the efficiency of container crop production are still being sought after, among others, by the use of mixtures of substrates (MEISL 2006). A factor which significantly influences plant yielding is the application of fertilizers. In the opinion of BOSIACKI et al. (2011), Controlled Release Fertilizers (CRF) are frequently used in pot culture of ornamental shrubs, with the effect of controlled release of nutrients obtained owing to the application of biodegradable coating, e.g. composed of natural resin. These fertilizers enable the simplification of the whole plant nutrition and fertilisation system (SALAŠ 2004). Nutrients are gradually released to the substrate from fertilizer granules under the influence of steam when the inner osmotic pressure exceeds ambient pressure (SEMPEHO et al. 2014, RUTTEN 1980). If optimal temperature and moisture conditions for CRF application are maintained, this ensures gradual and universal release of nutrients throughout the plant growing period at a single application of fertilizer (GOLCZ et al. 2009, KOZIK et al. 2009, BOSIACKI et al. 2011). To improve this process, new coating technologies and blends of fertilizers coated for specific release rates are being employed to customize fertility for specific environments and crops (GRABLE et al. 2017). Fertigation is a different nutrient application method, combining irrigation and fertilization and producing a synergistic effect (XIUKANG, YINGYING 2016). Nutrients dissolved in water, typically at a low concentration, constitute a nutrient solution. An advantage of fertigation lies in the precise control of its chemical composition and adaptation to current nutrient requirements as well as developmental phase of plants (TREDER et al. 2007 after: BRAVDO, PROEBSTING 1993). Plant yielding under fertigation is superior to that obtained when using top-dressing and irrigation separately.

The species with medium nutritional requirements in nursery production are considered, among others *Berberis*, *Juniperus* and *Thuja*. However, there is a limited number of studies on the design of the chemical composition of fertigation nutrient solutions for these plants. For this reason, the aim of this study was to assess the applicability of fertigation nutrient solutions of varied chemical composition in nutrition of selected taxa: barberry (*Berberis ×ottawensis* var. *Superba*), juniper (*Juniperus ×pfitzeriana* var. *Mordigan Gold*) and arborvitae (*Thuja occidentalis* var. *Smaragd*) grown in a peat substrate.

## MATERIAL AND METHOD

Plant-growing experiments (2 independent cycles) were conducted from May to September in 2013-2014 (26<sup>th</sup> May - 16<sup>th</sup> September and 15<sup>th</sup> May - 26<sup>th</sup> September, respectively) in a greenhouse located at the Experimental Station of Departments of the Faculty of Horticulture and Landscape Architecture, the Poznań University of Life Sciences. The greenhouse was equipped with a modern climate control system. The aim of these experiments was to assess the effect of fertigation with nutrient solutions varying in their chemical composition (NS-I and NS-II) on the growth and yielding of selected taxa of ornamental shrubs grown in pots.

### Plant material

The experiments were conducted using the following taxa: *Berberis ×ottawensis* var. Superba, *Juniperus ×pfitzeriana* var. Mordigan Gold and *Thuja occidentalis* var. Smaragd. *Berberis ×ottawensis* var. Superba is a popular barberry *Berberis ×ottawensis* cultivar, considerably tall (up to approx. 3 m in height) and purple coloured, with large (up to 5 cm) entire leaves. It is recommended for planting in sunny locations to ensure better leaf coloring. *Juniperus ×pfitzeriana* var. Mordigan Gold is a shrub with a broad, sprawling habit, growing up to 2 m in diameter and approx. 1 m in height. Foliage is golden-yellow, with awl-shaped leaves remaining coloured throughout the year. This juniper cultivar has low soil requirements and it is recommended for planting in sunny locations. *Arborvitae* var. Smaragd is a highly popular shrub with a tapering, pyramidal, compact habit. It reaches approx. 6 m in height. Its evergreen foliage is rich green in colour. This shrub is typically recommended for hedges or espaliers.

Three nutrition levels were tested for each taxon, with each combination represented by 10 plants (3 nutrition levels x 3 taxa x 10 plants x 2 years = 180 plants). A replication comprised one plant.

### Nutrition levels

Plants were grown in highmoor peat substrate. Prior to pH adjustment, its chemical composition was as follows: NH<sub>4</sub> traces, NO<sub>3</sub> traces; P 1.98; K 14.3; Ca 61.5; Mg 42.4; Na 22.9; Cl 20.4; SO<sub>4</sub> 1.57; Fe 45.2; Mn 1.33; Zn 0.5 and Cu 0.60, at EC 0.12 mS cm<sup>-1</sup>. In order to obtain optimal pH for the tested taxa (5.0 - 5.5 for arborvitae and juniper; 6.0 - 6.5 for barberry) the neutralization curve was prepared using calcium carbonate. On its basis 2 g CaCO<sub>3</sub> dm<sup>-3</sup> were applied to the conifers, while for broad-leaved plants were supplied 6.5 g CaCO<sub>3</sub> dm<sup>-3</sup> substrate. Plants with the root ball were transplanted to 3 dm<sup>3</sup> pots filled with this substrate. In this study, the control comprised the combination with Osmocote Exact Standard (5-6 M), a controlled release fertilizer (CRF), with the following chemical composition

(in %): N 15; P<sub>2</sub>O<sub>5</sub> 9; K<sub>2</sub>O 12; MgO 2; Fe 0.45; Mn 0.06; Zn 0.015; Cu 0.05; B 0.03 and Mo 0.02, which was applied at 2 g dm<sup>-3</sup>.

In these experiments, two nutrient solutions with the following chemical composition (in mg dm<sup>-3</sup>) were applied:

- nutrient solution I (described as NS-I): N-NH<sub>4</sub> <10, N-NO<sub>3</sub> – 120; P – 50; K – 100; Ca – 100; Mg – 50; Fe – 1.2; Mn – 0.3; Zn – 0.50; Cu – 0.03; B – 0.011; pH – 5.50; EC – 1.60 mS cm<sup>-1</sup>;
- nutrient solution II (described as NS-II): N-NH<sub>4</sub> <10; N-NO<sub>3</sub> – 160; P – 60; K – 130, Ca – 110, Mg – 60, Fe – 1.5, Mn – 0.4; Zn – 0.50; Cu – 0.04; B – 0.011; pH – 5.50; EC – 2.00 mS cm<sup>-1</sup>.

Fertigation was carried out throughout the entire plant growing period (1 x week) at a dose 250 ml pot<sup>-1</sup> in the case of arborvitae and barberry and a dose of 400 ml pot<sup>-1</sup> for juniper. The control combinations were watered using identical volumes of water. In the course of the experiment, an optimal moisture content was maintained in the substrate.

### **Biometric plant measurements**

Measurements were taken at the beginning and termination of the plant growing experiment in each year of the study. The following parameters were measured: plant height, length of lateral shoots and plant width in barberry, plant height, length of the main shoot, length of lateral shoots type I and II in juniper and plant height, plant spread and plant projected area in arborvitae.

### **Chemical analyses of plant material**

Plant samples for chemical analyses were collected at the completion of the plant growing experiment in each year of the study. In the case of barberry they were leaves collected from central sections of shoots, whereas in the case of junipers and arborvitae the plant material consisted of small shoots with scales collected from central parts of main shoots. The collected plant material was dried at 45-50°C and then ground. In order to assay the total forms of N, P, K, Ca and Mg, the plant material was digested in concentrated sulphuric acid (96%; ultra pure) with the addition of hydrogen peroxide (30%, ultra pure). Mineralization for assays of Fe, Mn, Zn and Cu was run using the wet method in a mixture of nitric and perchloric acids (ultra pure) (3:1, v/v). After digestion of the plant material, the following determinations were performed: N-total using the distillation method according to Kjeldahl in a Parnas Wagner apparatus; P, colorimetrically with ammonium molybdate, and K, Ca, Mg, Fe, Mn, Zn and Cu using flame atomic absorption (on a AAS, on a Carl Zeiss Jena apparatus).

## Statistical analyses

Statistical analyses were conducted for each taxon separately with inferences made at  $\alpha = 0.05$ . The data obtained were analyzed statistically using Statistica ver. 12 software (StatSoft Inc., Tulsa, OK, USA).

## RESULT AND DISCUSSION

### Chemical composition of plants

Fertigation caused significant improvement of arborvitae N nutrition (for NS-I and NS-II); for barberry such an effect was produced by NS-II, whereas in juniper there was no difference in relation to the control (Table 1). In the

Table 1

Effect of fertigation on the content of macro- ( $\text{g kg}^{-1}$  d.m.) and microelements ( $\text{mg kg}^{-1}$  d.m.) in aerial parts of plants

Nutrient	<i>Berberis xottawensis</i> var. Superba			<i>Thuja occidentalis</i> var. Smaragd			<i>Juniperus xpfitzeriana</i> var. Mordigan Gold		
	control	NS-I	NS-II	control	NS-I	NS-II	control	NS-I	NS-II
N	8.95 $a$	9.30 $a$	10.50 $b$	8.60 $a$	13.55 $b$	14.90 $b$	12.00 $a$	11.75 $a$	12.25 $a$
P	2.65 $a$	3.75 $b$	4.65 $c$	2.15 $a$	2.55 $b$	3.20 $c$	2.15 $a$	2.70 $b$	2.65 $b$
K	14.10 $a$	13.10 $a$	15.90 $a$	10.15 $a$	13.10 $b$	12.70 $b$	9.90 $a$	12.55 $b$	13.40 $b$
Ca	9.70 $b$	10.05 $b$	10.75 $a$	16.75 $a$	17.40 $a$	18.20 $a$	9.30 $a$	9.15 $a$	9.05 $a$
Mg	1.40 $b$	1.55 $b$	1.65 $a$	1.45 $a$	1.75 $b$	1.70 $b$	1.75 $a$	2.10 $b$	2.05 $b$
Fe	40.70 $b$	41.05 $b$	35.30 $a$	81.85 $b$	77.35 $b$	71.10 $a$	49.25 $a$	52.00 $a$	48.75 $a$
Mn	39.65 $b$	29.40 $a$	27.80 $a$	177.65 $b$	188.00 $b$	160.10 $a$	96.00 $b$	80.15 $a$	86.35 $a$
Zn	14.60 $a$	13.95 $a$	14.70 $a$	54.00 $a$	59.40 $b$	52.95 $a$	29.90 $a$	28.80 $a$	27.85 $a$
Cu	3.97 $b$	3.58 $a$	3.43 $a$	6.56 $b$	4.36 $a$	4.77 $a$	5.15 $b$	5.91 $c$	4.37 $a$

Values in rows, within every taxon, described with different letters varied significantly at  $p = 0.05$ .

case of P, the application of fertigation for all tested taxa had a significant effect consisted in an increased P content in relation to the control. In arborvitae and juniper, the applied fertigation significantly increased K content in plants; in contrast, it had no effect on its content in barberry. Generally, no significant changes were recorded in Ca nutrition between the tested combinations, except for barberry, where there was a decrease in Ca (at a simultaneous reduction of Mg content) in response to NS-II. Fertigation significantly improved Mg nutrition of arborvitae and junipers. In the case of barberry and arborvitae, NS-II caused a significant decrease in Fe levels. The applied fertigation generally caused a significant decrease in Mn contents in plants

(apart from NS-I for arborvitae). Zn levels in plants were stable irrespective of their nutritional status (except for NS-I in arborvitae). In barberry and arborvitae, the applied fertigation significantly decreased the Cu content, while in juniper its content was higher (for NS-I) or lower (for NS-II) than in the control.

### Plant growth parameters

Fertigation significantly improved growth in barberry (Figure 1). The longest main shoot was reported in plants fertilized with the nutrient solution with lower EC (NS-I), whereas the length of shoots type I and II did not differ significantly between the tested nutrient solutions and it was significantly greater than in the control.

In arborvitae, the application of fertigation (both NS-I and NS-II) significantly influenced the height of experimental plants (Figure 2). In turn, plant width and plant spread were greatest following the application of the nutrient solution with lower EC (NS-I).

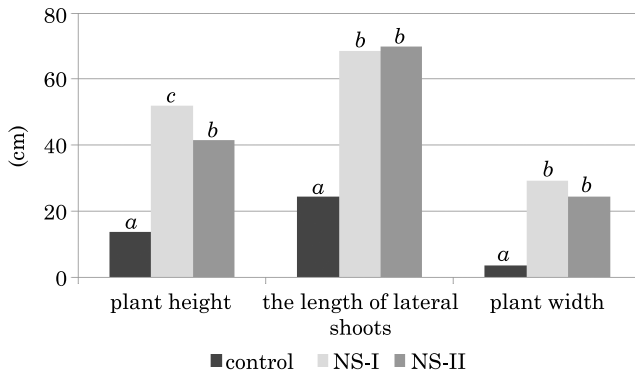


Fig. 1. Effect of fertigation of the growth of *Berberis x ottawensis* var. Superba shrubs (cm plant<sup>-1</sup>), mean for 2013-2014 (Key to Fig. 1-3: values of each parameter described with different letters differ significantly at  $p = 0.05$ )

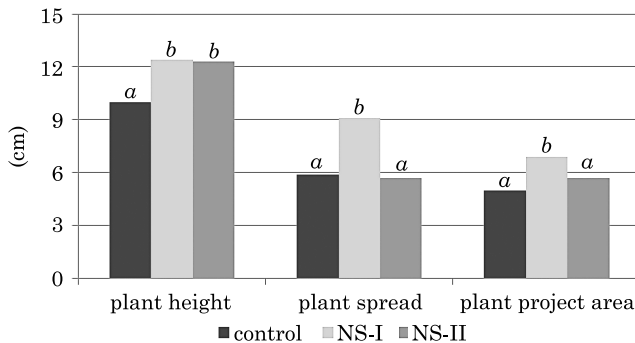


Fig. 2. Effect of fertigation of growth of *Thuja occidentalis* var. Smaragd shrubs (cm plant<sup>-1</sup>), mean for 2013-2014

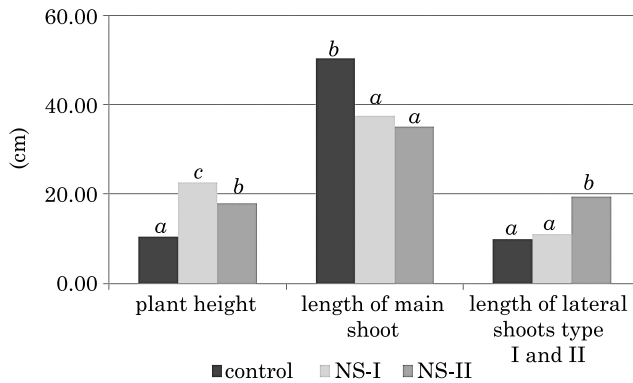


Fig. 3. Effect of fertilization of growth of *Juniperus x pfitzeriana* var. Mordigan Gold shrubs (cm plant<sup>-1</sup>), mean for 2013-2014

For junipers, fertilization caused a significant increase in the plant height in relation to the control, at the same time significantly reducing the growth of main shoots (Figure 3). In the case of shoots type I and II, the nutrient solution with a higher nutrient concentration (NS-II) significantly increased their length in comparison to the other combinations.

In studies conducted to date on cultivation of nursery plants, a significant effect of substrate has been recorded with respect to values of their growth traits and analyzed parameters in both deciduous and coniferous plants (ŠRÁMEK, DUBSKÝ 2002, BANACH et al. 2013). In the opinion of BANACH et al. (2013), the best breeding value was recorded for planting material produced in the peat substrate with an addition of a mycorrhizal fungus (*Hebeloma crustuliniforme*). In the cited experiment, plants were also grown in substrate based on highmoor peat. The applied nutrition has been a factor significantly affecting growth for potted ornamental plants (ŠRÁMEK, DUBSKÝ 2007, BOSIACKI et al. 2009, 2011, MICHAŁOJĆ, KOTER 2012).

The tested taxa are considered as plants with medium nutrient requirements. The studies tested the application of nutrient solutions with the N:P:K ratios  $\approx 1.0.4:0.8$ . It was found that the effect of plant nutrition levels on the plants' biometric parameters varied. In terms of the length of the main shoot and growth increments of shoots type I or II in relation to the control (standard CRF), the nutrient solution with lower EC (NS-I) may be recommended for the fertilization of barberry. In comparison to the other tested combinations, this nutrient solution may also be considered optimal for arborvitae. Studies conducted to date on fertilization of arborvitae (*Thuja*  $\times$  var. Green Giant) concerned the effect of increasing N concentrations (GRIFFIN et al. 1999a). Nutrition with this element (ranging from 0 to 320 mg dm<sup>-3</sup> nutrient solution) influenced dry matter of both the aerial parts and the roots. Maximum shoot weight was obtained at Nitrogen Application Rates (NAR) of approximately 100 mg dm<sup>-3</sup>, representing a 200% increase in relation to the control (without N nutrition). GLONEK and KOMOSA (2013a,b) found

that application of optimal nutrient solution may increase the yields of high-bush blueberry by about 21.9% comparing with drip irrigation and the optimal soil fertility obtained on the basis of spread fertilization. Similar effects, varied with the different chemical composition of nutrient solution, have been found in our study.

GLONEK and KOMOSA (2013*a,b*) found that the chemical composition of nutrient solution may significantly influence plant yielding with the simultaneous influence on the plant nutrient status. It may be assumed that factors potentially effecting improved yielding in barberry in our studies under the application of NS-I include: improved P nutrition at the simultaneous reduction of Mn and Cu levels in relation to the control. Phosphorus is an element undergoing strong chemical sorption in soil/substrate, while at the same time it is found in high energy bonds, ATP and ADP (HOLFORD 1997, SCHACHTMAN et al. 1998, MAATHUIS 2009, NAEEM et al. 2013). Supplying this nutrient with fertigation may improve its uptake by plants. In the case of arborvitae, an improvement of plant yielding may be connected with plant nutrition with N, P, K, Mg and Zn at the simultaneous reduction of Cu content. A key role seems to be played by macronutrients, particularly N, which is considered to be the main yield-forming factor, as well as Mg as an element bound in the chlorophyll structure and significantly affecting its content in aerial parts of plants. In turn, K is responsible for cellular hydration (MAATHUIS 2009, MAATHUIS, SANDERS 1994).

The effect of fertigation on the growth of juniper was multidirectional. While NS-I significantly improved the length of the main shoot, at the same time it reduced growth increments in shoots type I and II. Additionally, while fertigation (similarly as in arborvitae) significantly modified the nutritional status of the examined plants, it also caused increased content of P, K and Mg.

The scientific literature provides a very limited body of data on the chemical composition of investigated taxa, and on the chemical composition of nutrient solutions recommended for their fertigation. In contrast, the N:K ratios changed more markedly following fertigation: from 1.0:0.8 (in the control) to 1.0:1.1 (for NS-I and NS-II). In the case of barberry (*Berberis ×ottawensis* var. Superba) fertigation caused a change in the N:P and N:K ratios (reducing them), while in the case of arborvitae the N:P ratio became wider (on average changing from 1.0:0.3 in the control to 1.0:0.2 for NS-I and NS-II), and the N:K ratio changed analogously from 1.0:1.2 (the control) to 1:1 (for NS-I) and 1.0:0.9 (for NS-II). The available literature presents no data concerning the chemical composition of the examined taxon. Meanwhile BĄBELEWSKI et al. (2017) found that application of geocompost may increase the N, P, K, Mg and Ca content in the leaves of container grown *Berberis thunbergii* cv. Green Carpet. In our studies conducted on *Berberis ×ottawensis* var. Superba, the mean N:P:K ratios in leaves were  $\approx$  1.0:0.45:1.33, but BĄBELEWSKI et al. (2017), who tested *Berberis thunbergii* cv.



Green Carpet, found a tendency towards a marked increase in the content of potassium in the leaves (N:P:K ratios  $\approx$  1.0:0.41:1.84). Generally, the content of N and P in leaves determined in this experiment was similar to the ones reported in the cited studies, i.e. higher content of Mg and simultaneously lower content of K and Ca.

The N and K content determined in our study in arborvitae tissues were generally lower, whereas the Ca content was clearly higher than reported by MEISL (2006). At the same time, the content of P and Mg was similar to that given by this author. GRIFFIN ET AL. (1999a) stated that changes in the chemical composition of arborvitae were a result of N fertigation, with shoot concentrations of N, P, Mg, and S being maximized at approximately 71, 41, 48, and 52 mg dm<sup>-3</sup> N, respectively. The uptake of K and Ca was not affected by the N concentrations in nutrient solution. GRIFFIN et al. (1999b) concluded that high doses of N are not required to achieve a rapid growth of containerized var. Green Giant arborvitae.

## CONCLUSIONS

This study showed a positive and significant effect on the growth parameters of barberry and arborvitae caused by the nutrient solution with the following chemical composition (mg dm<sup>-3</sup>): N-NH<sub>4</sub> <10; N-NO<sub>3</sub> – 120; P – 50; K – 100; Ca – 100; Mg – 50; Fe – 1.2; Mn – 0.3; Zn – 0.50; Cu – 0.03; B – 0.011 at pH – 5.50 and EC – 1.60 mS cm<sup>-1</sup>. In the case of juniper (*Juniperus ×pfitzeriana* var. Mordigan Gold), the changes in biometrical parameters varied, depending on the nutrient solution. In view of the results of biometric measurements, tentative guideline values for barberry (*Berberis ×ottawensis* var. Superba) may be assumed at (g kg<sup>-1</sup> d.m. leaves): N – 9.30; P – 3.75; K – 13.10; Ca – 10.05 and Mg 1.55 (mg kg<sup>-1</sup> d.m. leaves): Fe – 41.05; Mn – 29.40; Zn – 13.95 and Cu – 3.58. Tentative nutrient guideline values for arborvitae (*Thuja occidentalis* var. Smaragd<sup>1</sup>) are as follows (g kg<sup>-1</sup> d.m.): N – 13.55; P – 2.55; K – 13.10; Ca – 17.40 and Mg – 1.75 (mg kg<sup>-1</sup> d.m.): Fe – 77.35; Mn – 188.00; Zn – 59.40 and Cu – 4.36. Further studies are needed to achieve optimization of the chemical composition of nutrient solutions used in fertigation of nursery plants.

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