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THE INFLUENCE OF SUBSTRATE pH ON GROWTH OF ROCKY MOUNTAIN JUNIPER (*Juniperus scopulorum*) 'BLUE ARROW' IN CONTAINER CULTIVATION

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ABSTRACT

The experiment on cultivation of the Rocky Mountain juniper 'Blue Arrow' variety in containers was conducted in years 2000-2002 in an unheated glasshouse. The plants were cultivated in a substrate composed of a mixture of high moor peat and frittered, composted pine bark in volume ratio 1:1, with a different substrate pH in H₂O: 4.5; 5.0; 5.5; 6.0; 6.5. In order to obtain substrate pH in H₂O 7.2; 20% mineral soil was added to pine bark (40%) and high moor peat (40%). During vegetation season biometric measurements were performed i.e. the height of plants and length of lateral shoots [cm] were measured and the number of lateral shoots was counted. Also the pH of cultivation substrate was measured. When the experiment was completed, fresh root weight and the weight of fresh above-ground part of plants were measured. Before and after completion of the experiment, chemical analysis of the cultivation substrate was performed for each combination to estimate the content of macronutrients. On the basis of the results obtained it was concluded that, for the cultivation of the Rocky Mountain juniper 'Blue Arrow' variety in containers, the most suitable were growing substrates with pH in H₂O 4.5 and 5.0. The highest and the most intense colour of plants of Rocky Mountain juniper 'Blue Arrow' variety as well as the highest average fresh root weight and weight of above-ground were obtained when cultivated in such conditions. The substrate with the addition of mineral soil had a negative effect on the growth of Rocky Mountain juniper 'Blue Arrow' variety plants and then on the colour of scales.

Key words: Rocky Mountain juniper, *Juniperus scopulorum* Sarg., 'Blue Arrow', growing substrate pH, container cultivation.

INTRODUCTION

Junipers are known to people as extremely sun-loving plants, however not possessing high habitat requirements. Many cultivars have been created, differing not only in a shape of crown but also in the length or the colour of needles or scales (scale-like leaves) as well as in the requirements of soils and habitat.

A novelty of the Polish market, gaining bigger and growing appreciation is the variety of Rocky Mountain juniper 'Blue Arrow' found by Tesselaar in Ontario, Canada in 1980 [4]. The variety possesses a very narrow, compact, columnar shape of crown, intensive blue colour of scales, is more resistant to dying out of shoots caused by the fungus *Phomopsis juniperovora* and grows slower than the variety 'Skyrocket' [1]. It is suggested for planting in rock gardens, on moorlands, in container compositions, for hedges etc [3].

At present the information in literature about the recommendations for the pH of growing substrate in gymnospermous plants container cultivation are scarce. Hryniewicz-Sudnik et al. [2] suggest for the cultivation of savin juniper (*Juniperus sabina* L.) in containers the substrate composed of high moor peat with pH 5.5 – 6.0 or the mixture of peat, bark and hotbed substrate in volume ratio 3:3:4 with pH 7.2. Wright and Hinesley [11] showed how the pH substrate influences the nutrients uptake by eastern red cedar (*Juniperus virginiana* L.). Korszun and Kolasiński [5] researched that for the growth of *Taxus baccata* 'Fastigiata' grown in container cultivation, the most suitable is very acid and acid pH of growing substrate (pH in H₂O 4.5-5.0). Information mentioned above cannot be used as growing recommendations for the Rocky Mountain 'Blue Arrow' juniper container cultivation.

The research conducted at the Division of Dendrology and Nursery of Agricultural University of Poznań on the influence of growing substrate pH on the growth of gymnospermous plants show that some species and cultivars possessing colour scales or needles have different pH requirements than taxons with green scales and needles. The aim of the experiment was to set the optimal substrate pH for growth of the Rocky Mountain 'Blue Arrow' juniper variety cultivated in containers.

MATERIALS AND METHODS

Research on the cultivation of the Rocky Mountain juniper 'Blue Arrow' variety in containers was conducted in an unheated greenhouse. The experiment was established in 2000 from cuttings rooted in spring 1999 and continued until 2002. In the experiment two types of growing substrate with different pH was used. The pH of the substrate was determined on the basis of a neutralization curve, with the aid of precipitated calcium and magnesium carbonates. The first type of substrate was composed of 50% high moor peat and 50% frittered and composted pine bark. The pH value in H₂O was 4.5, 5.0, 5.5, 6.0, 6.5. To obtain neutral pH of the growing substrate (pH in H₂O 7.2) second type of growing substrate was used composed of 40% of high moor peat, 40% pine bark and 20% mineral soil.

In the first year of the cultivation to each substrate, 1.5 g of the multi-nutrient Osmocote plus 5-6 months' of fertilizer per dm³ and, in the second year, 2.0 g per dm³ were added. The fertilizer and precipitated calcium and magnesium carbonates were added individually to each substrate placed in containers.

All plants were grown in containers of volume 2.7 dm³. At the beginning of each month the height and length of lateral shoots [cm] were measured and the number of lateral shoots was counted. Also the pH of the substrate was examined. After two years of container cultivation, when vegetation ceased, 10 plants were chosen at random from each combination and the weight of roots and parts above ground were measured.

The experiment was designed in entirely random blocks of 3 replications, of 8 plants each. Altogether 144 plants were examined. The obtained results were statistically analysed with the aid of Duncan's test with the significance level $\alpha = 0.05$.

RESULTS

In the first year of container cultivation the Rocky Mountain 'Blue Arrow' juniper started growth on 1st June and grew until 1st September 2000. The most intensive growth of the juniper plants was observed in July and August (fig. 1). In the second year of cultivation, the dynamics of the junipers' growth was different depending on the pH of the growing substrate. In the substrate with mineral soil component plants did not grow until 1st July 2001. Weak growth was observed only after 1st July to 1st September 2001. In the rest of the combinations the 'Blue Arrow' variety grew equally from 1st May until 1st September 2001 (fig. 2).

Fig. 1. The influence of the growing substrate pH on the dynamics of growth of plants Rocky Mountain juniper 'Blue Arrow' variety in the first year of cultivation

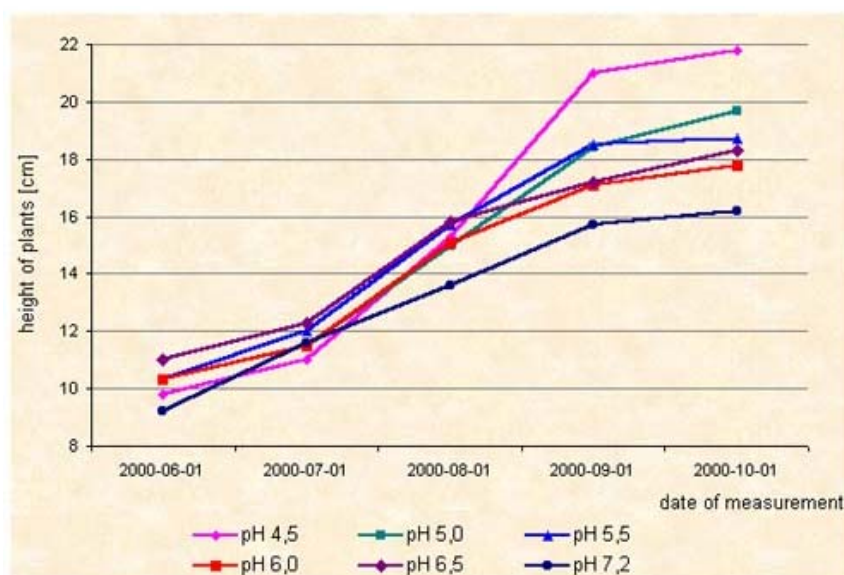
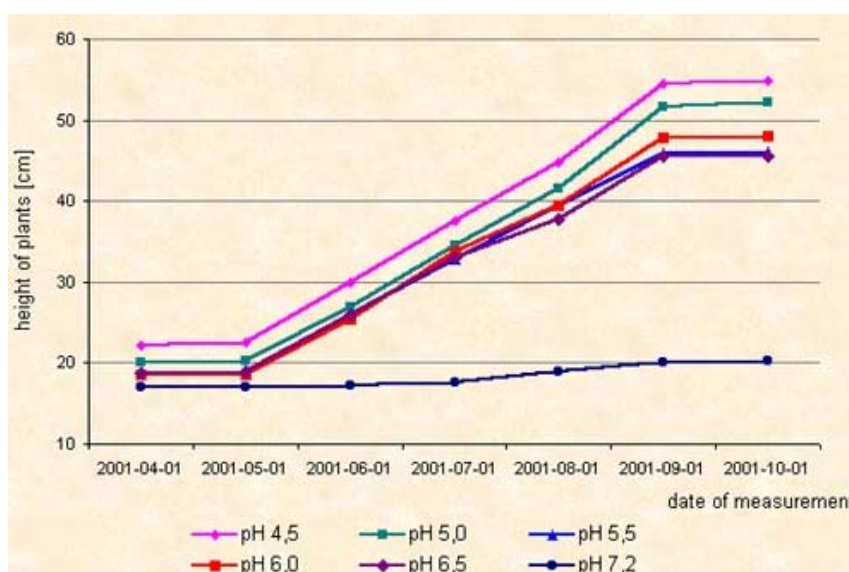


Fig. 2. The influence of the growing substrate pH on the dynamics of growth of plants Rocky Mountain juniper 'Blue Arrow' variety in the second year of cultivation



After one year of container cultivation the highest were the plants grown in substrates with pH 4.5 and 5.0, reaching height of 21.8 cm and 19.7 cm respectively, and the shortest grown in substrate with pH 7.2-16.2 cm. Junipers cultivated in the substrate composed of mixture of peat and pine bark with the pH 5.5 and 6.5 did not differ in height and statistically fell into one group. After two years of cultivation the results were similar. Very acid and acid substrates (pH 4.5 and 5.0) were the best for the growth of the 'Blue Arrow' variety. The variety in these combinations possessed an average height of 54.8 cm and 52.2 cm. The substrate with the addition of mineral soil very unfavourably influenced the growth and development of the plants and also their colour ([tab. 1](#) and [fig. 3](#)).

Table 1. Average height of plants of Rocky Mountain juniper ‘Blue Arrow’ variety after ceasing of vegetation in the following years of cultivation dependant on the growing substrate pH

pH in H ₂ O	Height of plants [cm]	
	After a year of cultivation (2000)	After two years of cultivation (2001)
4.5	21.8 c ¹⁾	54.8 d
5.0	19.7 bc	52.2 cd
5.5	18.7 ab	48.0 b
6.0	17.8 ab	46.1 b
6.5	18.3 ab	45.7 b
7.2	16.2 a	20.2 a
F emp	3.04*	57.14**

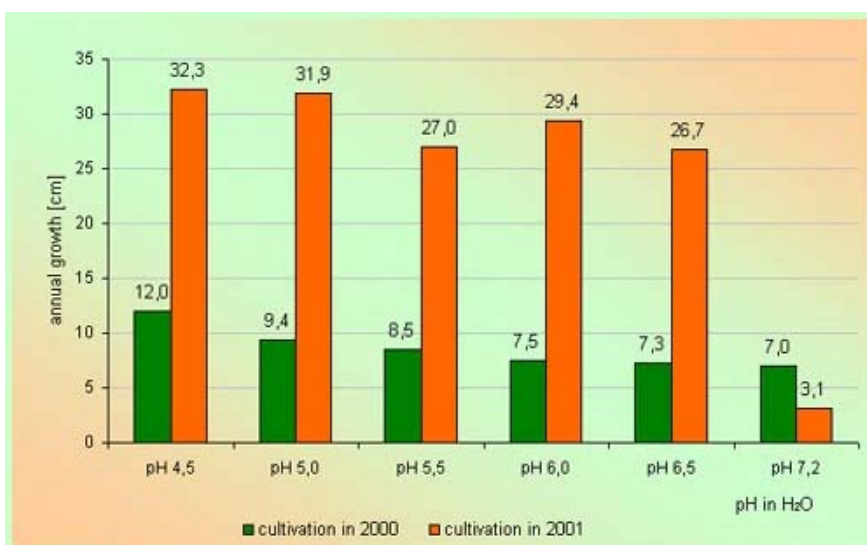
¹⁾ average values in columns marked with the same letter do not differ statistically; $\alpha = 0.05$

Fig. 3. The height of plants of the ‘Blue Arrow’ variety after two years of container cultivation: 1 – pH 4.5, 2 – pH 5.0, 3 – pH 5.5, 4 – pH 6.0, 5 – pH 6.5, 6 – pH 7.2



The greatest increase in length of the main shoot in the first year of cultivation of *Juniperus scopulorum* ‘Blue Arrow’ in containers was obtained for plants grown in substrates with pH 4.5 and 5.0 i.e. 12.0 cm and 9.4 cm respectively. In the growing substrate mixtures with pH 6.0, 6.5 and 7.2 the increases in length were similar, and varied from 7.0 cm to 7.5 cm. In the next year of cultivation, plants grew more intensively. In the substrate with pH 4.5 and 5.0 junipers produced growth of main shoot 32.3 cm and 31.9 cm respectively and in the substrate with the addition of mineral soil only 3.1 cm ([fig. 4](#)).

Fig. 4. Average length of annual growth of plant of Rocky Mountain juniper 'Blue Arrow' variety depending on the pH of the growing substrate



The average length of lateral shoots of the plant in individual years of cultivation was very different and dependent on the substrate pH. In 2000 the longest lateral shoots – 3.2 cm were obtained in plants grown in the mixture of peat and pine bark with pH 6.0 and the shortest – 1.3 cm in the growing substrate with pH 7.2. In the next year the shoots were a few times longer, mainly on the plants grown in the substrate with pH 6.0 – 22.5 cm and 4.5 – 20.0 cm and the shortest again in plants grown in substrate with pH 7.2 – only 10.1 cm. The values for plants grown in substrates with pH 5.0, 5.5 and 6.5 did not differ statistically among one another (tab. 2).

Table 2. Average length of growth and the number of shoots of the plants of Rocky Mountain juniper 'Blue Arrow' variety after two years of cultivation depending on the pH of the growing substrate

pH in H ₂ O	Length of lateral shoots [cm]		Number of lateral shoots	
	After a year of cultivation (2000)	After two years of cultivation (2001)	After a year of cultivation (2000)	After two years of cultivation (2001)
4.5	2.5 bc ¹⁾	20.0 c	4.8 b	5.0 b
5.0	2.4 bc	16.9 b	5.0 b	5.2 b
5.5	2.1 b	17.9 b	4.5 b	6.9 c
6.0	3.2 d	22.5 d	4.2 b	6.0 bc
6.5	3.0 cd	17.0 b	4.9 b	5.4 b
7.2	1.3 a	10.1 a	2.0 a	2.5 a
F emp.	9.87**	17.46**	7.95**	5.74**

1) see table 1.

The average number of lateral shoots per plant in both years of cultivation was similar. In the first year, the junipers produced between 2 (pH 7.2) and 5 shoots (pH 5.0). There were no statistically significant differences in the number of shoots in plants grown in substrates with pH from 4.5 to 6.5. In the second year of cultivation the number of lateral shoots per plant reached from 2.5 (pH 7.2) to 6.9 (pH 5.5). The values of researched feature for plants grown in substrates with pH 4.5, 5.0 and 6.0 were similar and created one statistical group (tab. 2).

After two years of cultivation in containers the fresh weight of roots and above-ground parts were measured. The pH of the substrate influenced the average fresh weight of the root system only on plants cultivated in the mixture of high moor peat, pine bark and mineral soil. In that case the junipers produced a small number of roots and their weight was only 1.3 g. In the remaining substrates the values of fresh root weight did not differ significantly. The substrate pH also influenced the weight of the fresh above-ground plant part. The highest fresh weight was produced by plants cultivated in substrate with pH 4.5 and 5.0 i.e. 41.4 g and 37.5 g respectively, and the lowest in substrate with pH 7.2, only 9.4 g. In the remaining growing substrates the weight of above ground part varied from 30.3 g to 35.7 g, however, these values did not differ statistically (tab. 3).

Table 3. Fresh root weight and above ground part weight of plants of Rocky Mountain juniper ‘Blue Arrow’ variety after two years of cultivation dependent on the pH of the growing substrate

pH in H ₂ O	Fresh weight	
	roots [g]	above ground part [g]
4.5	14.7 b ¹⁾	41.4 c
5.0	14.0 b	37.5 c
5.5	13.9 b	35.7 b
6.0	13.4 b	36.4 b
6.5	12.6 b	30.3 b
7.2	1.3 a	9.4 a
F emp.	57.12**	37.51**

1) see table 1.

In the experiment the pH of the growing substrate was examined. In the first year of cultivation the changes of pH in all combinations were small and did not deviate significantly from the pH set at the beginning of the experiment ([tab. 4](#)). In the second year, little lowering of the pH of the growing substrate was observed in substrates with start pH values of 4.5, 5.5, 6.0 and 6.5. The largest difference was observed in the growing substrate with mineral soil component, where pH showed the value of 5.9 instead of the assumed 7.2 ([tab. 5](#)).

Table 4. The pH of the growing substrate for plants of Rocky Mountain juniper ‘Blue Arrow’ variety in the first year of container cultivation

Date	pH in H ₂ O					
	4.5	5.0	5.5	6.0	6.5	7.2
2000-06-08	4.2	4.8	5.2	5.6	6.0	7.0
2000-07-05	4.4	4.8	5.3	5.6	6.2	7.1
2000-08-03	4.5	4.9	5.4	6.0	6.4	7.1
2000-09-04	4.5	5.0	5.4	6.0	6.4	7.2
2000-10-02	4.5	5.0	5.5	6.0	6.4	7.2

Table 5. The pH of the growing substrate for plants of Rocky Mountain juniper ‘Blue Arrow’ variety in the second year of container cultivation

Date	pH in H ₂ O					
	4.5	5.0	5.5	6.0	6.5	7.2
2001-06-01	4.6	4.9	5.4	5.9	6.2	6.7
2001-07-02	4.5	4.9	5.4	5.7	6.0	6.3
2001-08-01	4.6	5.0	5.3	5.6	5.9	6.2
2001-09-01	4.5	5.0	5.3	5.5	5.8	6.0
2001-10-01	4.4	5.0	5.4	5.6	5.8	5.9

Table 6. The content of macronutrients, pH and salts concentration in the growing substrates in 2001 after vegetation of juniper plants ceased in the first year of container cultivation of plants of Rocky Mountain juniper ‘Blue Arrow’ variety

Assumed at the beginning of the experiment	Macronutrients in mg · dm ⁻³ substrate						pH in H ₂ O	Salts concentrations in g NaCl · dm ⁻³ of the substrate
	N-NH ₄	N-NO ₃	P	K	Ca	Mg		
4.5	56	112	55	190	770	65	4.9	0.7
5.0	70	126	60	200	860	70	5.4	1.0
5.5	49	105	55	230	1020	65	5.8	0.7
6.0	56	77	52	160	1170	75	6.2	0.6
6.5	49	105	115	150	1230	80	6.4	0.6
7.2	84	203	42	260	1470	92	6.0	1.2

Table 7. The content of macronutrients, pH and salts concentration in the growing substrates in 2001 after vegetation of juniper plants ceased in the second year of container cultivation of plants of Rocky Mountain juniper ‘Blue Arrow’ variety

Assumed at the beginning of the experiment	Macronutrients in mg · dm ⁻³ substrate						pH in H ₂ O	Salts concentrations in g NaCl · dm ⁻³ of the substrate
	N-NH ₄	N-NO ₃	P	K	Ca	Mg		
4.5	14	70	51	236	495	194	4.6	1.6
5.0	21	26	83	197	608	203	5.1	1.4
5.5	18	55	56	238	739	243	5.5	1.2
6.0	18	68	53	225	914	250	5.7	1.5
6.5	32	51	112	563	895	229	5.9	1.2
7.2	11	200	172	343	1220	284	5.8	1.4

In February 2001 and 2002, before the vegetation of the plants started, analyses of macronutrients in the growing substrates for each combination separately were carried out. The pH and salinity of the substrates were also measured. In 2001 the highest content of nitrogen (N-NH₄ and N-NO₃), potassium, calcium and magnesium was detected in the substrate with the addition of mineral soil. The substrate with pH 6.5 possessed the highest content of phosphorus. The pH of the substrate rose for substrates with start pH values of 4.5, 5.0, 5.5 and 6.0 and fell in substrates with start pH values of 6.5 and 7.2. The highest salinity (1.2 g NaCl·dm⁻³ and 1.0 g NaCl·dm⁻³) was observed in the substrate with pH 7.2 and 5.0 respectively (tab. 6). In 2002 again the highest content of the majority of nutrients, i.e. nitrogen (N-NO₃), phosphorus, calcium and magnesium, was detected in substrate with pH 7.2. The highest content of potassium and nitrogen in a form of N-NH₄ was detected in the substrate with pH 6.5. The pH of the substrate fell in all of the combinations and the salinity rose, reaching from 1.2 g to 1.6 g NaCl·dm⁻³ (tab. 7).

DISCUSSION

The cultivar of the Rocky Mountain juniper ‘Blue Arrow’ is not frequently propagated and cultivated in Polish ornamental plant nurseries. From its introduction to Poland in the 1990s it has been gaining popularity. Due to its columnar shape and scale colour it is very highly appreciated and recommended for the creation of garden compositions and for the establishment of hedges. There was no research on container cultivation of ‘Blue Arrow’ variety of Rocky Mountain juniper. In the literature available the detailed description of not only this variety but also of the species *Juniperus scopulorum* is rare. There is a lack of information about their cultivation requirements. In natural habitats Rocky Mountain juniper grows in rocky soils, poor in nutrients [6] and on mugwort semi-deserts [2].

The plants of the Rocky Mountain ‘Blue Arrow’ juniper should be grown in containers. It is a method commonly used at present in ornamental plant nurseries. It possesses many advantages and it is profitable for plants [7, 8, 10]. Bugała [1] states, that during replanting, junipers do not keep the root lump well. Container cultivation helps to prevent this disadvantageous phenomenon. And above all, it makes it possible to plant junipers in the ground during the majority of the months of the year, with the exception of the period with freezing temperatures, and allows almost 100% of plants to take root [8, 9].

In the literature cited there is no information about the optimal pH of the growing substrate for junipers' growth in container cultivation. In the experiment described, the best results were obtained when the plants were cultivated in the growing substrate composed of composted, frittered pine bark and high moor peat in volume ratio 1:1. Plants cultivated in such growing substrate, when it was acid and very acid (pH in H₂O 4.5 and 5.0), were the highest, possessed the highest annual growth of shoots as well as the most intense colouring of scales.

CONCLUSIONS

1. The best growth of plants Rocky Mountain juniper 'Blue Arrow' variety was obtained when they were cultivated in growing substrates with pH in H₂O 4.5 and 5.0.
2. Acid growing substrate has positive influence on the number and the length of lateral shoots.
3. The growing substrate with the addition of mineral soil, with pH in H₂O 7.2 had strong negative effect on growth and the colouring of young plants.

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