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NITROGEN FERTILISATION OF *Stewartia pseudocamellia* CULTIVATED IN SUBSTRATES OF DIFFERENT REACTION

NAWOŻENIE AZOTEM STEWARCJI KAMELIOWATEJ *Stewartia pseudocamellia* UPRAWIANEJ W PODŁOŻU O ZRÓŻNICOWANYM ODCZYNIE

Abstract: The study was conducted on Stewartia (*Stewartia pseudocamellia* Maxim.) plants, grown in containers under field conditions. The shrubs were fertilised with two nitrogen forms: ammonia NH_4^+ and nitrate NO_3^- at the substrate pH values of 3.9 and 5.5. The plants were top-dressed with reference to the analysis of the substrate. During the vegetation season the leaves were harvested twice in order to analyse the content of easily soluble forms and nutrients.

In the experiment a gradual increase of acidity and salt content in the substrate was observed, as compared with the original content. After the first and second year of cultivation, low content of mineral nitrogen in the substrates was noticed. In both years of cultivation, higher contents of phosphorus and lower contents of potassium in the substrates of shrubs fertilised with ammonia form were detected. The content of easily soluble forms of elements in Stewartia leaves remained practically unchanged throughout vegetation. The study revealed a very low content of mineral nitrogen in the leaves of Stewartia. The contents of easily soluble forms of nutrients (K, Ca, Mg) determined in the leaves varied with reference to both the substrate acidity and the form of nitrogen fertiliser used. The total nutrients contents, except of the total nitrogen content, were comparable in the first and second harvest. The content of total phosphorus and magnesium in the leaves was dependent on the nitrogen form, higher contents were noted in objects fertilised with ammonia form. However, Stewartia showed greater uptake of potassium, when fertilised with the nitrate form. The experiments also revealed the effect of substrate acidity on the uptake of potassium by the plants.

Keywords: nitrogen, pH, macroelements content, *Stewartia pseudocamellia*

Stewartia pseudocamellia Maxim., the *Theaceae* family genus [1], is rarely grown in Polish nurseries and gardens. In the USA, the Stewartia cultivars (including the interspecies hybrids) were available on the market as early as in 1992 [2]. The

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genus has been widely propagated and cultivated also in Japan [3]. The small size of the shrubs, characteristic flowering at the end of June and in July, as well as attractive colouring in the autumn, contributed to the wider popularity of the genus from Japan and Korea. What hinders its wider cultivation in Poland is the unavailability of seeds and the lack of knowledge as to the nutrition and fertilisation requirements of the plants.

The aim of the present study was to specify the effect of fertilisation with different forms of nitrogen on the macroelements nutrition of Stewartia plants grown on a substrate of pH values 3.9 and 5.5.

Materials and methods

The study was conducted in 1998–1999 on four- or five-year-old plants of Stewartia (*Stewartia pseudocamellia* Maxim. var. koreana), grown in 5 dm^3 containers in field conditions.

The two-factor experiment was conducted using the random block method in four replications. Each treatment included 10 plants per replication. Factor I was nitrogen form: ammonia NH_4^+ (using ammonium sulphate, ammonium phosphate) and nitrate NO_3^- (using calcium nitrate, potassium nitrate). Factor II was the substrate pH values: 3.9 and 5.5.

The pH = 3.9 substrate was a mixture of peat and fine composted pine bark, mixed in a 2:1 (v/v) ratio. The pH = 5.5 substrate was the substrate made on the basis of the first one deacidified with calcium carbonate. Before (1^{st} year – April), during (May, June) and at the end of vegetation season (September) the substrate was analysed after extraction with 0.03 mol · dm^{-3} acetic acid. The following nutrient contents in the substrate were adopted: 200 mg N, 70 mg P, 160 mg K and 20 mg Mg · dm^{-3}. The substrate acidity was determined as pH with potentiometric method (at 1:2 substrate to water ratio) and the electrolytic conductivity (EC) was measured with a conductometer [4]. During the season the plants were top-dressed twice (May, June) according to substrate analysis, using ammonium sulphate, ammonium phosphate and potassium sulphate in the objects with NH_4-N form, as well as calcium nitrate, potassium nitrate and triple superphosphate in the rest of the objects. In the middle (July) and at the end of vegetation season (September, before foliage discolouration) the leaves picked of the middle part of the twigs were subjected to analysis. Following drying, the leaves were analysed for the content of easily soluble forms of nutrients (in 2 % acetic acid) and after dry combustion, they were examined for the total content of components (except N). Mineral nitrogen was measured with Bremner's micromethod (modified by Starck), and total nitrogen by means of automatic distillation with boric acid after wet mineralisation. The content of phosphorus was determined with molybdenic-vanadic method and the concentration of K, Ca and Mg by means of the spectrophotometry of atomic absorption [4]. An overhead microemitters system was installed to be applied during vegetation season, and the soil humidity was maintained at ca 70 %.

Results

During the experiment the substrate acidity level increased by 0.11 (at pH = 5.5 and the NH_4-N form) to 1.57 (at pH = 3.9 and the NO_3-N form) in the first year and by 0.03 to 1.8 in the second year, with NH_4-N at pH = 5.5 and NO_3-N at pH = 3.9, respectively, as compared with the initial levels (Table 1). During the two-year cultivation, a gradual increase in the electrolytic conductivity in the substrate was observed.

Table 1

Changes of substrate pH and total salt concentration measured as EC [$dS \cdot m^{-1}$] during Stewartia cultivation

Object	Initial		After 1st year of cultivation		After 2nd year of cultivation	
	pH	EC	pH	EC	pH	EC
NH_4-N; pH = 3.9	3.9	0.15	4.52	0.21	4.53	0.56
NO_3-N; pH = 3.9	3.9	0.10	5.47	0.13	5.70	0.46
NH_4-N; pH = 5.5	5.5	0.15	5.61	0.16	5.53	0.62
NO_3-N; pH = 5.5	5.5	0.10	6.29	0.16	6.06	0.53

The content of mineral nitrogen balanced from 18.4 to 40.3 $mg \cdot dm^{-3}$ after the first year of cultivation and from 7.0 to 9.3 $mg \cdot dm^{-3}$ after the second year (Table 2). The highest nitrogen content was noticed in the object fertilised with the ammonia form at pH = 3.9, whereas the lowest content was found in the substrate where the nitrate form was used at pH = 5.5. After the two-year cultivation a greater amount of nitrogen was determined in the substrates of initial pH = 3.9.

The phosphorus content in the two years of cultivation was higher in the objects where the ammonia form was used.

Table 2

Changes of forms of mineral components contents [$mg \cdot dm^{-3}$] in the substrate during Stewartia cultivation

Object	NH_4^+	NO_3^-	$N_{min.}$	P	K	Ca	Mg
Initial							
	24.5	14.0	38.5	20.1	66.6	192.5	41.3
After 1st year of cultivation (IX 1998)							
NH_4-N; pH = 3.9	19.3	21.0	40.3	29.1	48.2	466.8	63.7
NO_3-N; pH = 3.9	10.5	11.4	21.9	17.8	51.1	625.9	73.5
NH_4-N; pH = 5.5	12.3	13.1	25.4	26.1	44.3	813.4	74.8
NO_3-N; pH = 5.5	7.9	10.5	18.4	16.4	67.2	1096.2	80.1
After 2nd year of cultivation (IX 1999)							
NH_4-N; pH = 3.9	9.3	0.0	9.3	32.5	94.9	705.8	104.4
NO_3-N; pH = 3.9	5.8	3.5	9.3	21.0	105.2	1144.4	149.7
NH_4-N; pH = 5.5	7.0	0.0	7.0	32.0	88.0	949.1	80.3
NO_3-N; pH = 5.5	7.0	0.0	7.0	23.7	128.3	1632.4	164.3

Greater content of available potassium in the substrate was observed when NO_3-N form was used, although the content of potassium was greater at the higher pH value. When fertilised with ammonia form, greater contents of potassium were noted in less acidic substrate. The calcium content in the substrates after two-year cultivation presented the lowest value in the NH_4-N and pH = 3.9 object, and the highest value in the one of NO_3-N and pH = 5.5. The content of available magnesium after the first year of cultivation ranged from 63.7 to 80.1 mg · dm^{-3}, with respect to ammonia form at pH = 3.9 and nitrate form at pH = 5.5. After two years of cultivation the contents levelled higher at the values from 80.3 (NH_4^+ and pH = 5.5) to 164.3 mg · dm^{-3} (NO_3^- and pH = 5.5).

In the middle and at the end of the vegetation season, in the first and second year of cultivation, Stewartia leaves were subjected to analysis. Changes in the content of soluble forms of nutrients were presented with reference to the first year of the study (Table 3).

Table 3

Changes of mineral form of macroelements contents [% d.m.] in Stewartia leaves during 1st year of cultivation[1]

Object	NH_4-N	NO_3-N	K	Ca	Mg
In the middle of vegetation (VII 1998)					
NH_4-N; pH = 3.9	0.014c[2]	0.0063a	1.32ab	0.40a	0.48a
NO_3-N; pH = 3.9	0.006a	0.0060a	1.50ab	0.54b	0.48a
NH_4-N; pH = 5.5	0.010bc	0.0050a	1.26a	0.39a	0.46a
NO_3-N; pH = 5.5	0.008ab	0.0080a	1.64b	0.58b	0.40a
After vegetation (IX 1998)					
NH_4-N; pH = 3.9	0.0078b	0.0093a	1.30ab	0.47ab	0.47b
NO_3-N; pH = 3.9	0.0060a	0.0088a	1.27ab	0.52b	0.38ab
NH_4-N; pH = 5.5	0.0063ab	0.0065a	0.87a	0.44a	0.37ab
NO_3-N; pH = 5.5	0.0070ab	0.0088a	1.72b	0.53b	0.31a

[1] P was not determined, due to analytical difficulties; [2] means marked by the same letter do not differ significantly at p = 0.05.

The content of soluble nutrients in Stewartia leaves stayed at approximately the same level throughout vegetation. The content of NH_4-N and NO_3-N was very low. The greatest amount of ammonia nitrogen was noticed in the object fertilised with NH_4^+ form of nitrogen at pH = 3.9 value, whereas the smallest amount was found in the one where calcium nitrate was used in the substrate of the same acidity level. No statistical differences were shown in the content of nitrate nitrogen in the objects. Potassium content was greatest in the leaves of plants fertilised with nitrate form at the pH = 5.5 value, and lowest when ammonium sulphate was used in the substrate of the same acidity. Greater amounts of calcium, both in the middle and at the end of vegetation season, were observed in objects fertilised with calcium nitrate. In the middle of vegetation season no significant differences in the content of magnesium in Stewartia leaves were noticed. However, at the end of the season, the highest magnesium value was registered in the leaves of plants grown in the substrate of pH = 3.9 value and fertilised with NH_4-N form of nitrogen. The smallest amount of magnesium was determined at NO_3-N used in the substrate of greater acidity.

Table 4

Changes of total macroelements contents [% d.m.] in Stewartia leaves during cultivation

Object	N	P	K	Ca	Mg
In the middle of 1st year of cultivation (VII 1998)					
NH_4-N; pH = 3.9	2.10a[1]	—[2]	1.85ab	0.50a	0.50a
NO_3-N; pH = 3.9	2.26a	—	1.95ab	0.58a	0.45a
NH_4-N; pH = 5.5	2.22a	—	1.53a	0.53a	0.50a
NO_3-N; pH = 5.5	2.11a	—	2.15b	0.56a	0.42a
After 1st year of cultivation (IX 1998)					
NH_4-N; pH = 3.9	2.17b	—	1.68ab	0.54ab	0.48b
NO_3-N; pH = 3.9	1.85a	—	1.64ab	0.58b	0.33a
NH_4-N; pH = 5.5	1.95ab	—	1.56a	0.47a	0.39ab
NO_3-N; pH = 5.5	1.77a	—	1.84b	0.59b	0.33a
After 2nd year of cultivation (IX 1999)					
NH_4-N; pH = 3.9	1.39a	0.24b	1.46ab	1.29a	0.38b
NO_3-N; pH = 3.9	1.31a	0.14a	1.24a	1.94b	0.24a
NH_4-N; pH = 5.5	1.48a	0.21b	1.12a	1.41a	0.40b
NO_3-N; pH = 5.5	1.47a	0.13a	1.80b	2.13b	0.21a

[1] Means indicated by the same letter do not differ significantly at p = 0.05; [2] not determined due to analytical difficulties.

The total nutrients contents, except of the total nitrogen, were comparable in the first and second leaves harvest (Table 4). In the middle of vegetation, the content of nitrogen balanced between 2.10 and 2.26 % d.m. and did not differ significantly in the objects. At the end of vegetation season, the content of total nitrogen in the leaves began to decrease. Moreover, a significant difference was noticed between the analysed objects. The greatest amount was noticed when the plants grown in the substrate of pH = 3.9 value were fertilised with ammonium form of the fertiliser, and the smallest amount of total nitrogen was present in the leaves of objects in which calcium nitrate was used at both levels of substrate acidity. After the second year of cultivation, no significant differences in the nitrogen content in leaves were noticed. At the end of the second vegetation season, the leaves of the objects where ammonium form was used showed nearly twice as high content of total phosphorus as those fertilised with the nitrate form. The total content of potassium in all three measurements was the lowest in the leaves of plants fertilised with ammonium form in the substrate of higher acidity. The greatest amount of total potassium was detected in the plants fertilised with the nitrate form at the pH = 5.5 level. In the middle of vegetation period, no statistically significant differences were noticed in the total Ca and Mg content in the leaves of all objects. After the first and second year of cultivation, the highest content of calcium and lowest content of magnesium was noticed in the objects where the nitrate form was used. The leaves harvested in the second year of cultivation revealed the lowest content of total nitrogen with reference to the previous year, but no statistically significant differences were present between the objects. The content of total phosphorus and magnesium in the leaves was dependent on the nitrogen form used, higher contents were noticed in objects fertilised with ammonia form. The greatest content of total potassium – 1.80 %, was observed in the plants fertilised with N-NO_3. The content of total calcium in the leaves harvested in the second year of cultivation was significantly higher (by three times on average). A considerable effect of nitrogen fertilisation on calcium nutrition of Stewartia plant was also observed. The use of nitrate form led to the increase of total calcium content in the leaves.

Discussion

The water used for irrigation (neutral acidity – pH = 7.1 and hardness of 18 ºdH) might have caused the substrates to become less acidic. The differences in the pH values of the objects were induced by the types of fertilisers used. As a physiologically acidic fertiliser, ammonium sulphate, was able to partly neutralise the effect of water, as opposed to calcium nitrate which enhanced that effect. According to Tumilowicz [5], due to its origins, Stewartia should be grown in more acidic substrates, similar to those used in *Rhododendron* shrubs cultivation (pH = 4.5–5). Our studies confirmed the initial results [6] indicating that the plants prefer more acidic substrate, yet tolerate lower acidity and do not show any disorders even at the pH = 6.3 value.

Mineral fertilisers, used at the same doses, increase the total salt concentration in the substrate to a different extent. The increase of the salt concentration caused by $NaNO_3$ was considered as the value of 100. With reference to this value, relative increase in the salt concentration was 69 for ammonia sulphate, and 53 for calcium nitrate [7]. That might explain a higher concentration of the soil solution in the objects fertilised with ammonia sulphate. The increase might also have been caused by accumulation of ballast substances introduced during fertilisation with fertilisers of low mineral content.

During the two years of cultivation similar amounts of nutrients were introduced into all objects. After the first and second year of cultivation, low content of mineral nitrogen in the substrates was noticed. The nitrogen uptake was accompanied by high temperatures in the summer and greater watering of plants. The absence of nitrate form in the substrate can be indicative of leaching of that element as non-sorbed in the soil [8]. Low nitrogen content in the substrate can also result from passing too much time between the date of last fertilisation and taking substrate samples for analysis. The ratio of NO_3^- and NH_4^+ ions uptake by the plants depends on many factors, such as eg plant genus, kind and dose of nitrogen fertiliser, the rate of nitrification process, sorption capacity and substrate acidity, as well as on temperature and availability of oxygen and light [9–12]. The plants take greater amounts of nitrogen in the form of nitrate ions rather than ammonia ions, due to the greater content of nitrate ions in the substrate and possibility of immediate uptake by the roots. Greater amount of the ammonia form in the substrate after the second year of cultivation could have been caused by the limited

NH_4-N uptake due to the smaller range of optimum substrate acidity [8]. Nitric ions are taken faster in acidic environment whereas ammonia ions – in the neutral one [13]. During the two years of cultivation the same tendencies were observed. In the objects where ammonia form was used, higher phosphorus contents and lower potassium contents were detected in the substrate. High content of calcium and magnesium in the substrates, as compared with the initial value, was mostly caused by the high content of these elements in the water used for irrigation. Using calcium nitrate in fertilisation of the objects with nitrate form amounted to the increased calcium content in these objects.

The literature available so far has not confirmed the data concerning the content of nutrients in Stewartia leaves. The values determined are comparable to the optimum contents in the leaves of *Gardenia jasminoides*, a genus of the same *Theaceae* family [14]. Lower content of nutrients was observed in the leaves harvested at the end of vegetation season than in those harvested in the middle of the season, which can be explained with withdrawal of mineral components from the leaves to other parts of the plant before the resting period. In early phases of plant growth, the content of nitrogen, phosphorus and potassium is higher than in later phases [8]. The nitrogen contents in vegetative parts decline very quickly after having reached maximum concentration before blooming. That is connected with migration of the nutrients from vegetative parts to the seeds and with the dying process of the senescence leaves [15]. At the end of the first year's vegetation season, the highest content of total nitrogen (2.17 and 1.95 % d.m.) was detected in the leaves of shrubs fertilised with ammonia form of nitrogen. In the second year, a tendency of greater nitrogen content in the objects fertilised with ammonium form and in the objects of higher acidity was observed. All species from heathland had higher N content in the presence of ammonium than with nitrate as a sole nitrogen source [16]. It can signify that similarly to the *Ericaceae* family (acidophilic plants), Stewartia belongs to the plants that prefer ammonium ions as the source of nitrogen in the soil [8, 9, 17]. Optimum nitrogen content in plants is a broad value of 0.5 to 5 % N in the dry mass of vegetative organs. The content depends on the plant genus and age, as well as on the degree of nitrogen content of the plant [8]. The content of nitrogen in poinsettia shoots was lower than in the plants fertilised with nitrate form rather than with ammonia form [10]. However, Ganmore-Neumann and Kafkafi's [9] studies revealed higher content of nitrogen in the above-mentioned part of the nitrate-nourished plants. Limited uptake of nitrates and their low accumulation in the shoots may signify some disorders of these processes in the plant.

Our study exposed a very low content of ammonia and nitrate nitrogen in the leaves of Stewartia plant. Comparable contents of the element had been found in our previous research [6]. The pH value have been shown to affect N uptake rates and in some cases differentially affect NH_4^+ and NO_3^- uptake rates [12]. Depending on the species and conditions, uptake can be stimulated or inhibited by changing pH. Moreover, such low content can be a result of fast transformation of mineral nitrogen into organic nitrogen compounds [11]. Accumulation of nitrates in the plant depends on the amount of nitrate nitrogen in the environment, as well as on the rate of reduction process in the plant. In the mineral composition of plants fertilised with ammonia form of nitrogen, nitrate ions can be traced as a result of nitrification process of ammonia ions in the soil. Yet, what should be accentuated is that the concentration of nitrate ions is lower in that situation than during fertilisation with nitrate fertilisers [10, 11].

Contents of soluble nutrient forms specified in the middle and at the end of the vegetation season show differences in the number of mineral components (K, Ca, Mg) with reference to substrate acidity, as well as the form of nitrate fertiliser [11]. As ammonia and nitrate ions make 80 % of the total content of ions taken by the plants, the nitrogen form has a significant effect on the uptake of other cations and anions. Ammonia form stimulates the uptake of PO_4^{3-} anions, whereas reduces the uptake of Ca^{2+} and Mg^{2+} cations [8–10, 12]. In this experiment, cations contents tended to decrease in the presence of NH_4-N, causing increased cation uptake limitation. Plants from acid soils often have lower cation contents than plants from less acidic habitats [16, 18].

The total nitrogen content in the leaves was higher at the end, than in the middle of the vegetation period. Concentration of N is usually higher in spring than in the summer [15]. With respect to what has been stated above, the plants fertilised with ammonia form revealed higher contents of total phosphorus. Presented studies have shown a better uptake of potassium by Stewartia plants in the presence of nitrate form in the substrate. The form in which nitrogen is introduced into the substrate plays a significant role in the relations between nitrogen and potassium. In general, potassium – similarly to other cations – is said to be taken more intensively in the presence of nitrates, while ammonia ions probably act quite contrary to K^+ [7]. The opponents of this thesis state that the content of potassium in the plants fertilised with ammonia nitrate is similar or higher than in those using nitrates. What should be highlighted is that the sum of potassium, calcium, magnesium and sodium cations taken by the plants nourished with ammonia nitrogen is lower than in those using nitrates, yet the content of phosphorus is higher [8]. The study also revealed the effect of substrate acidity on potassium uptake by the plants. Less acidic substrate allowed for better uptake of the component. Acidic reaction does not foster the uptake of potassium or other elements [16, 18].

The higher calcium content in the leaves of Stewartia was observed in case of nitrate nitrogen fertilisation, which complies with other reports [13] that ammonia ions generally reduce the uptake of calcium (because of competitive relations between NH_4^+ and Ca^{2+}), while nitrate ions stimulate the uptake of that element. Similarly, the increase in the content of calcium in the substrate leads to the increase of its content in the leaves [8].

In the case of magnesium, no statistically significant differences were noted in the effect of individual nitrogen form of fertiliser, or in the substrate acidity on the uptake of that element. The reports that the plants fertilised with ammonia nitrate take less Mg^{2+} cations when compared with the plants fertilised with nitrates [8, 10, 12], have not been confirmed, either.

Conclusions

1. The studied specimens used the ammonia form of nitrogen (NH_4-N) in a better and more effective way.

2. The shrubs took greater amounts of potassium and calcium when fertilised with nitrate form of nitrogen (NO_3-N).

3. The plants fertilised with ammonia form of nitrogen showed higher contents of phosphorus and magnesium.

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NAWOŻENIE AZOTEM STEWARCJI KAMELIOWATEJ *Stewartia pseudocamellia* UPRAWIANEJ W PODŁOŻU O ZRÓŻNICOWANYM ODCZYNIE

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Abstrakt: Badaniami objęto rośliny stewarcji (*Stewartia pseudocamellia* Maxim.), uprawiane w latach 1998–1999 w pojemnikach w warunkach polowych. Krzewy nawożono amonową lub azotanową formą azotu przy odczynie podłoża pH = 3,9 i 5,5. Rośliny nawożono pogłównie na podstawie analizy podłoża. W sezonie wegetacyjnym dwukrotnie pobrano liście do analiz na zawartość łatwo rozpuszczalnych form składników pokarmowych oraz ogólną ich zawartość.

W czasie trwania doświadczenia obserwowano stopniowy wzrost pH oraz ogólnego stężenia soli w podłożu w stosunku do wartości wyjściowych. Po zakończeniu każdego roku uprawy stwierdzono małą zawartość azotu mineralnego w podłożach. W obu latach uprawy obserwowano większą zawartość fosforu oraz mniejszą zawartość potasu w podłożu krzewów nawożonych formą amonową w porównaniu z nawożonymi formą azotanową. Zawartość łatwo rozpuszczalnych form składników w liściach stewarcji utrzymywała się na zbliżonym poziomie przez cały okres wegetacji. Badania wykazały bardzo małą zawartość azotu mineralnego w liściach stewarcji. Oznaczone zawartości łatwo rozpuszczalnych form składników pokarmowych (K, Ca, Mg) wykazały zróżnicowanie w zależności od odczynu podłoża, jak również od formy nawozu azotowego. Całkowite zawartości składników pokarmowych w obu terminach pobierania liści były porównywalne, z wyjątkiem azotu ogólnego. Ogólna zawartość fosforu i magnezu w liściach była uzależniona od zastosowanej formy azotu, przy czym większe zawartości notowano w obiektach nawożonych formą amonową. Natomiast potas był lepiej pobierany przez stewarcje w obecności formy azotanowej w podłożu. W badaniach wykazano również wpływ odczynu podłoża na pobieranie potasu przez rośliny.

Słowa kluczowe: azot, pH, zawartość makroelementów, *Stewartia pseudocamellia*