

EFFECT OF DIFFERENT FERTILIZATION ON THE GROWTH AND NUTRITION OF AZALEA (*Rhododendron* L.)

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Abstract

A study on azalea (*Rhododendron* L.), 'Kilian' and 'Persil', was conducted in 2009–2010. Plants were grown in pots in the open air, in a peat substrate with a pH of 4.8. The effect of the following fertilization methods was studied: I – traditional fertilization (single fertilizers were applied in 2 rates); II – a slow-release fertilizer (Hortiform pH); III – combined fertilization ($\frac{1}{4}$ of the rate of nutrients was applied in the form of single fertilizers and $\frac{3}{4}$ in the form of Hortiform pH). The slow-release fertilizer Hortiform pH and combined fertilization were applied once in each study year when filling the pots with growing medium. Fertilizers were applied at the basic rate (D1) and at a twice higher rate (D2). In the first year of cultivation, the study showed no significant effect of fertilization method on shoot length in both azalea cultivars, whereas in the second year the longest shoots were found after application of the slow-release fertilizer Hortiform pH. In both years of the study, significantly longer shoots were found in the cultivar 'Persil' after application of the lower fertilizer rate (D1) than after application of the higher fertilizer rate (D2). On the other hand, the study showed that the fertilizer rate had no effect on shoot length in 'Kilian'. After application of the higher fertilizer rate, a higher content of nitrogen and potassium as well as a lower content of phosphorus, calcium, and magnesium were determined in the leaves of both cultivars. The study found the following percentages to be the optimal nutrient content in azalea leaves: 1.88 – 2.20% N; 1.0 – 1.7% K; and 0.60% – 1.20% Ca, while the phosphorus content of 0.09 – 0.25% and the magnesium content of 0.14 – 0.25% were shown to be the lower limit for optimal plant nutrition. After the end of the growing season, a low content of all nutrients in the medium was found in both study years, irrespective of the applied fertilizer rate and fertilization method.

Key words: *Rhododendron*, mineral nutrition, slow-release fertilizer, plant growth, chemical composition

INTRODUCTION

Azaleas and rhododendrons have found a permanent place in gardens and parks across Poland. Their inflorescences are characterized by a beautiful palette of colours at the turn of May and June (Chojnowska and Chojnowski, 2003). Attention is also attracted to high winter hardiness of azalea under temperate climate conditions. This is confirmed by the occurrence of yellow azalea (*Rhododendron luteum* Sweet.) in the wild in the village of Wola Żarczycka near Leżajsk in the Podkarpacie region (Czekalski, 1986, 2008).

Plants of the family Ericaceae, such as *Andromeda*, *Calluna*, *Erica*, *Kalmia*, and *Pieris*, have low nutritional requirements. The genus *Rhododendron* is also included in this group (Aendekerk, 1999). Nutrient-poor soils are the natural growth environment for azaleas and rhododendrons (Węglowski, 1990; Berg and Heft, 1992).

Research and nursery practice prove that the supply of a proper amount of nutrients stimulates these species to growth (Bi et al. 2007).

A characteristic environmental factor for plants of the family Ericaceae is pH whose optimal range is between 4.0 and 5.5 (Aendekerk, 1997). However, it has been shown that small amounts of calcium are required in order to ensure proper growth and development of plants. But too high amounts of this element cause in rhododendrons root reduction and iron-deficiency-induced chlorosis (Chaanin and Preil, 1994; Preil and Ebbinghaus, 1994).

Intensive nitrogen fertilization has a positive effect on plant growth and leaf chlorophyll content. The

leaf blades of these plants are characterized by a dark green colour. However, too low rates of nitrogen reduce plant growth and development. Light green leaf colour, caused by low chlorophyll content, and leaf fall have been shown to occur after application of 0 to 50 kg N × ha⁻¹ (Alt et al. 1994). Rates higher than 100 kg N × ha⁻¹ can be a cause of increased susceptibility to fungal diseases and reduced winter hardiness (Witt, 1994; Muras and Lukosek, 2000).

The production of good quality azalea seedlings requires appropriate fertilization. In practice, single mineral fertilizers and compound fertilizers, among other slow-release fertilizers, are used for fertilization. Slow-release fertilizers include non-controlled release fertilizers and controlled release fertilizers (CRF). The type of coating, temperature, and substrate moisture content are the factors that determine controlled nutrient release (Chohura, 2004). The application of these fertilizers reduces the amount of nutrients leached to groundwater with rainfall (Stuart et al. 1995).

The aim of the present study was to determine the effect of different methods of application of mineral fertilizers and their rates (the basic rate and a twice higher rate) on the growth and nutritional status of two azalea cultivars during the first two years of cultivation.

MATERIALS AND METHODS

The study on azalea (*Rhododendron* L.) 'Kilian' with orange and salmon coloured inflorescences and the white coloured 'Persil', was conducted in 2009–2010.

The initial material comprised one-year *in vitro* propagated seedlings. The plants were grown in pots in the open air. Peat with an initial pH of 4.6 was used as growing medium, which was limed to a pH of 4.8 by applying 2 g of CaCO₃ × dm⁻³. In the first year of the study (2009), the plants were planted in 2 dm³ pots, while in the second year (2010) in 5 dm³ pots. Throughout the entire growing season, the plants were watered using a drip irrigation system. The experiment was set up as a completely randomized design in eight replications. The experimental unit was one plant.

The examined factors were as follows:

- fertilization method;
- fertilizer rate;
- cultivar.

Three fertilization methods were used: I – traditional fertilization (single fertilizers were applied at 2 rates); II – a slow-release fertilizer, Hortiform pH, was applied once when filling the pots with growing medium; III – combined fertilization in which L of the rate of nutrients was applied in the form of single fertilizers and I in the form of Hortiform pH when filling the pots with growing medium.

Fertilizers were applied at two rates: the basic rate (D1) and a twice higher rate (D2). Irrespective of fertilization method, in each study year the following amounts of nutrients were supplied when the rate D1 was used (g × dm⁻³ of medium): N – 0.78; P – 0.16; K – 0.60; Mg – 0.24, as well as the following micronutrients (mg × dm⁻³): Fe – 20.00; Cu – 13.20; Zn – 0.74; Mn – 5.10; B – 1.60; Mo – 3.60. A double amount of nutrients was supplied with the rate D2 was used.

Single fertilizers were applied in the following form: NH₄NO₃ 34% N; KNO₃ 15.5% N; 37.3% K; Ca(H₂PO₄)₂ × H₂O (20.2% P); MgSO₄ × H₂O (17.4% Mg); Fe – EDTA; CuSO₄ × 5 H₂O; ZnSO₄ × 7 H₂O; MnSO₄ × H₂O; H₃BO₃; (NH₄)₆Mo₇O₂₄ × 4 H₂O. The slow-release fertilizer Hortiform pH had the following composition: N – 17%; P – 3.52%; K – 11.2%; Mg – 1.8%; B – 0.01%; Co – 0.002%; Cu – 0.01%; Fe – 0.1%. This fertilizer contains nitrogen in the form of slowly soluble ureaform.

Biometric measurements of the plants were made on the designated current year's shoots every 10 days, starting from 3 July and continuing until 10 September in 2009 and from 26 May until 19 August in 2010. In 2010 the measurement period was shortened, since the results obtained in 2009 showed that long shoots of azalea finished their growth around the middle of August.

Leaves were collected for analysis in the 2nd decade of August 2009 and 2010. Healthy and fully developed leaves were sampled from the middle part of the current year's shoots. Leaf samples were dried at a temperature of 60–70°C and ground. Subsequently, the following was determined:

- total nitrogen by the Kjeldahl method in a Foss Tecator digestion system.

After plant material mineralization at 550°C, the following was determined:

- phosphorus colourimetrically with ammonium-vanadium-molybdate (Thermo, Evolution 300) as well as potassium, calcium, and magnesium by AAS (Ostrowska et al. 1991).

In the substrate, the following were determined in 0.03 M CH₃COOH extract: N-NH₄, N-NO₃ by the Bremner distillation method modified by Starck, phosphorus, potassium, calcium, and magnesium using the same method as in the case of the plant material, S-SO₄ with BaCl₂, Cl with AgNO₃, pH in H₂O, and salt concentration (EC) conductometrically.

The results were statistically analysed by analysis of variance. The significance of differences was evaluated by Tukey's multiple confidence intervals and LSDs were calculated at a significance level of = 0.05.

RESULTS AND DISCUSSION

The results on the effect of different fertilization methods and fertilizer rates on the growth of azalea shoots are shown in Table 1. In the first year (2009), the study found no significant effect of fertilization method on shoot length in both azalea cultivars, whereas in 2010 this factor was shown to significantly affect shoot length. The longest shoots were found in the cultivar 'Persil' after application of the slow-release fertilizer Hortiform pH (12.7 cm), slightly shorter ones after application of combined fertilization (10.6 cm), and the shortest ones after application of traditional fertilization (8.8 cm). A similar effect of fertilization method was shown in 'Kilian' in the case of which shoot length was, respectively: 15.9 cm, 15.1 cm, and 13.5 cm (Table 1). Thus, in both cultivars the shortest shoots were recorded after application of traditional fertilization in the form of single mineral fertilizers.

Different fertilizer rates significantly affected shoot length only in the case of the cultivar 'Persil'. In both years of the study, significantly longer shoots were found after application of the lower fertilizer rate (D1), compared to the higher one (D2). This relationship shows that 'Persil' has lower nutritional requirements, since after application of the higher rate (D2) the plants responded with growth inhibition, irrespective of the fertilization method. Moreover, in the treatments in which the traditional fertilization method and the double fertilizer rate were used about 20% of plants were eliminated in the second year of the study. In the cultivar 'Kilian', different fertilizer rates were not found to have a significant effect on the length of azalea shoots (Table 1).

The nutritional status of the plants was evaluated based on an analysis of leaves sampled for assay in the second decade of August. In the leaves of the azalea 'Persil', on average 1.89% N-total, 0.13% P, 1.10% K, 0.76% Ca, and 0.16% Mg were recorded, while in the leaves of cv. 'Kilian' 2.17% N-total, 0.16% P, 1.30% K, 1.06% Ca, and 0.22% Mg. The leaves of 'Kilian' were shown to have a higher nutrient content than 'Persil'.

The basic fertilizer rate (D1) and the double rate (D2) differentiated the chemical composition of the plants. After application of the higher fertilizer rate, the cultivar 'Persil' was found to have a higher content of nitrogen and potassium, thus the nutrients that are taken up quickly and easily by plants, and a lower content of phosphorus, calcium, and magnesium. Furthermore, the study showed a beneficial effect of the lower fertilizer rate (D1) in the form of Hortiform pH on shoot length only in this cultivar. The average leaf nitrogen content was 1.74% N-total, which would be evidence of the

optimal nitrogen content in 'Persil', since the higher rate (D2) reduced shoot growth (Table 1, Fig.1). A similar relationship was found in the leaves of 'Kilian', though after application of the higher rate (D2) the plants took up substantially larger amounts of these nutrients than in 'Persil' (Fig. 2). This proves that the cultivar 'Kilian' is characterized by a higher growth rate, since the leaf nitrogen content was 1.90% N (D1) and 2.43% N (D2). Taking into account the absence of differences in shoot length, this content should be considered to be optimal for this cultivar.

The study conducted by Bri et al. (1992) demonstrates that the nutrient content in the leaves of evergreen azalea was determined by the rate of fertilizer applied. The leaf total N content was shown to be higher in the case of fertilization with a higher rate of compound fertilizers. According to Czekalski (2011/2012), nitrogen is best supplied to plants in the ammonium form, as it is more beneficial to the plants in question than the nitrate form. Rhododendrons take up significantly more ammonium nitrogen and the other nutrients are taken up more slowly in the presence of this form and the soil does not become deacidified. According to Breš et al. (1997), the standard nitrogen content in azalea leaves ranged 2.3% – 2.8% N. On the other hand, Aenderk (1997) found that the optimal nitrogen content in azalea leaves was 1.64 % N.

The phosphorus content in azalea leaves was differentiated by fertilization method and it ranged from 0.09% P after application of the slow-release fertilizer to 0.24% P after application of traditional fertilization. These results show that phosphorus contained in Hortiform pH was not easily available to plants. This relationship occurred in both cultivars (Figs. 3 and 4). A content below 0.15% P is considered to be the critical phosphorus content in the indicator parts of azalea, while the standard content is from 0.20 to 0.40% P (Breš et al. 1997). According to Aenderk (1997), the optimal phosphorus content in azalea leaves is 0.25–0.41% P, whereas plants exhibiting phosphorus deficit have from 0.06% to 0.11% P in their leaves. Thus, the leaf content of this element in the present study should be rated as low.

The leaf potassium content in the azalea cultivars studied ranged from 0.94% to 1.70% K. As mentioned before, the highest amount of potassium was recorded in the plants after application of traditional fertilization. Furthermore, the plants fertilized with the double fertilizer rate were shown to have a significantly higher content of this nutrient (Figs 1 and 2), whereas the fertilization method significantly influenced the content of this element only in the leaves of the cultivar 'Kilian'. The level of 0.9% – 1.5 % K is

reported to be the optimal potassium content for azalea by Breś et al. (1997), while according to Aendekerk (1997) it is 1.1% – 2.3% K. Deficiency symptoms are observed when the leaf potassium content for the genus *Rhododendron* is 0.19% – 0.5% K. The present study demonstrates that fertilization with the lower fertilizer rate fully meets the potassium requirements of the plants.

The calcium content in azalea leaves was from 0.68% to 1.21% Ca. It should be stressed that the calcium content in the plants after application of the lower fertilizer rate (Figs 1 and 2) and after application of Hortiform pH was higher (Figs 3 and 4). Breś et al. (1997) say that the range between 0.5% and 1.5% Ca is the standard content. Therefore, the calcium content after application of the lower fertilizer rate should be considered to be optimal.

The magnesium content in the studied plants ranged from 0.14% to 0.25% Mg. According to Breś et al. (1997), the level of 0.17% Mg should be considered to be the critical magnesium content in azalea leaves, while the standard content is from 0.2% to 0.4% Mg. According to Aendekerk (1997), the optimal magnesium content for the genus *Rhododendron* is in the range from 0.3 to 0.6% Mg. In the present study, the plants of both cultivars fertilized with the lower rate took up magnesium at an optimal amount, whereas the double rate reduced the uptake of this nutrient (Figs 1 and 2). The lower content of calcium and magnesium in the leaves of plants fertilized with the higher fertilizer rate can result from the antagonistic effect of other dietary minerals.

The analysis of the growing medium was designed to evaluate its nutrient availability after the end of the growing season and substrate samples were therefore collected for analysis in October. The obtained results are shown in Tables 2 and 3.

In both years of the study, trace amounts of mineral nitrogen were found in the substrate, which is evidence that it has been completely used up in the growing medium or leached outside the root zone, hence these results are not included in Tables 2 and 3.

In 2009 the phosphorus content was from 11 to 122 mg P dm⁻³, but its highest content was found in the substrate after application of the higher fertilizer rate in traditional form (Table 2). In 2010 phosphorus content in the medium outside the detection limit of

the method applied was observed, irrespective of the rate of fertilizers and the method of their application (Table 3).

The potassium content in the medium ranged from 19 to 163 mg K × dm⁻³. In 2009 the potassium content in the medium was most differentiated by fertilization method; its lowest content was found after application of Hortiform pH, while the highest one after application of traditional fertilization (Table 2).

Calcium was supplied to the substrate in all treatments at one level before the establishment of the experiment, setting the value of pH at 4.8. After the first growing season, the calcium content in the medium was from 955 to 1751 mg Ca × dm⁻³ and the value of pH ranged from 5.61 to 5.96. The study did not reveal an unambiguous effect of the investigated factors on calcium content and pH in 2009. On the other hand, in 2010 a much lower content of calcium in the medium and a decrease in pH were found (Table 3).

The sulphur content in the medium was from 17 to 176 mg S-SO₄ × dm⁻³, while the chlorine content from 0 mg to 120 mg Cl × dm⁻³. Both the chlorine and sulphur content did not exceed the permissible content of these nutrients for peat substrates (Breś et al. 1997).

Fertilization in nursery culture is extremely important, since flowering and flower bud set can be stimulated in the genus *Rhododendron* by applying proper rates of nitrogen and potassium (Stuart et al. 1995; Bielenin and Matysiak, 2004). On the other hand, an excess of nitrogen has a negative effect on winter hardiness, in particular in evergreen azalea *Rhododendron x kuruje* (Henning et al. 2008).

The following values are given as the optimal levels of mineral nutrients in the substrate for the genus *Rhododendron* during the growing period (mg × dm⁻³): 50–100 N-NO₃; 40–80 P; 100–150 K; 50–70 Mg (Kónczak-Kornatowska, 2009).

In the present study, the following amounts of nutrients were supplied when the rate D1 was applied (mg × dm⁻³): 100 N; 40 P; 150 K; 60 Mg, while these amounts were two times higher in the case of the rate D2. The low content of nutrients in the substrate should be noted in the years 2009 and 2010 after the end of the growing season, irrespective of the fertilizer rate applied.

Table 1
Effect of fertilization method and fertilizer rate on shoot growth in the azalea 'Persil' and 'Kilian' in 2009–2010

Fertilization method (A)	Cultivar	Fertilizer rate (B)	'Persil'		Mean of years	'Kilian'		Mean of years
			Shoot length (cm)			Shoot length (cm)		
			2009	2010		2009	2010	
Conventional		D1	11.2	13.0	12.1	10.4	17.0	13.7
		D2	8.0	3.0	5.5	11.6	15.0	13.3
Mean for conventional fertilization			9.6	8.0	8.8	11.1	16.0	13.5
Slow-release fertilizer		D1	12.0	21.0	16.5	11.3	21.0	16.1
		D2	6.8	11.0	8.9	10.4	21.0	15.7
Mean for slow-release fertilizer			9.4	16.0	12.7	10.9	21.0	15.9
Combined		D1	12.5	17.0	14.8	10.1	17.0	13.6
		D2	7.6	5.0	6.3	14.0	19.0	16.5
Mean for combined fertilization			10.1	11.0	10.6	12.1	18.0	15.1
Mean for cultivar			9.7	11.7	10.7	11.3	18.3	14.8
Mean for fertilizer rate		D1	11.9	17.0	14.5	10.6	18.3	14.5
		D2	7.5	6.3	6.9	12.0	18.3	15.2
LSD _(0.05) for fertilization method (A)			n.s.	4.2		n.s.	3.9	
LSD _(0.05) for fertilizer rate (B)			0.8	2.9		n.s.	n.s.	
LSD _(0.05) for AxB			n.s.	n.s.		n.s.	n.s.	

Table 2
Content of P, K, Ca, Mg, S-SO₄, Cl (mg dm⁻³), pH_(H₂O), and EC in the medium in October 2009

Cultivar	Rate	Fertilization method	P	K	Ca	Mg	S-SO ₄	Cl	pH	mS × cm ⁻¹
Persil	D1	Conventional	62	86	1751	133	91	57	5.96	0.23
		Slow-release fertilizer	25	20	999	82	54	75	5.83	0.20
		Combined	20	28	969	87	66	34	5.75	0.22
	D2	Conventional	40	82	696	127	78	45	5.68	0.20
		Slow-release fertilizer	11	20	1097	77	60	46	5.76	0.15
		Combined	20	25	982	79	50	63	5.84	0.12
Kilian	D1	Conventional	65	86	1018	114	149	76	5.95	0.36
		Slow-release fertilizer	14	21	1341	78	137	51	5.85	0.31
		Combined	16	22	955	72	117	50	5.82	0.22
	D2	Conventional	122	163	954	169	176	51	5.61	0.47
		Slow-release fertilizer	12	19	1248	66	164	52	5.85	0.37
		Combined	38	27	1099	79	158	6	5.79	0.32
Mean for rate	D1		33	44	1172	94	102	57		0.25
	D2		40	56	1013	99	114	44		0.27
Mean for cultivar	'Persil'		30	43	1082	97	66	53		0.19
	'Kilian'		44	56	1102	96	150	48		0.34
Mean for fertilization method	Conventional		72	104	1105	135	124	57		0.31
	Slow-release fertilizer		15	20	1171	76	103	56		0.26
	Combined		23	25	1001	79	98	38		0.22

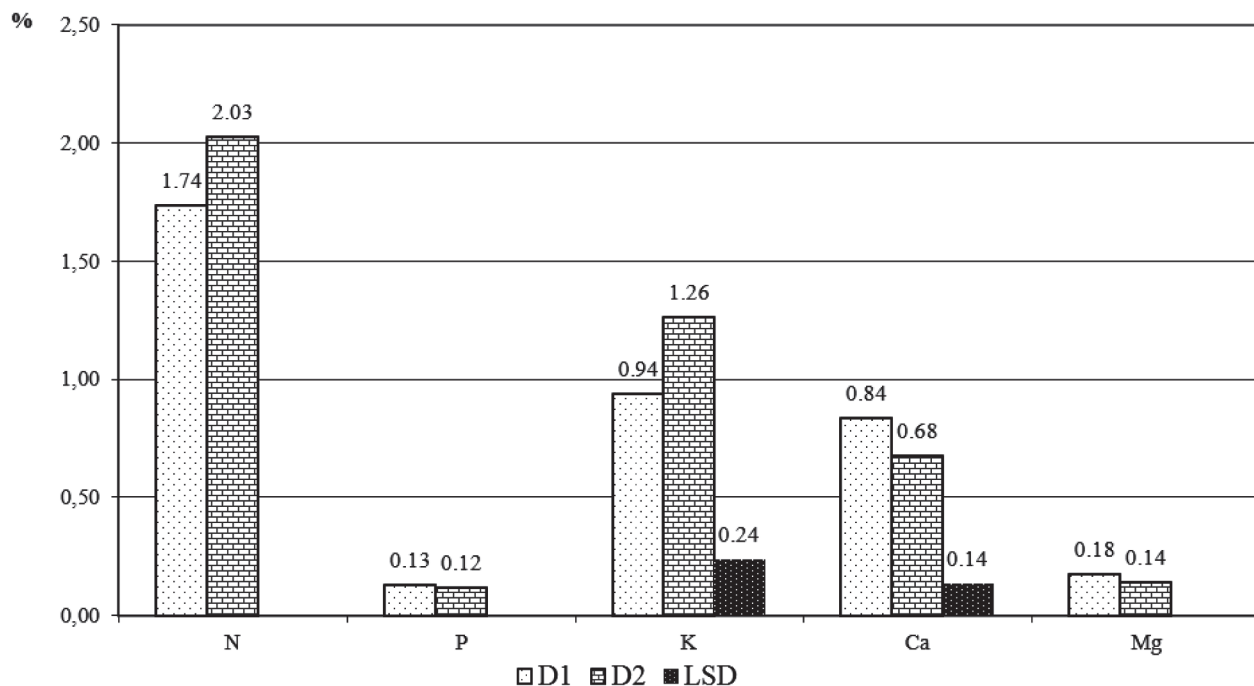


Fig. 1. Effect of fertilizer rates on the content of N-total, P, K, Ca, Mg (% d.m.) in the leaves of the azalea 'Persil'. Mean for 2009–2010.

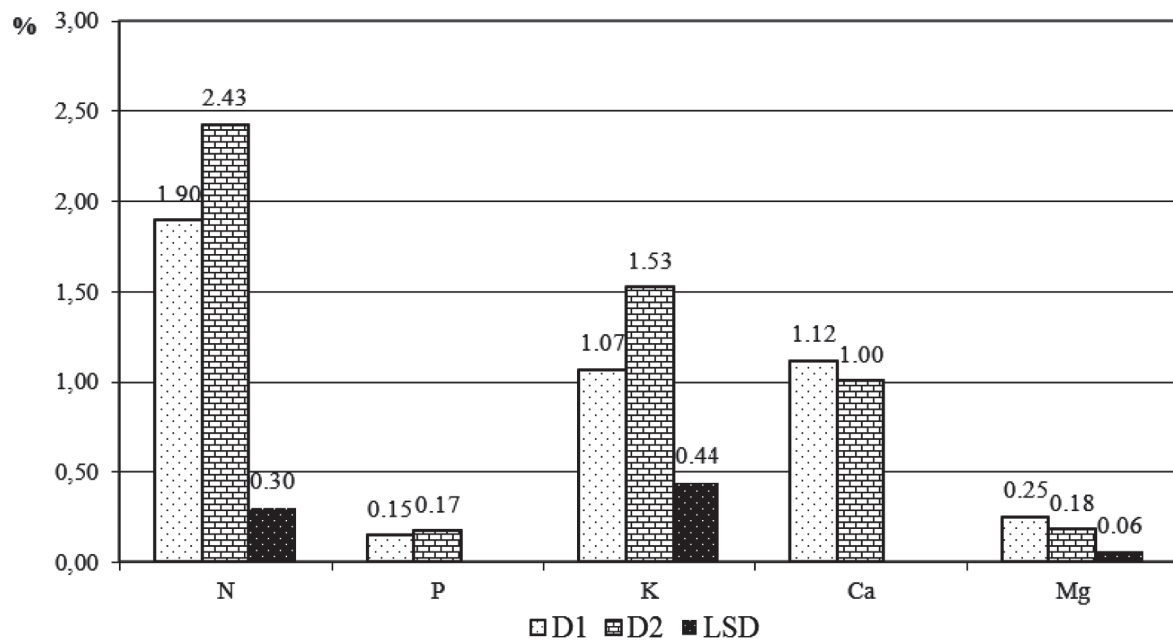


Fig. 2. Effect of fertilizers rates on the content of N-total, P, K, Ca, Mg (% d.m.) in the leaves of the azalea 'Kilian'. Mean for 2009–2010.

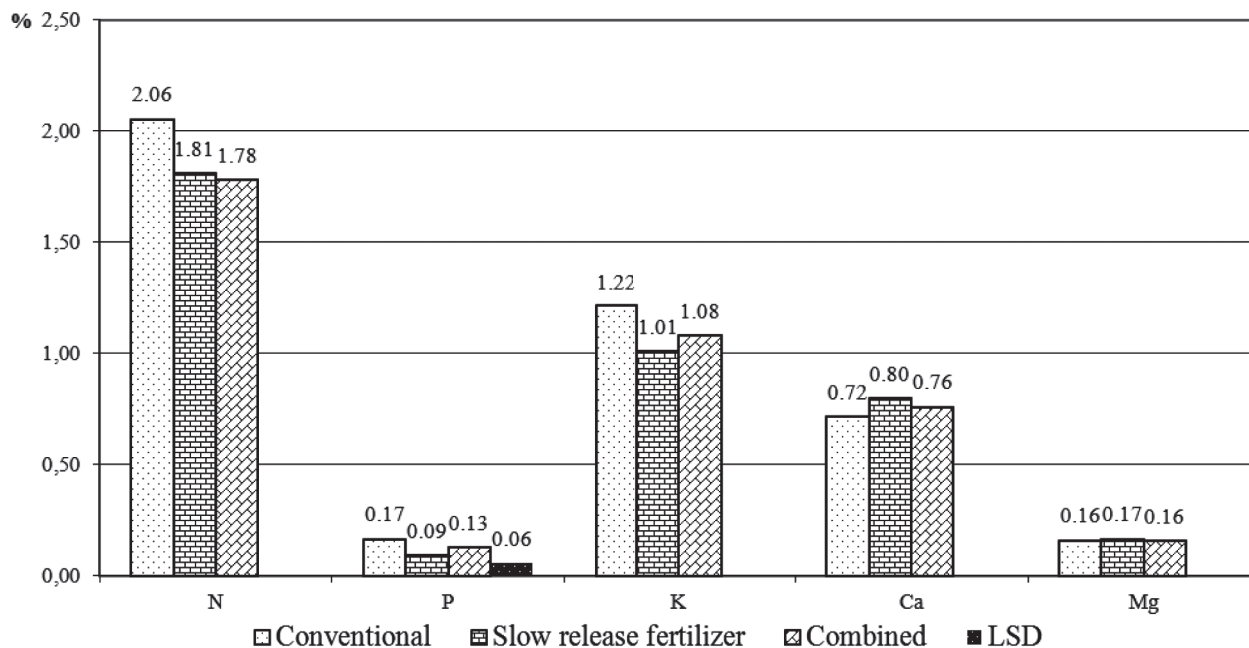


Fig. 3. Effect of fertilization method on the content of N-total, P, K, Ca, Mg (% d.m.) in the leaves of the azalea 'Persil'. Mean for 2009–2010.

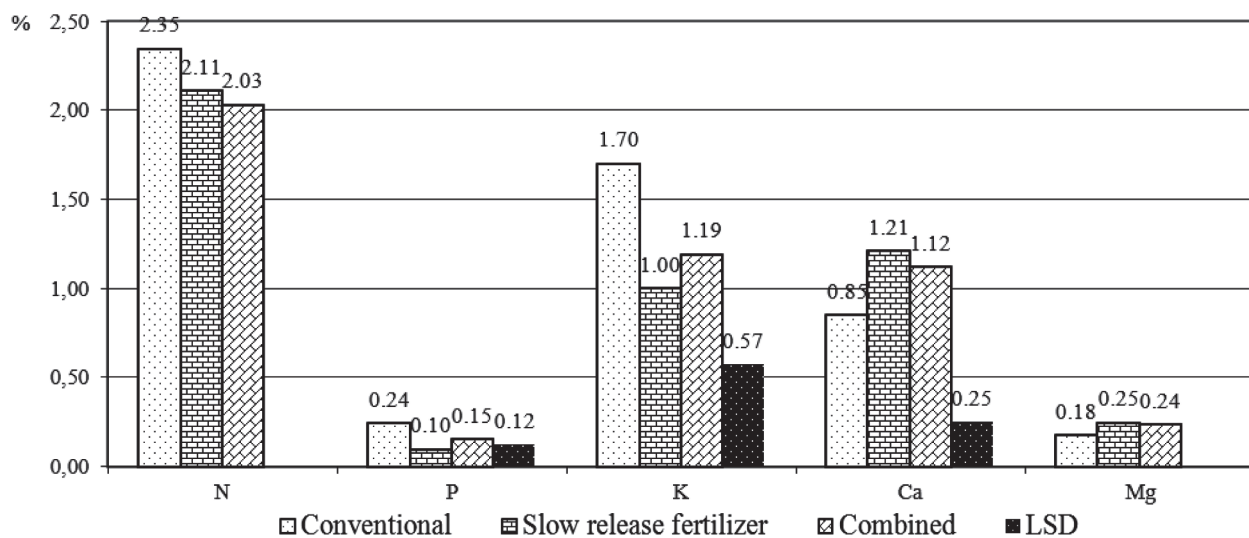


Fig. 4. Effect of fertilization method on the content of N-total, P, K, Ca, Mg (% d.m.) in the leaves of the azalea 'Kilian'. Mean for 2009–2010.

CONCLUSIONS

1. In the first year of cultivation of container-grown azaleas, no significant effect of fertilization on shoot length was found in both azalea cultivars, whereas in the second year of cultivation significantly longer shoots were found in both cultivars after application of the slow-release fertilizer (Hortiform pH), compared to the other fertilization methods.
2. In both years of the study, significantly longer shoots were found in the 'Persil' after application of the lower fertilizer rate (D1). The study found no

effect of the fertilizer rate on shoot length in the 'Kilian'.

3. After application of the higher fertilizer rate, a higher content of nitrogen and potassium as well as a lower content of phosphorus, calcium, and magnesium were detected in the leaves of both azalea cultivars.

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Wpływ zróżnicowanego nawożenia na wzrost i odżywianie azalii wielkokwiatowej (*Rhododendron* L.)

Streszczenie

Badania dotyczące azalii (*Rhododendron* L.) odmiany ‘Kilian’ oraz ‘Persil’ przeprowadzono w latach 2009–2010. Rośliny uprawiano w doniczkach na terenie otwartym, w podłożu torfowym o pH 4,8. Badano wpływ sposobu nawożenia: I – tradycyjny (pojedyncze nawozy zastosowano w 2 dawkach); II – nawóz o spowolnionym działaniu (Hortiform pH); III – nawożenie łączone (L dawki składników pokarmowych w postaci nawozów pojedynczych oraz I w postaci Hortiformu pH. Nawóz o spowolnionym działaniu Hortiform pH oraz nawożenie łączone zastosowano jednorazowo podczas napełniania wazonów podłożem w każdym roku badań. Nawozy zastosowano w dawce podstawowej (D1) oraz dwukrotnie większej (D 2). W pierwszym roku uprawy u obydwu odmian azalii stwierdzono brak istotnego wpływu sposobu nawożenia na długość pędów. Natomiast w drugim roku najdłuższe pędy wykazano po zastosowaniu nawozu o spowolnionym działaniu Hortiform pH. W obydwu latach badań po zastosowaniu mniejszej dawki nawozów (D1) stwierdzono istotnie dłuższe pędy u odmiany ‘Persil’ niż po

zastosowaniu większej dawki nawozów (D2). Wykazano natomiast brak wpływu dawek nawozów na długość pędów u odmiany 'Kilian'. W liściach obydwu odmian po zastosowaniu większej dawki nawozów oznaczono większą zawartość azotu i potasu, a mniejszą zawartość fosforu, wapnia i magnezu. Jako optymalną zawartość składników pokarmowych w liściach azalii uznano:

1,88 – 2,20% N, 1,0 – 1,7% K i 0,60% – 1,20% Ca, a zawartość fosforu 0,09 – 0,25 % i magnezu 0,14 – 0,25 jako dolny zakres optymalnego odżywiania roślin. Po zakończonym okresie wegetacji w obydwu latach badań wykazano niską zawartość wszystkich składników pokarmowych w podłożu niezależnie od zastosowanej dawki nawozów i sposobu nawożenia.

