ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 17, No. 10 2010

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EFFECT OF NUTRITION WITH MAGNESIUM IN VARIOUS MOISTURE CONDITIONS OF SOIL ON THE DYNAMICS OF ELONGATION GROWTH OF MEDICAL SAGE (*Salvia officinalis* L.)

WPŁYW DOGLEBOWEGO ŻYWIENIA MAGNEZEM W ZRÓŻNICOWANYCH WARUNKACH WILGOTNOŚCIOWYCH GLEBY NA DYNAMIKĘ WZROSTU ELONGACYJNEGO SZAŁWII LEKARSKIEJ (*Salvia officinalis* L.)

Abstract: The aim of the studies was to determine the effect of nutrition of the soil with magnesium in differentiated soil moisture conditions on the dynamics of the elongation growth of medical sage. The first factor of the two year pot experiment was the level of the nutrition with magnesium (0; 0.30; 0.90 g of Mg per pot), the other factor was the level of soil moisture (30 and 60 % of full water volume). Large usefulness of the logistic function for the description of the elongation growth of *Salvia officinalis* L. was statistically confirmed.

Keywords: medical sage, magnesium, soil moisture, elongation growth, logistic function

Medical sage belongs to herb plants of relatively large significance. The measure of intensity of plants physiological processes is, among other things, their elongation growth. The most natural measure of plants growth are the changes in their height. The elongation growth is most often presented graphically in a form of curves which are plots of some mathematical functions. To describe the growth of medical sage, a continuous sigmoidal logistic function, common in biometry, was used [1]. A basic factor affecting growth of plants is balanced mineral nutrition. It is estimated that about 60 % of arable land in Poland is characterised by a small amount of available magnesium and therefore mineral nutrition of plants with this element becomes more and more significant [2–5].

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The aim of the study was to determine the effect of in-soil nutrition with magnesium in various moisture conditions on the dynamics of elongation growth of medical sage. Usefulness of the logistic function for the description of this plant was also assessed.

Material and methods

A two year pot experiment (Mitcherlich pots) were carried out in the vegetation hall (greenhouse) of University of Agriculture in Szczecin. A method of complete randomization in the two factor system was used in ten replications, where: the 1st factor – the level of nutrition with magnesium (Mg0, Mg1, Mg2), the 2nd factor – the level of soil moisture content (30 % and 60 % of full water volume).

The medium for plants consisted of the soil material taken from the arable humus level of a post-cultivated soil of 6th quality class and its mechanical composition was light loamy silty sand.

The same doses of indispensable macro- and microelements, except magnesium, were used. The doses of magnesium in a form of $MgSO_4 \cdot 7H_2O$ were differentiated in the following way: Mg0 – 0 g Mg per pot, Mg1 – 0.30 g Mg per pot, Mg2 – 0.90 g Mg per pot. Doses of the remaining mineral elements per pot were: N – 1.0 g in a form of NH_4NO_3, K – 1.66 g in a form of K_2SO_4 and KC1 (1:1), P – 0.44 g in a form of NaH_2PO_4, Ca – 0.36 g in a form of $CaCO_3$, a solution of microelements according to Hoagland – 5 cm^3, a solution of 1 % $FeCl_3$ – 5 cm^3. In the course of filling the pots, current moisture and full water volume were annually determined. During the whole period of plants vegetation, the soil moisture was maintained at the level of 30 or 60 % of full water volume, depending on the combination of the experiment, using a gravimetric method [6].

In order to determine the dynamics of elongation growth in both vegetation seasons, the height of six (from each combination of the experiment) randomly selected plants (always the same) was measured every seven days since the moment the thinning of plants in the pots was made.

To describe the growth process, a logistic function was used:

$$h = \frac{h_{max}}{1 + b \cdot \exp(-kt)}$$

where: h – height of plants,
h_{max} – maximum height of plants,
t – vegetation time,
b, k – coefficients.

Coefficients of the logistic model were estimated using a method of the smallest squares after linearization of a function by means of logarithmic transformation [7, 8]:

$$\ln\ [(h_{max}/h) - 1] = \ln b - kt$$

Additionally, other parameters of the logistic function were calculated, ie initial value h_0, coordinates of the inflexion point (t_i, h_i) and characteristic of this point maximum growth rate $(dh/dt)_{max}$.

These calculations were made on the basis of the following formulae $h_0 = h_{max}/(1 + b)$: $t_i = (\ln b)/k$; $h_i = 0.5h_{max}$; $(dh/dt)_{max} = 0.25\ kh_{max}$.

Using an analytical form of the logistic function, curves showing the elongation growth of plants h = h(t) were plotted for each combination of the experiment during the 1st and the 2nd year of the studies (Fig. 1). In order to compare the degree of the fitting of theoretical curves to the experimental data, values of determination coefficient R^2 were calculated.

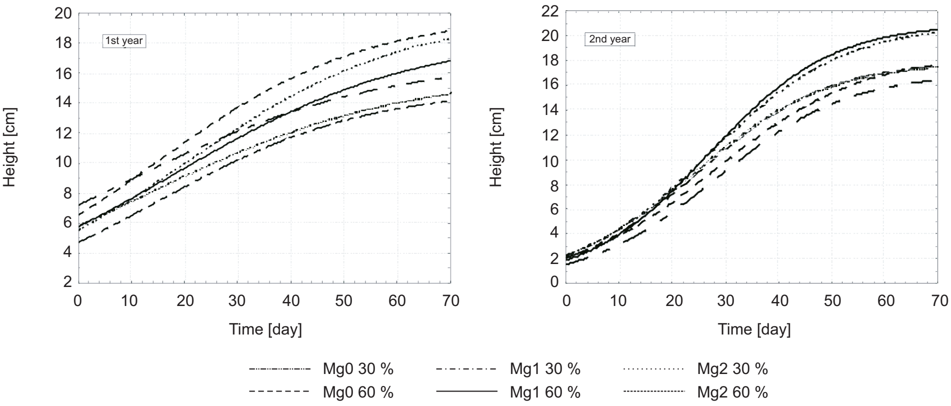

Fig. 1. Growth curves of medical sage plants from combinations of the experiment

Results and the discussion

Parameters of the logistic function for individual combinations of the experiment are shown in Table 3. The determination coefficient R^2 ranges from 0.931 to 0.994. The data in Table 3 show that the logistic function describes sufficiently enough the actual course of the elongation growth of medical sage. This is reflected in the values of determination coefficients R^2, very close to one. Similar results of the studies were also obtained by Gregorczyk [9]. He confirmed usefulness of the logistic function for mathematical modelling of the elongation growth of herb plants.

During the first year of the studies, intensive growth of plants lasted from the 8th to the 20th day of vegetation (counting from the thinning of the plants in the pots) depending on the combination of the experiment; at this time the curve of absolute growth is at the point of inflexion. The earliest, ie on the 8th day of vegetation, maximum growth rate was observed in medical sage in the combination of Mg1 30 % of full water volume, whereas the latest (ie on the 20th day of vegetation), in plants in the combination of Mg2 60 % of full water volume. During the second year of the studies the growth curve of sage plants reached the point of inflexion later than in the first year.

Table 1

Kinetics of the elongation growth of medical sage plants from individual combinations of the experiment (the averages of the measurements of 6 plants) 1st year of the experiment

Measurement	Day of vegetation*	Height of plants [cm]					
		Mg0 30 %	Mg1 30 %	Mg2 30 %	Mg0 60 %	Mg1 60 %	Mg2 60 %
1	1	4.0	6.0	5.0	6.0	6.0	6.0
2	8	7.0	9.0	7.0	8.0	7.0	7.0
3	15	8.0	10.0	9.0	10.5	9.0	9.0
4	22	9.0	12.0	10.0	13.0	10.0	10.5
5	29	10.0	12.5	11.0	14.0	12.0	12.0
6	36	11.0	13.0	12.0	15.0	12.5	13.5
7	43	11.5	13.5	12.5	16.0	13.0	14.5
8	50	13.0	14.0	13.0	16.5	15.0	16.0
9	57	13.5	15.0	13.5	18.0	16.0	17.5
10	64	15.0	17.0	16.0	20.0	18.5	20.0

* From the day of thinning the plants in pots.

Table 2

Kinetics of the elongation growth of medical sage plants from individual combinations of the experiment (the averages of the measurements of 6 plants) 2nd year of the experiment

Measurement	Day of vegetation*	Height of plants [cm]					
		Mg0 30 %	Mg1 30 %	Mg2 30 %	Mg0 60 %	Mg1 60 %	Mg2 60 %
1	1	2.0	2.0	2.5	2.0	2.0	2.0
2	8	4.0	3.0	4.0	3.5	4.0	4.0
3	15	6.0	4.0	6.0	5.0	5.5	6.0
4	22	8.5	6.5	9.0	8.0	8.5	10.0
5	29	10.0	8.0	10.0	10.0	11.0	11.5
6	36	12.0	10.0	12.0	11.5	14.0	14.0
7	43	14.0	13.0	14.0	14.0	16.0	16.0
8	50	16.0	14.0	16.0	15.0	18.0	18.0
9	57	17.0	16.0	17.0	16.5	20.0	19.0
10	64	18.0	17.0	18.0	18.5	21.0	21.0

* From the day of thinning the plants in pots.

The earliest, ie on the 24th day of vegetation, appearance of the maximum growth rate was observed in sage plants in the combination of Mg2 30 % of full water volume, whereas the latest appearance of that rate occurred on the 28th day in sage in the combination of Mg1 30 % of full water volume and in Mg0 60 % of full water volume. The maximum value of the growth rate of sage plants during the first year of the studies ranged from 0.17 cm $\cdot$ day^{-1} (combination of Mg1 30 % of full water volume and Mg2 30 % of full water volume) to 0.25 cm $\cdot$ day^{-1} (combination of Mg0 60 % of full water volume) – Table 3. During the second year almost two times larger maximum

Table 3

Parameters of the logistic function approximating the elongation growth of medical sage plants from individual combinations of the experiment $h = h_{max}/(1 + b \cdot \exp(-kt))$

Experimental combination	Year of experiment	h_{max} [cm]	k [day^{-1}]	b	t_i [day]	h_i [cm]	h_0 [cm]	$(dh/dt)_{max}$ [$cm \cdot day^{-1}$]	Coeficient of determination R^2
Mg0 30 %	I	15.0	$5.13 \cdot 10^{-2}$	2.19	15.24	7.50	4.71	0.19	0.964
	II	18.0	$8.18 \cdot 10^{-2}$	7.72	25.00	9.00	2.06	0.37	0.991
Mg1 30 %	I	17.0	$4.06 \cdot 10^{-2}$	1.36	7.51	8.50	7.22	0.17	0.931
	II	17.0	$8.08 \cdot 10^{-2}$	9.84	28.29	8.50	1.57	0.34	0.988
Mg2 30 %	I	16.0	$4.21 \cdot 10^{-2}$	1.73	13.07	8.00	5.85	0.17	0.947
	II	18.0	$7.91 \cdot 10^{-2}$	6.68	24.35	9.00	2.29	0.36	0.989
Mg0 60 %	I	20.0	$5.02 \cdot 10^{-2}$	2.07	14.52	10.00	6.51	0.25	0.971
	II	18.5	$7.29 \cdot 10^{-2}$	7.82	28.19	9.25	2.10	0.34	0.990
Mg1 60 %	I	18.5	$4.43 \cdot 10^{-2}$	2.22	17.98	9.25	5.75	0.21	0.958
	II	21.0	$8.61 \cdot 10^{-2}$	10.16	26.91	10.50	1.88	0.45	0.994
Mg2 60 %	I	20.0	$4.80 \cdot 10^{-2}$	2.62	20.04	10.00	5.53	0.24	0.972
	II	21.0	$7.78 \cdot 10^{-2}$	8.19	27.03	10.50	2.29	0.41	0.990

daily increases were recorded in plants in all combinations of the experiment. The largest daily maximum growth ($(dh/dt)_{max}$= 0.45 cm · day^{-1}) was characteristic of the plants in the combination of Mg1 60 % of full water volume, whereas the smallest (0.34 cm · day^{-1}) was recorded in plants in the combination of Mg1 30 % of full water volume and in Mg0 60 % of full water volume) – Table 3. From the 8th to the 20th day of vegetation during the first year of the studies and from the 24th to the 28th day during the second year (the end of the intensive growth stage) the growth rate of sage decreased gently. In both years of studies *S. officinalis* L. reached a similar maximum height, ranging from 15 cm (combination of Mg0 30 % full water volume – 1st year of studies) to 21cm (combination of Mg1 60 % of full water volume – 2nd year of studies) (Table 3). The observed final height of sage corresponds to the data found in literature [10, 11]. It should be mentioned that sage plants growing on a soil with moisture of 60 % of full water volume reached a larger maximum height in both years of studies than those growing on a soil with moisture of 30 % of full water volume. The difference in a mean height of plants in successive years amounted to 3.5 and 2.5 cm, respectively. Analyzing the elongation growth of sage in both years of studies, no significant differences were observed in its dynamics in plants to which various doses of magnesium were applied. On the whole, it can be said that the course of the elongation growth of *S. officinalis* L. was typical, ie sigmoidal. From the curves of the growth three characteristic stages can be distinguished: initial slow growth, the stage of maximum growth and final slow growth.

Conclusions

1. The elongation growth of medical sage was typical ie sigmoidal, independently of the experimental combination studied.
2. No significant differences were observed in the dynamics of the elongation growth in sage fed with differentiated doses of magnesium.
3. Large usefulness of the logistic function for the description of the growth of the researched plants was confirmed.

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WPŁYW DOGLEBOWEGO ŻYWIENIA MAGNEZEM W ZRÓŻNICOWANYCH WARUNKACH WILGOTNOŚCIOWYCH GLEBY NA DYNAMIKĘ WZROSTU ELONGACYJNEGO SZAŁWII LEKARSKIEJ (*Salvia officinalis* L.)

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Abstrakt: Celem pracy było określenie wpływu doglebowego żywienia magnezem, w zróżnicowanych warunkach wilgotnościowych gleby na dynamikę wzrostu elongacyjnego szałwii lekarskiej. Pierwszym czynnikiem doświadczalnym był poziom żywienia magnezem (0; 0,30 i 0,90 g na wazon), drugim – poziom uwilgotnienia gleby (30 i 60 % pełnej pojemności wodnej). Statystycznie potwierdzono dużą przydatność funkcji logistycznej do opisu wzrostu elongacyjnego badanej rośliny. Wzrost *Salvia officinalis* L., w obu latach badań, niezależnie od kombinacji doświadczenia miał typowy, sigmoidalny przebieg. Nie stwierdzono różnic w dynamice wzrostu elongacyjnego szałwii żywionej zróżnicowanymi dawkami magnezu.

Słowa kluczowe: szałwia lekarska, magnez, wilgotność gleby, wzrost elongacyjny, funkcja logistyczna