

**KINETICS OF GROWTH OF JAPANESE KNOTWEED
(*POLYGONUM CUSPIDATUM* SIEBOLD & ZUCC.)**

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Summary

The work investigated kinetics of the elongate growth of the Japanese knotweed shoots, singly and doubly harvested, on the objects of a variable initial nitrogen fertilization level (25, 50, 75 and 100 kg N·ha⁻¹). The model of the crop growth incorporated on the Gregory - Naidenov function, as the equation $H(t) = H_{\max}[1 - b \cdot \exp(-kt)]$, where H – height of shoot, t – time, H_{\max} – maximum height of shoot, b , k – coefficients. The curves of the growth and the growth rate were drawn for all variants of the field experiment. In general, the higher dynamics of the growth was characteristic for the Japanese knotweed plants mowed once, especially those fertilized with the 100 kg N·ha⁻¹ dose. The applied deterministic model has proved adequate in the statistic sense (the values of the determination coefficients $R^2 > 0.977$) and therefore can be recommended for the formal characteristics of the elongate growth dynamics of the Japanese knotweed.

Key words and phrases: nonlinear regression, Gregory-Naidenov function of growth, energy crop

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1. Introduction

In the botanic sciences the term “growth” is most frequently defined (in the phenomenological sense) as the irreversible increase in the dimensions and weight of the plant, resulting from the production of the organic matter in the process of ontogenesis (Wareing and Philips 1985). Since the growth is considered as the quantitative phenomenon, it can be measured. The most frequent measure of the growth is the accumulation of a dry biomass, yet relative to the studied object such a measure can apply to the of plant, the surface area of leaves, the height of shoot, etc. Considering the growth along the entire ontogenetic period and/or its significant part, it seems convenient to express the growth dynamics by means of a selected measure of growth as a continuous function of time (Causton and Wenus 1987, Gregorczyk 1998, Thornley 1976).

An accordant function (mathematical model), adequate in the substantial and statistical senses, should provide a synthetic representation of the growth process, and even serve for the prognostic goals.

Japanese knotweed is a fast growing, perennial plant, of insignificant soil and fertilization demands. Considering its merits, the Japanese knotweed can be used as an energy crop, cultivated on a degraded or fallow land, therefore its cultivation should contribute to the suppression of the increasing greenhouse effect (Baker 1988, Osone and Tateno 2003, 2005, Suzuki 1994).

2. Material and methods

The experiment was set in 2004 on the experimental plots in RZD Lipnik by Stargard Szczecinski. The Japanese knotweed plants were growing in concrete circles filled with light soil. Four levels of single nitrogen fertilization were applied, i.e. 25, 50, 75 and 100 kg N·ha⁻¹ and the number of harvest was differentiated (single or double). The summer crop (August) and the fall crop (November) were harvested annually. In 2007, starting from May 10, at weekly intervals, the height of six selected shoots were measured for each variant (two shoots in a circle). The measurements were ended on July 19, prior to the summer harvest. Considering the scatterplots of the primary data, the description of the elongate growth of Japanese knotweed incorporated the Gregory-Naidenov

function, also called monomolecular (France and Thornley 1984, Sztencel and Zelawski 1984, Zelawski and Lech 1980).

$$H(t) = H_{\max} [1 - b \exp(-kt)] \quad (2.1)$$

where:

H – height of shoot,

t – time,

H_{\max} – maximum height of shoot,

b, k – coefficients.

The first derivative of function (2.1), i.e. the growth rate is given by the formula

$$dH/dt = kH_{\max} b \exp(-kt) = k(H_{\max} - H). \quad (2.2)$$

The maximum growth rate is achieved by the plants at the beginning of vegetation (when $t = 0$)

$$[dH/dt]_{\max} = kH_{\max} b. \quad (2.3)$$

Additionally, the initial value H_0 was obtained from the formula

$$H_0 = H_{\max} (1 - b). \quad (2.4)$$

The calculations were based on the data of eleven measurements, counting the time from the day of the first observation and assuming the values of the final length of shoots as the H_{\max} parameter. The coefficients of the model were estimated by the least squares method, after prior linearization of the function by the logarithm transformation to the form

$$\ln(1 - H/H_{\max}) = -kt + \ln b. \quad (2.5)$$

To compare the degree of matching the theoretical curves to the experimental data, the values of the R^2 determination coefficient were counted. Two-way analysis of variance was applied for the values of maximum height of shoots (H_{\max}).

3. Results and conclusions

The results of the conducted calculations are included in Table 1. The final heights of Japanese knotweed shoots varied due to the number of mowing and the nitrogen fertilization variant. Considerably shorter shoots were grown on plants harvested twice (statistically significant differences). The applied nitrogen fertilization also affected the final heights of the shoot; however this factor modified more evidently the growth of the Japanese knotweed harvested once (from 158 cm on the N 25 dose to 179 cm on N 100). The conclusions, concerning changes of the parameter values b , k , H_0 have entirely descriptive character.

Table 1. Parameters of curves of the Japanese knotweed height growth for different number of harvest and the variants of nitrogen fertilization

Number of harvest	Nitrogen fertilization	H_{\max} (cm)	H_0 (cm)	b	k (d^{-1})	$(dh/dt)_{\max}$ ($cm\ d^{-1}$)	R^2
One	N25	158	48.6	0.6924	0.08747	9.57	0.977
	N50	161	54.9	0.6590	0.08278	8.78	0.979
	N75	164	49.3	0.6990	0.07954	9.12	0.980
	N100	179	76.3	0.5736	0.07631	7.84	0.979
Double	N25	138	49.0	0.6445	0.06703	5.96	0.982
	N50	132	49.4	0.6259	0.07365	6.09	0.986
	N75	138	53.2	0.6145	0.07958	6.75	0.987
	N100	130	49.6	0.6187	0.07595	6.11	0.981

In the singly mowed plants, relative to the fertilization variant, the values of the b parameter were included in the interval between 0.5736 and 0.6990, and the values of the k coefficient (i.e. the growth rate constant) oscillated within the range 0.07631 – 0.08747 d^{-1} . The initial value H_0 , characterizing the plant growth potential was the highest for the N 100 variant amounting to 76.3 cm, whereas for the N 75 variant it was the lowest (49.3 cm).

In the plants mowed twice, relative to the fertilization variant, the values of the b parameter were included in the interval between 0.6145 and 0.6445, and the values of the k coefficient oscillated within the range 0.06703 – 0.07958 d^{-1} . The initial value H_0 was the highest for the N 75 variant amounting to 53.2 cm.

The monomolecular analysis indicates that the fastest growth of plants occurs when the value of the calculated coefficient (b) is low and simultaneously the growth rate constant (k) is relatively high, as:

$$\lim_{b \rightarrow 0} H_{\max} [1 - b \exp(-kt)] = H_{\max} \quad (3.1)$$

$$\lim_{k \rightarrow \infty} H_{\max} [1 - b \exp(-kt)] = H_{\max} \quad (3.2)$$

The curves of growth and the respective curves of growth rate for the variant of single harvest are shown in Figure 1. Generally, the highest differences in the course of the growth curves are seen between the plants in the variants N 100 and N 25. The parallelism test of two straight lines (Wójcik and Laudański 1989) for the regression coefficients applied to the equation (2.5), entitles to the rejection of the null hypothesis at the significance level 0.05. Simultaneously the shoots of Japanese knotweed fertilized with the N 100 dose were characterized by a higher starting potential (higher initial value H_0) at the commencement of measurements, what reflected in the final size of those plants as compared to those fertilized with the lowest dose of nitrogen. The growth rate curves have the shape of graphs of the exponentially decreasing functions, provided the highest value of the maximum growth rate ($9.57 \text{ cm}\cdot\text{d}^{-1}$) was observed in the shoots of the N 25 fertilization variant.

Figure 2 presents the graphs of the growth and the growth rate functions for the double harvest variant. The growth curves, for all fertilization variants, have a similar configuration, which proves an insignificant effect of the initial nitrogen fertilization on the growth dynamics of the Japanese knotweed harvested twice. The differences in the configuration of the growth rate curves are also considerably insignificant; the maximum theoretical growth rate oscillates from $5.96 \text{ cm}\cdot\text{d}^{-1}$ for the N 25 variant to $6.75 \text{ cm}\cdot\text{d}^{-1}$ for the plants fertilized with the $75 \text{ kg N}\cdot\text{ha}^{-1}$ dose.

The values of the determination coefficient were higher than 0.977, what proves the relevancy of the Gregory-Naidenov function choice to the analyzed process of growth.

The interpretation of the growth model should consider the fact that the physiological process of plant growth is a complex phenomenon affected by multiple intrinsic and extrinsic factors. Due to this not all curves of growth are expected to supply a complete and biologically justified description of the activity of such a complex system, as is the growing vegetative organism. The functions with a horizontal asymptote serve solely to describe the phenomenological growth, and their parameters do not characterize general biological or physiological mechanisms.

The application of the selected functions seems however useful in analyzing finished processes of growth of particular crops.

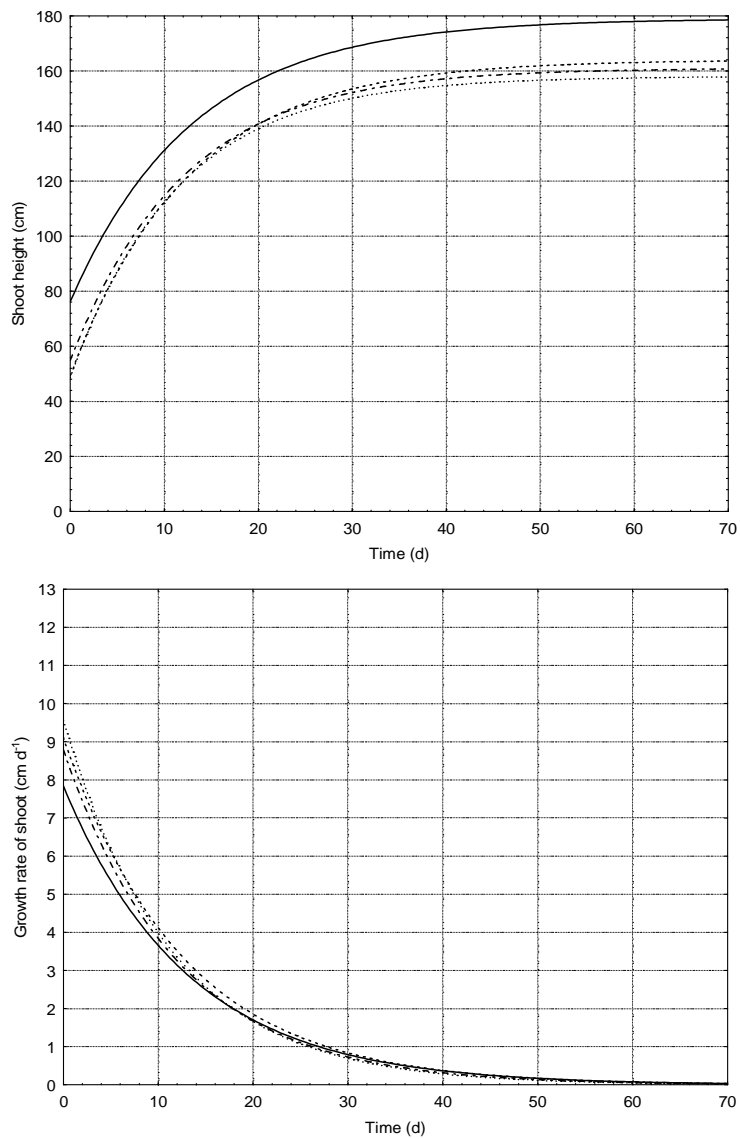


Fig. 1. Curves of growth and growth rate of the one harvested Japanese knotweed growth depended on nitrogen dose fertilization

..... N 25

- · - · - · N 50

- - - - - N 75

————— N 100

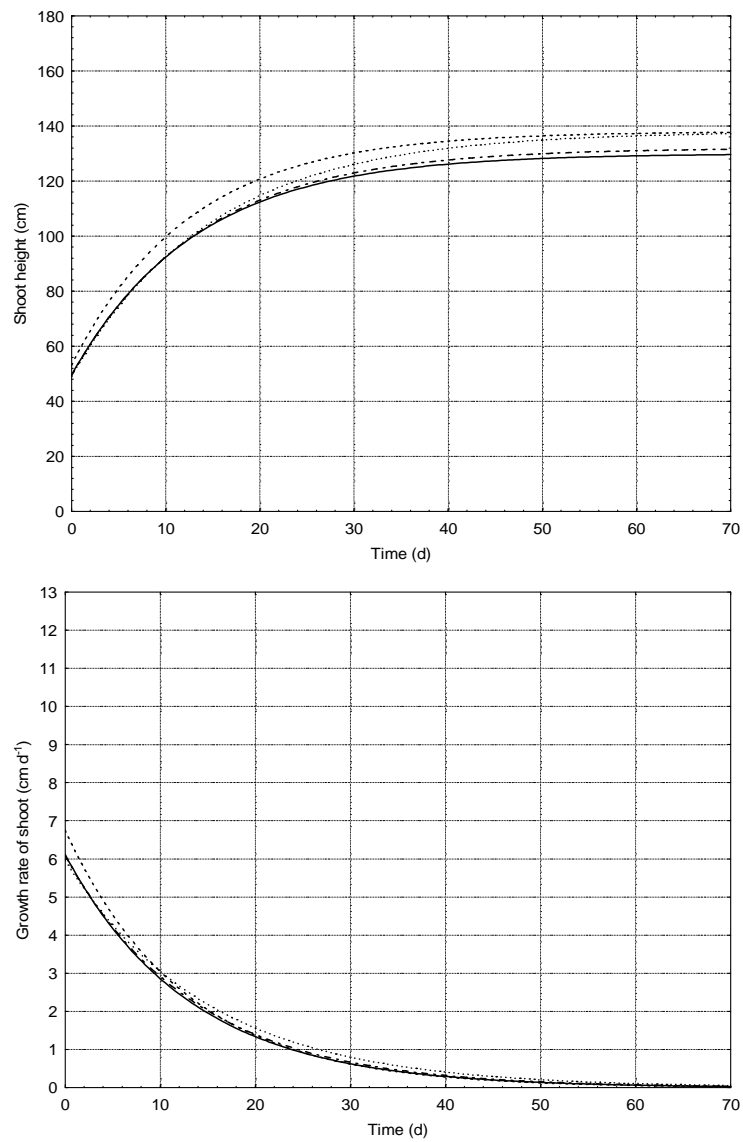


Fig. 2. Curves of growth and growth rate of the double harvested Japanese knotweed growth depended on nitrogen dose fertilization

.....	N 25	- · - · - ·	N 50
- - - - -	N 75	—————	N 100

The most important in the statistical sense is then the choice of an adequate continuous function, the constant coefficients of which can be relatively easily reckoned by means of symbolic and/or numerical methods, and the ascertained differences in the course of the growth curves can be related to the estimates of respective parameters despite the impossibility of an exact biological interpretation of the regression coefficients.

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KINETYKA WZROSTU ROŚLIN RDESTU OSTROKOŃCZYSTEGO (*POLYGONUM CUSPIDATUM* SIEBOLD & ZUCC.)

Streszczenie

Badano kinetykę wzrostu pędów rdestu ostrokończystego (*Polygonum cuspidatum* Siebold & Zucc.) - zbieranego jednokrotnie lub dwukrotnie - z obiektów o różnym poziomie startowego nawożenia azotowego (25, 50, 75 i 100 kg N·ha⁻¹). Do modelowania wzrostu użyto funkcji Grego-rego - Naidenova postaci $H(t) = H_{\max}[1 - b \cdot \exp(-kt)]$, gdzie: H - wysokość pędu, t - czas, H_{max} - maksymalna wysokość pędu, b, k - współczynniki. Wykreślono krzywe wzrostu i szybkości wzrostu dla wszystkich kombinacji doświadczenia. Ogólnie większą dynamiką wzrostu charakteryzowały się rośliny rdestu koszone jednokrotnie, a spośród nich nawożone dawką 100 kg N·ha⁻¹. Zastosowany deterministyczny model okazał się adekwatny w sensie statystycznym (wartości współczynników determinacji R² większe od 0,977) i może być wykorzystywany do formalnej charakterystyki wzrostu elongacyjnego rdestu ostrokończystego.

Słowa kluczowe: regresja nieliniowa, funkcja wzrostu Gregory`ego-Naidenova, rośliny energetyczne

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