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The effect of foliar fertilization with Alkalin PK in American ginseng culture*

Wpływ nawożenia dolistnego Alkalinem PK w uprawie żeń-szenia amerykańskiego*

Summary. American ginseng (*Panax quinquefolium* L.) is a famous medicinal plant with adaptogenic, immunostimulating and anti-aging properties. In four-year-lasting field experiment located on light loamy sand soil the effect of foliar fertilization with 0.33% Alkalin PK 10:20 (foliar fertilizer with very high pH-11.5) as well as Alkalin with fungicides on American ginseng yields and morphological parameters were examined.

Twice a year Alkaline PK application as well as Alkalin with fungicides positively affected American ginseng root, stem, laeves quality parameters as well as the weight of fruits and seeds. Alkalin also limited plant disease infestation and as a consenquence increased plant population in four consecutive years of vegetation. The applications were connected with higher accumulation of phosphorus and potassium in plant tissues.

Key words: American ginseng, *Panax quinquefolium* L., foliar fertilization

INTRODUCTION

American ginseng (*Panax quinquefolium* L.) is one of the most widely used medicinal herbs in the world. It is native to North America, nevertheless, attempts of its cultivation are made in many other countries (i.e. in China, Australia, New Zealand, Holland and Poland). The active constituents of ginseng are dammarance saponins, commonly referred to as ginsenosides, which have adaptogenic, anti-tumor, anti-stress, immunostimulating and anti-aging properties [Li and Wardle 2002, Li 1995, Savage 1991].

Many factors, including soil moisture, its fertility and pH affect the growth and yielding of ginseng [Konsler and Shelton 1990, Li and Wardle 2002., Smythe *et al*. 1988, Court *et al*. 1996]. Ginseng cultivation is not easy, due to its special requirements. The plant requires specific conditions (permeable soils, artificial shading, mulching) and is very susceptible to fungal diseases. What is more, its normal production cycle lasts three to six years [Li and Wardle 2002, Ginseng... 2001, 2003, Savage 1991]. Foliar

fertilization has not been used on commercial plantations so far; however, its positive influence on other medicinal plant species suggests that its application should increase the yields and quality of American ginseng raw material [Mengel 2002, Berbeć *et al*. 2003, Kołota and Osińska 1994, Kołodziej 2004].

The objective of this study was to determine the effects of foliar fertilization with Alkalin PK10:20 on the growth, development and yielding of American ginseng in four consecutive years of vegetation.

MATERIAL AND METHODS

A four-year-lasting (2003–2007) field experiment was carried out on light loamy sand soil neutral in reaction (pH 6.0), with high phosphorus (104.7 mg·kg^{-1} of soil) and potassium content (186.8 mg·kg^{-1} of soil) and very low magnesium (4.8 mg·g^{-1} of soil). Stratified seeds were seeded at the beginning of September 2003 on conventional, raised beds (30–40 cm high, 1.2 m. wide) at 15 × 3 cm spacing (on 2.4 m^2 plots with 4 replications). After seeding, the soil was mulched with oat straw, which was left on the beds during four vegetation periods. The plantation was shaded with plastic fabric in order to reduce light penetration up to 85%. In the spring of every year 40 kg N·ha $^{-1}$ (in a form of ammonium nitrate) and 20 kg Mg·ha $^{-1}$ (in a form of magnesium sulphate) were applied. Alkalin PK10:20 (preparation with very high pH = 11.5, containing 4.4% P and 16.6% K; producer Intermag sp. z o.o., Poland) was applied twice a year during intensive plant growth (at the beginning and the end of June) at 0.33% concentration (50 ml of solution per plot), compared to plots systematically sprayed with fungicides (acc. to Ginseng pest control recommendations, 2001) together with Alkalin PK as well as control plots (with tap water application). Every year plant density and leaves dimensions were determined at the beginning of July, whereas in autumn 20 randomly chosen plants were dug up, washed, measured and then dried in temp. 38ºC. The analyses were performed at the Department of Agricultural Chemistry from University of Agriculture in Kraków (ICP method). The obtained results were evaluated statistically with the use of Tukey t-test at 5% level of significance.

RESULTS AND DISCUSSION

Ginseng seeds germinated in the spring of 2004 (April – May). At the beginning of June the number of seedlings in comparison to the sown seeds was comparatively small (34–36%), while in practice it usually is much higher, amounting to 70–75% [Proctor 1994]. In the first year of vegetation dumping off caused by *Phytium*, *Fusarium, Rhizoctonia solani* and *Alternaria alternata* infested plants. A considerable increase in the number of infected plants, leading to a decrese of plant density was observed on control plots (Fig. 1). In the second year the microbiological analysis proved the existence of *Fusarium* ssp. and *Alternaria* ssp. Generally, the share of plants with disease symptoms was lower than in the first year of cultivation; however, the highest one was in the case of the control plots. In the next two years of ginseng vegetation *Alternaria ssp*., *Fusarium* ssp. and *Phytophthora ssp.* were observed. In the fourth year wet and warm weather in July and August created favourable conditions for *Pythium irregulare* devel-

opment, which seriously decreased plant population (Fig. 1). Like in the studies by Pastucha and Kołodziej [2007] the highest number of plants infected by pathogenic fungi were observed on the control plots, while the lowest one – after Alkalin and fungicides application. The common occurrence of these fungi on ginseng was testified to in the studies conducted earlier by Pięta and Berbeć [1995], Li and Utkhede [1993] and Pastucha and Kołodziej [2005]. On average, in the period from 1st to 4th years of the experiment, the most infected plants and as a result – the lowest plant population was noted in the control object, indicating the protective effect of foliar fertilization with Alkalin PK (Fig. 1). The obtained results agree with those by Sobolewski et al. [2005], Osińska and Kołota [1998], Kołota and Osińska [1994] as well as Kołodziej [2004], who observed that vegetable or ginseng subjected to foliar fertilization had fewer disease symptoms resulting in higher plant population.

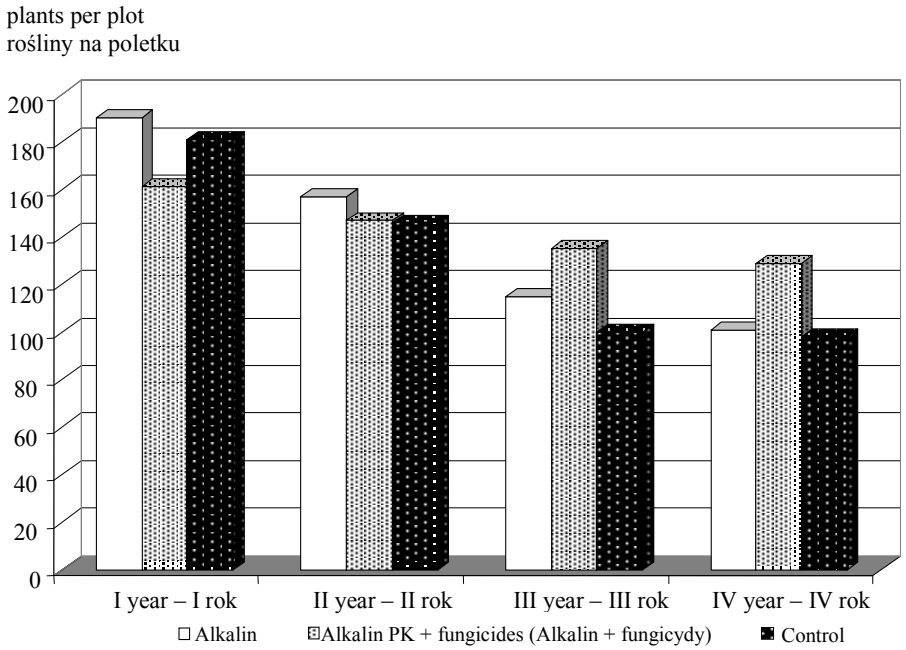

Fig. 1. Average plant density in four following years of ginseng vegetation (2004–2007)
Rys. 1. Obsada roślin w kolejnych czterech latach wegetacji żeń-szenia (2004–2007)

Along with plants' age there were observed changes in American ginseng morphology and chemical composition. Independently of foliar fertilizer application, the highest increases in roots and aboveground parts weight were observed between the first and the second (almost seven-fold) and the third and fourth years of ginseng vegetation (above two-fold) – Table 1–2. Older plants produced higher and thicker stems with better developed leaves and created longer and thicker roots with a higher number of lateral roots (Table 1–2). The size and weight of American ginseng plants in the following four years of cultivation was comparable to those obtained by Smythe et al. [1988], Konsler and Shelton [1990], Li and Wardle [2002] and Kołodziej [2004].

Table 1. American ginseng roots characteristic in four following years of vegetation
Tabela 1. Charakterystyka korzeni żeń-szenia amerykańskiego w czterech kolejnych latach wegetacji

Root – Korzeń	Object – Obiekt	Year – Rok			
		I	II	III	IV
Total length of root Całkowita długość korzeni (cm)	Alkalin	4.9a[1]	8.0a	10.0a	20.7a
	Alkalin + fungicides	5.0a	7.9a	12.1b	19.5a
	Control	5.4a	7.3b	9.5 c	11.6b
„Main body" length of root Długość produkcyjna korzeni (cm)	Alkalin	2.4a	3.1a	4.4a	5.9a
	Alkalin + fungicides	2.3a	3.2a	5.0a	6.8b
	Control	2.9a	3.1a	3.7b	5.2c
Number of lateral roots (unit · plant^{-1}) Liczba korzeni bocznych (szt. · roślina^{-1})	Alkalin	1.3a	3.1a	3.6a	7.6a
	Alkalin + fungicides	1.2a	3.1a	3.5a	7.2a
	Control	1.1a	2.9a	2.5b	6.3b
Diameter of root Średnica korzeni (cm)	Alkalin	0.56a	1.31a	1.43a	1.96a
	Alkalin + fungicides	0.55a	1.29a	1.45a	1.95a
	Control	0.56a	0.87b	1.31b	1.87b
Weight of single root (g · plant^{-1}) Masa korzenia (g · roślina^{-1})	Alkalin	0.54a	4.02a	7.33a	17.65a
	Alkalin + fungicides	0.55a	4.12ab	7.43a	20.23a
	Control	0.59a	3.42b	6.79b	13.03b

a[1] values in columns followed by the same letter are not significantly different ($LSD_{0.05}$)
a[1] wartości liczbowe oznaczone tą samą literą nie różnią się istotnie (przy $\alpha = 0.05$)

In the first year of vegetation the experimental factor did not evidently affect the quality parameters of ginseng roots and aboveground parts of plant. In the following years spraying with Alkalin PK 10:20 positively influenced morphological parameters, yields and chemical composition of plants (Table 1–3). Generally, Alkalin PK treatment resulted in higher plants (from 1 to 9 cm in comparison to control), thicker stems (by 2.2 mm in the last year of cultivation) and better developed leaves (Table 2). Air dry matter of aboveground parts of plants was on average 9–12.7% higher than that from control plots. As far as yield of fruits and seeds per plant are concerned, Alkalin PK was the most effective in yields increasing. On average, total weight of fresh fruits and seeds from a single plant during the last three years of vegetation was, respectively by 50.7 and 56.7% higher in comparison to control plants (without Alkalin application) – Table 2.

Roots gathered from the plots with foliar fertilization were significantly longer (both: total and productive length) in comparison to the control ones (Table 1). Similarly to earlier studies [Magdziak and Kołodziej 2003], foliar fertilization also caused a significant increase in ginseng root diameters and the number of lateral roots (Table 1). Every year the highest air dry weight of roots was recorded on the plots with Alkalin PK or Alkalin with fungicides application. Generally, the air dry weight of a single root from the plots subjected to foliar fertilization was higher on average by 17.5% during the second year, 8% during the third and 35% in the fourth year of ginseng vegetation in comparison to the control object (Table 1). Similar findings confirming the yield increase after foliar fertilizer application were noted by Jabłoński [2002], who obtained on average a 6.4% increase in potato yields comparing to the control. Positive effects of foliar fertilization were also observed in vegetable production by Kołota and Osińska

[1994] and Berbeć et al. [2003] in thyme. In the case of American ginseng, foliar fertilization with Tytoń-vit, Tytanit, Mikrosol and Ekolist resulted in a significant increase of both aboveground parts and root yield [Magdziak and Kołodziej 2003, Kołodziej 2004].

Table 2. Aboveground parts characteristics of American ginseng in four following years of vegetation
Tabela 2. Charakterystyka części nadziemnych roślin żeń-szenia amerykańskiego w czterech kolejnych latach wegetacji

Root – Korzenie	Object – Obiekt	Year – Rok			
		I	II	III	IV
Plant height measured to the branching Wysokość roślin mierzona do rozgałęzienia (cm)	Alkalin	6.7a[1]	10.2a	17.8a	29.8a
	Alkalin + fungicides	6.8a	11.1a	18.1a	27.2a
	Control	6.7a	9.1b	16.2b	20.8b
Plant height measured with inflorescences Wysokość roślin mierzona wraz z kwiatostanem (cm)	Alkalin	6.7a	18.1a	29.2a	34.9a
	Alkalin + fungicides	6.8a	19.6a	30.3a	31.0a
	Control	6.7a	16.9b	24.3b	27.9b
Stem diameter Średnica łodygi (mm)	Alkalin	0.79a	2.05a	2.27a	5.66a
	Alkalin + fungicides	0.83a	2.06a	2.31a	4.49b
	Control	0.81a	2.03a	2.18b	3.44c
Average leaves length Średnia długość liści (cm)	Alkalin	4.92a	5.86a	7.51a	8.01a
	Alkalin + fungicides	4.90a	5.81a	7.52a	8.6b
	Control	4.66a	5.72a	7.48a	8.00a
Average leaves width Średnia szerokość liści (cm)	Alkalin	2.19a	2.77a	3.49a	3.81a
	Alkalin + fungicides	2.21a	2.79a	3.50a	3.87a
	Control	2.26a	2.70a	3.54a	3.74b
Weight of aboveground parts ($g \cdot plant^{-1}$) Masa części nadziemnych ($g \cdot roślina^{-1}$)	Alkalin	0.21a	1.80a	3.58a	9.16a
	Alkalin + fungicides	0.28a	1.91ab	3.55a	13.98b
	Control	0.29a	1.62b	3.27b	8.13c
Yield of fruits ($g \cdot plant^{-1}$) Plon owoców ($g \cdot roślina^{-1}$)	Alkalin	-	0.665a	3.886a	5.198a
	Alkalin + fungicides	-	0.701a	3.901a	5.517a
	Control	-	0.617ba	2.879b	2.97b
Yield of seeds ($g \cdot plant^{-1}$) Plon nasion ($g \cdot roślina^{-1}$)	Alkalin	-	0.198a	1.187a	1.645a
	Alkalin + fungicides	-	0.201a	1.203b	2.153b
	Control	-	0.191a	0.837c	0.905c

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Generally, American ginseng stems and leaves contained higher amount of K, Cu, Zn and Mn than roots. Twice a year spraying with 0.33% Alkalin PK was connected with higher accumulation of phosphorus and potassium in above- and underground parts of plants and at the same time did not affect other macro- and microelements content under study (Table 3).

Table 3. Chosen macro- and microelements content in aboveground parts and roots of American ginseng in four following years of vegetation
Tabela 3. Zawartość wybranych makro- i mikroelementów w częściach nadziemnych i korzeniach żeń-szenia amerykańskiego w czterech kolejnych latach wegetacji

Macro- and microelements Makro- i mikroelementy	Year – Rok	I		II		III		IV	
	Object – Obiekt	A	R	A	R	A	R	A	R
P (%)	Alkalin	0.17a	0.21a	0.18a	0.22a	0.18a	0.22a	0.25a	0.25a
	Alkalin + fungicides	0.17a	0.22a	0.19a	0.21a	0.17a	0.23a	0.24a	0.25a
	Control	0.16a	0.18b	0.15b	0.19b	0.16b	0.19b	0.18b	0.20b
K (%)	Alkalin	1.38a	1.07a	1.62a	1.08a	1.87a	1.12a	1.99a	1.16a
	Alkalin + fungicides	1.36a	1.00a	1.61a	1.21a	1.78a	1.30b	1.95a	1.28a
	Control	1.17b	0.78b	1.24b	0.91b	1.54b	1.01c	1.69b	1.05b
Ca (%)	Alkalin	0.12a	0.14a	0.14a	0.27a	0.14a	0.27a	0.15a	0.28a
	Alkalin + fungicides	0.11a	0.12a	0.14a	0.28a	0.14a	0.29a	0.14a	0.27a
	Control	0.10a	0.12a	0.12a	0.26a	0.14a	0.29a	0.15a	0.29a
Mg (%)	Alkalin	0.01a	0.05a	0.02a	0.05a	0.02a	0.09a	0.02a	0.13a
	Alkalin + fungicides	0.01a	0.05a	0.01a	0.04a	0.02a	0.09a	0.02a	0.13a
	Control	0.01a	0.05a	0.02a	0.05a	0.02a	0.10a	0.02a	0.11a
Cu ($mg \cdot kg^{-1}$ d m)	Alkalin	7.2a	1.8a	21.1a	2.5a	24.5a	4.1a	25.7a	5.9a
	Alkalin + fungicides	7.3a	3.2b	18.8a	2.8ab	19.4a	4.5a	24.3a	4.7b
	Control	4.5b	1.9a	6.1b	3.2a	8.0b	4.8a	8.5b	6.3a
Zn ($mg \cdot kg^{-1}$ d m)	Alkalin	17.4a	11.2a	21.0a	12.2a	25.3a	17.0a	26.0a	19.2a
	Alkalin + fungicides	16.7a	13.0a	21.8a	14.9a	22.5a	17.1a	28.1a	18.3a
	Control	17.6a	12.3a	23.6a	13.8a	25.0a	17.3a	28.5a	18.3a
Mn ($mg \cdot kg^{-1}$ d m)	Alkalin	33.8a	27.6a	42.7a	27.7a	43.7a	30.6a	52.4a	33.5a
	Alkalin + fungicides	33.7a	23.7a	38.7a	21.6b	49.0b	30.3a	48.1a	33.6a
	Control	32.9a	26.6a	39.2a	25.3a	46.7a	29.6a	55.2b	33.1a

a – values in columns followed by the same letter are not significantly different ($LSD_{0.05}$) – wartości liczbowe oznaczone tą samą literą nie różnią się istotnie (przy $\alpha = 0,05$),
A – aboveground parts – części nadziemne, R – roots – korzenie

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Streszczenie. Żeń-szeń amerykański (*Panax quinquefolium* L.) jest znaną rośliną leczniczą posiadającą właściwości adaptogenne, immunostymulujące oraz przeciwdziałające starzeniu się. W czteroletnim doświadczeniu polowym zlokalizowanym na piasku gliniastym lekko pylastym badano wpływ nawożenia dolistnego 0,33% Alkalinem PK 10:20 (nawozem dolistnym o bardzo

wysokim pH – 11.5) oraz Alkalinem łącznie z fungicydami na plony i parametry morfologiczne roślin żeń-szenia amerykańskiego.

Dwukrotna w ciągu każdego z czterech lat uprawy aplikacja Alkalinu PK oraz Alkalinu z fungicydami pozytywnie wpłynęła na parametry jakościowe korzeni, łodyg i liści oraz na masę owoców i nasion żen-szenia. Spowodowała także ograniczenie porażenia roślin przez grzyby chorobotwórcze, a w konsekwencji przyczyniła się do zachowania większej liczby roślin w kolejnych latach wegetacji. Dokarmianie Alkalinem spowodowało wzrost zawartości fosforu i potasu w tkankach roślin.

Słowa kluczowe: żeń-szeń amerykański, *Panax quinquefolium* L., nawożenie dolistne

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