The effect of foliar application of growth regulators on American ginseng (*Panax quinquefolium* L.)

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Summary

In a field experiment conducted in 1998-2002 on sandy-loam soil the effect of applying chosen growth regulators in an American ginseng culture was examined. In the second year of vegetation (June 2000) plants were sprayed with following substances (each in a dose of 100 and 200 mg/l): kinetin, daminozide, mixture (1:1) of gibberellic acid (GA_3) with potassium salt of α-naphtyl acetic acid – KNAA and IPO-1 (benzimidazole derivative) – a new preparation obtained from Institute of Organic Industry in Warsaw. Amongst the applied growth regulators positive effect on growth of plants and yield of roots, as well as on the content of active compounds had IPO-1, daminozide (in a dose of 100–200 mg/l) and, to a certain extent, kinetin (200 mg/l), while the mixture of GA_3 and KNAA affected the above-mentioned features negatively.

Key words: American ginseng, Panax quinquefolium L., growth regulators, yields, ginsenosides

INTRODUCTION

American ginseng (*Panax quinquefolium* L.), native to forests in North America, for over 100 years has been cultivated in the USA and Canada. Recently this species has been introduced in other countries, also in Poland [1, 2, 3].

Root of American ginseng (*Araliaceae* family) has a great medical value and is used in several preparations as well as an additive to the functional food [4, 5]. Cultivation of ginseng is much different from other herbs (growth of the plant is very slow - marketable yield is obtained only after 4-5 years of vegetation, a plantation needs artificial shading and mulching, plants are susceptible to fungal diseases) [5, 6].

Slow growth and development of plants as well as long time necessary for seeds to obtain physiological maturity (they require 18-22 months of stratification before sowing) caused an interest in using growth regulators as factors enhancing physiological processes. Experiments carried out by Sruamsiri et al. [7] and Ren et al. [8] showed that soaking seeds in a solution of gibberellic acid (GA_3) stimulated embryo development, shortened after-ripening period and increased a germination rate of seeds. In another experiment [9] treatment of seedlings with GA and 2,4-D resulted in higher growth efficiency, whereas daminozide decreased the growth ratio. Proctor et al. [10] found that treatment of plants or soil with thidiazuron (TDZ) induced bud formation and stimulated the growth of above-ground parts of plant. Fiebig et al. [11] found that foliar application of ethephon could replace an expensive manual inflorescence removal (in order to induce root growth).

MATERIAL AND METHODS

The field experiment on the effect of some growth regulators on growth and yielding of American ginseng was performed in 1998-2002 years on sandy-loam soil (pH 6.5), characterising with very high phosphorus and potassium contents and medium content of magnesium. Stratified seeds (on average 48% of field germination capacity) were sown at the beginning of October 1998 on raised beds (30-40 cm, 1.5 m wide) in distance 15 x 5 cm (320 seeds per plot) and afterwards the soil was mulched with oat straw. Before sowing magnesium sulphate (18 kg Mg/ha) and 30 kg N/ha every spring were applied. Shading plants with plastic fabric, control of fungal diseases and weeding during vegetation were ensured. In the second year (2000) of vegetation on the experimental plots (4 m^2) different growth regulators (each in two concentrations: 100 and 200 mg/l) were applied (every object in 4 replications). The sprays were performed in mid-June 2000, 400 ml per plot (control – without spraying). The following growth regulators were used: kinetin (6-furfurylaminopurine – KT; Merck, Darmstadt), daminozide (B-Nine 85 SP; Uniroyal Ltd., USA), mixture (1:1) of gibberellic acid - GA_3 (Arbostim 10 SL; Varichem T. Ostrowski) with potassium salt of α-naphtyl acetic acid – KNAA (Pommit Extra 110 SL; Varichem T. Ostrowski), and IPO-1 (benzimidazole derivative) – a new preparation obtained from Institute of Organic Industry in Warsaw. In the autumns of the following three years 10 plants from each object were measured. In the fourth year, roots were dug, washed, measured and dried (temp. 30-35 °C). The total content of ginsenosides was analysed in the laboratory of Department of Biology and Pharmaceutical Biotechnology at Medical University in Łódź. The HPLC method with saponin isolation by von Honerlagen and Tretter [12] was used.

RESULTS AND DISCUSSION

The growth regulators significantly influenced growth of plant. In the first year of vegetation ginseng plants created one leaf with three leaflets of total average height 5.9 cm, and small roots, whose air-dried weight ranged from 0.234g to 0.587g (mean – 0.364 g). Due to the experiment design (the growth regulators application took place in the second year) plant characteristic given in this paper started from the second year of American ginseng vegetation. In the second year plants on the plots with IPO-1 and kinetin dominated over others. Similar results were obtained by Nowak et al. [13] in the case of corn and by Mahmoud [14] in the case of sweet basil sprayed with the kinetin. As far as the height of plants in the consecutive years is concerned, besides of IPO-1, daminozide appeared to be the most effective (Figure 1). However, different results were obtained by Park at al. [9], who used daminozide in the culture of *Panax ginseng*. In our experiment a statistically proved inhibiting effect on growth was observed in the objects where the mixture of GA_3 and KNAA was applied (plants were almost 10 cm lower than on control plots).

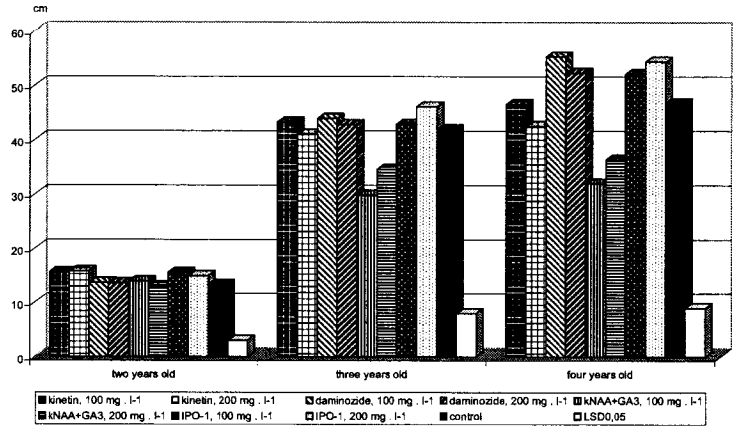

Fig. 1. Total height of Panax quinquefolium stems depending on the growth regulator and its dose in there following years of vegetation.

Air-dried mass of above-ground parts of single plants was formed according to height of plants, significantly lower being only in the case of daminozide application (Table 1). Similar inhibiting effect of daminozide, kinetin and GA_3 in a culture of broad bean was observed by Gabal et al. [15] and by Zalewska [16] in the case of daminozide sprays of gladiolus.

In the culture of ginseng, the plant population decreased in the consecutive years (due to fungal diseases). According to Reeleder et al. [17] and others [1, 3], after four years 50% or even fewer plants will survive. In our experiment the KNAA-GA_3 mixture and kinetin had a statistically proved negative effect on the plant population after four years of vegetation (Table 1).

Table 1

Plant density and the weight of air-dried above-ground parts of American ginseng at the end of the fourth year of vegetation.

growth regulator	dose (mg/l)	plant density (plants/m²)	percentage of plants surviving from the first year to the harvest	the weight of air-dried above-ground parts (g/plant)
kinetin	100	24	37.5	5.115
	200	30	46.9	4.551
daminozide	100	48	75.0	5.208
	200	40	62.5	4.733
KNAA and GA_3	100	27	42.2	2.793
	200	22	34.4	2.810
IPO-1	100	42	65.6	5.615
	200	48	75.0	5.384
control		29	45.3	5.037
$LSD_{0.05}$:		10.1		1.7196

The weight of air-dried roots significantly depended on the experimental factors, too (Figure 2). In the autumn of the second year roots on plots with IPO-1 and kinetin application significantly overweighed the others. In the third and fourth years, growth of roots was stimulated by IPO-1, daminozide and kinetin (the last one to a smaller extent), while GA_3 and KNAA brought about an inhibiting effect in comparison with the control. Generally, the weight of single roots of American ginseng was similar, or even higher than stated in Canada (in the fourth year - from 5.8 to 15.1 g) [17, 18] and our earlier Polish experiments (from 5.2 to 17.8 g) [1, 3].

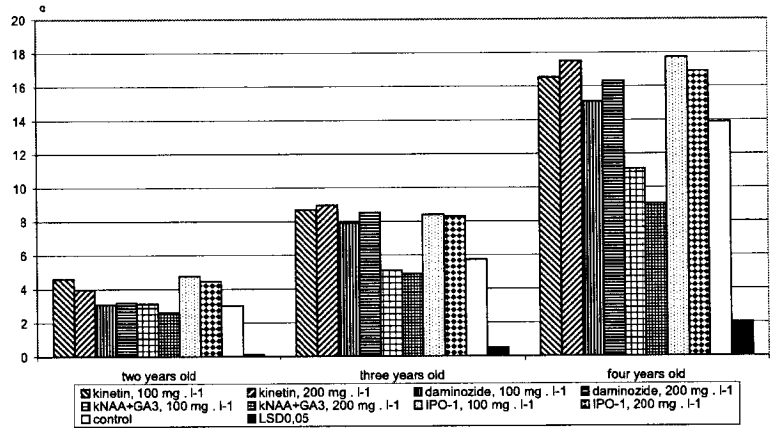

Fig. 2. Average weight of air-dried roots, depending on the growth regulator and its dose in following years of American ginseng cultivation.

Ginseng roots, containing ginsenosides as the main active component, are dug after 4-5 years of vegetation. In the experiment the highest yields of roots (about twice as high as in the case of the control) were obtained from the plots with IPO-

1 and daminozide application. These results were chiefly caused by the number of plants remaining after four years of vegetation. Kinetin (only in higher doses) caused an increase in root yields (by 28%), whereas yields from plots with kinetin application in a dose of 200 mg/l were at the same level as in the control one. The lowest plant population and weight of single root in objects with mixture of GA_3 and KNAA resulted in the smallest root yields ranging from 26% in the case of lower dose and 50% in the case of the dose of 200 mg/l in comparison with control one (Table 2, Figure 2). Nowak and Ciećko [19] observed the same tendency in the case of GA_3 application in Swedish turnip.

Table 2

Yields of four-year-old roots of American ginseng, the ginsenoside content and theoretical yield of ginsenosides depending on the experimental factors.

growth regulator	dose (mg/l)	yields of air dry weight of roots (g /m²)	ginsenosides content (mg/g)	theor. yields of ginsenosides (g/m²)
kinetin	100	400.9	40.6	16. 28
	200	516.3	52.6	27.16
daminozide	100	721.2	88.9	64.11
	200	643.7	77.8	50.08
KNAA and GA_3	100	294.3	68.1	20.04
	200	197.7	83.7	16.55
IPO-1	100	730.5	76.6	55.96
	200	806.8	95.7	77.21
control		399.5	42.0	16.78
$LSD_{0.05}$:		153.16	15.87	

The growth regulators brought about a significant increase in active components in ginseng roots – Table 2. The highest content of ginsenosides was in objects with IPO-1 (higher dose) and daminozide at lower dose (by 54 mg/g and 47 mg/g, respectively, in comparison with the control one). A lower dose of daminozide and a higher dose of IPO-1 resulted in an increase of the ginsenoside content by about 35 mg/g. The mixture of GA_3 and KNAA brought about a significant increment of the total content of ginsenosides, too. Kinetin resulted in a significant increase of sum of ginsenosides only at the higher dose – Table 2. In general, the content of ginsenosides from the plants treated with the growth regulators examined was higher than reported by Li and Mazza (25.5–38.9 mg/g) [20] and Reeleder et al. (62.69–86.88 mg/g) [17].

The ginsenoside content and root yields enable calculating a theoretical yield of ginsenosides. In the experiment, they significantly depended on the experimental factors: the highest being in the case of IPO-1 and daminozide application. The theoretical yield of ginsenosides from the control object and ones where kinetin (especially in lower dose) and GA_3 with KNAA mixture were applied, were much lower – see Table 2.

CONCLUSIONS

1. From among four growth regulators applied in the second year of American ginseng vegetation, positive effect on growth of plants and yield of roots were seen in the case of a new preparation IPO-1 (benzimidazole derivative), daminozide and – to certain extent – kinetin, while mixture of GA_3 and KNAA affected the growth of plants negatively.

2. Foliar application of IPO-1 and daminozide enhanced plant growth and contributed to a bigger plant population resulting in much higher yields of roots in comparison with the control and the objects where kinetin and the mixture of GA_3 and KNAA were applied.

3. All the examined growth regulators affected the ginsenoside content in roots, the most effective being IPO-1 and daminozide (double-fold increase in comparison with the control). Kinetin caused an increase in the total amount of ginsenosides only when it was applied in higher dose (200 mg/l).

4. From among the tested growth regulators, IPO-1 and daminozide were the most effective agents (in doses of 100–200 mg/l) and they are to be recommended in the culture of American ginseng.

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WPŁYW DOLISTNEGO STOSOWANIA REGULATORÓW WZROSTU W UPRAWIE ŻEŃ-SZENIA AMERYKAŃSKIEGO (*PANAX QUINQUEFOLIUM* L.)

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Streszczenie

W doświadczeniu polowym przeprowadzonym w latach 1998-2002 na glebie piaszczysto-gliniastej badano wpływ dolistnego stosowania wybranych regulatorów wzrostu i rozwoju roślin w uprawie żeń-szenia amerykańskiego. W drugim roku uprawy w pełni wegetacji roślin (VI 2000) rośliny opryskano następującymi regulatorami wzrostu (w dwóch stężeniach: 100 i 200 mg/l): kinetyna, daminozyd, mieszanina 1:1 kwasu giberelinowego (GA_3) i soli potasowej kwasu α-naftylooctowego (KNAA) oraz IPO-1 (pochodna benzymidazolu).
Spośród zastosowanych substancji IPO-1, daminozyd (w stężeniu 100 i 200 mg/l) oraz do pewnego stopnia kinetyna (200 mg/l) wywarły pozytywny wpływ na wzrost roślin, plony korzeni i zawartość substancji aktywnych. Natomiast mieszanina GA_3 i KNAA zahamowały wzrost roślin i obniżyły plony oraz zawartość ginsenozydów.

Słowa kluczowe: żeń-szeń amerykański, Panax quinquefolium L., regulatory wzrostu, plonowanie, ginsenozydy