

THE EFFECT OF PLANTATION ESTABLISHMENT METHOD AND ATONIK APPLICATION IN GOLDENROD (*Solidago virgaurea* L. ssp. *virgaurea*) CULTIVATION

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Abstract. In four-year-lasting field experiment yielding and chemical composition of goldenrod (*Solidago virgaurea* L. ssp. *virgaurea*) herb depending on different methods of plantation establishment and natural growth regulator Atonik application were analysed. In the experiment different methods of goldenrod plantation establishment were compared: A. direct spring diaspores sowing, B. spring planting of seedlings, C. direct autumn diaspores sowing, D. autumn planting of seedlings as well as spraying with 0.1% solution of Atonik twice a year. Diaspores were sown directly onto the field in rows 40 cm apart, whereas seedlings were produced in multicell trays in plastic tunnel throughout 5 weeks and then transplanted onto the field in 40 cm × 15 cm row spacing. Raw material was harvested every year at the beginning of blooming stage and after that chemical analyses comprised leiocarposide content (by HPLC method) were done. The highest yields of raw material were obtained in the second and third years of cultivation, while in the fourth year a considerable yields decrease was observed, indicating that goldenrod plantation should last two or three years. Higher raw material yields characterized by higher leiocarposide content were collected from the plots with spring seedlings transplanting or autumn diaspores sowing, thus these methods of plantation establishment should be recommended on commercial plantations of goldenrod. Additionally, plants should be sprayed with 0.1% Atonik in order to increase raw material yields.

Key words: goldenrod (*Solidago virgaurea* L. ssp. *virgaurea*), methods of plantation establishment, Atonik, leiocarposide

INTRODUCTION

Solidago virgaurea is a herbaceous perennial plant from *Asteraceae* family, occurring in nature in Europe, and lately also in North Africa, North America and Asia. *Solidaginis herba* is used to treat urinary tract inflammation, prevent or treat kidney stones,

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help reduce inflammation, relieve muscle spasms, fight infections and cancer, and lower blood pressure. Medicinal properties of goldenrod raw material depend on its chemical constituents: phenolic glycosides – leiocarposide, flavonoids (quercetin, rutin), saponins, essential oil and tannins [Kalemba 1992, Hiller and Bader 1996, Blumenthal et al. 1998, Melzig 2004].

Because *S. virgaurea* is accessible in a limited scale, commercial raw material is often supplemented by other species from the genus *Solidago*, decreasing drug medicinal value. This is why it is very important to introduce goldenrod from the nature into agromonomical practice [Bohr and Plescher 1999].

One of the best methods of yields increment and at the same time quality improvement of herbs is natural growth stimulators application. Atonik is a preparation containing sodium-5-nitro-guaiacolate, sodium o-nitrophenolate and sodium p-nitrophenolate, which are natural plants constituents, occurring in a very small quantities. Used in an exogenic way Atonik increases auxins activity, stimulates flowering process, allows fast adopting to unfavorable environment conditions and enhances yields [Zahradniček et al. 1998, Mikos-Bielak and Kukielka 2000, Černý et al. 2002, Gruszczyk and Berbec 2004, Kołodziej 2004].

MATERIAL AND METHODS

The aim of four-years-lasting field experiment was to compare effects of four methods of plantation establishment and spraying with natural growth regulator Atonik on goldenrod growth and yielding. Investigations were carried out on experimental fields in the University of Agriculture in Lublin, located on slightly loamy sand in Trzciniec (in Lubelski region, 51°7'46''N, 22°10'59''E). Soil was characterized by mean humus (1.53%), very low phosphorus (12.2 mg · kg⁻¹ of soil), potassium (24.9 mg · kg⁻¹ of soil) and magnesium (2.0 mg · kg⁻¹ of soil) content and was acid in reaction (pH – 4.7). In the experiment different methods of goldenrod plantation establishment were compared: I. direct spring diaspores sowing (17th of April), II. spring seedlings transplanting (20th of April), III. direct autumn diaspores sowing (10th of September), IV. autumn seedlings transplanting (12th of September). For plantation establishment goldenrod (*Solidago virgaurea* L. ssp. *virgaurea*) [Rutkowski 1998] diaspores obtained from local populations growing in nature in Lubelski region were used. Diaspores were sown directly onto the field (at the amount of 500 g · ha⁻¹ on 0.5–1 cm depth) in rows 40 cm apart. Seedlings were produced in multicell trays in plastic tunnel throughout 5 weeks and than transplanted onto the field in 40×15 cm rows spacing. Every year plants were sprayed with 0.1% solution of Atonik (produced by Asahi Chemical Mfg. Co Ltd., Osaka, Japan) with a hand-held sprayer. Spraying was performed twice a year: on 10 June and 30 June using 200 ml of solution per plot (on control plots, without Atonik application, spraying was carried out with tap water).

Every spring, prior to plant vegetation, the following mineral fertilization was applied: 40 kg N · ha⁻¹ – in a form of ammonium nitrate 34% N, 30.3 kg P · ha⁻¹ – in a form of superphosphate (7.9% P) and 24.1 kg K · ha⁻¹ – in a form of potassium salt (48.1% K). During plants vegetation routine treatment of garden (weeding, inter-row

cultivation) was performed. Raw material was harvested every year at the beginning of blooming stage (10–15 cm above the ground). Herbs from the plots and the ones from five randomly chosen plants were gathered separately. Both of them were subjected to drying at temperature 35°C. Chemical analyses of leucosapogenin content (by HPLC method in three following years of cultivation) were performed in Phytochemical Laboratory in Kłęka. The experimental design was a randomized complete block design with three replications (plots of 6 m²). Data were analyzed with the SAS general linear model procedure (version 8.2 SAS Institute, Cary, N.C.). Testing for significance of mean effects and interactions was calculated by means of ANOVA analysis of variance.

RESULTS AND DISCUSSION

Atonik and different methods of plantation establishment significantly affected yields and chemical composition of goldenrod (tab. 1–2).

Table 1. Yield of air-dry goldenrod herb, g·m⁻²
Tabela 1. Plony powietrznie suchej masy ziela nawłoci, g·m⁻²

| Plantation establishment method Metoda zakładania plantacji | Atonik application Stosowanie Atoniku | Year of plant vegetation Rok wegetacji roślin | | | | Total Razem |
|--|--|--|-----|-----|-----|----------------|
| | | I | II | III | IV | |
| Spring sowing | + | 17 | 710 | 536 | 419 | 1682 |
| Siew wiosenny | - | 17 | 670 | 486 | 355 | 1528 |
| Mean – Średnio | | 17 | 688 | 511 | 387 | 1605 |
| Spring planting of seedlings | + | 218 | 930 | 983 | 583 | 2714 |
| Wiosenne sadzenie rozsady | - | 161 | 898 | 646 | 361 | 2066 |
| Mean – Średnio | | 189 | 914 | 814 | 472 | 2390 |
| Autumn sowing | + | 68 | 901 | 711 | 476 | 2156 |
| Siew jesienny | - | 45 | 720 | 681 | 465 | 1911 |
| Mean – Średnio | | 56 | 810 | 696 | 571 | 2033 |
| Autumn planting of seedlings | + | 195 | 811 | 556 | 311 | 1873 |
| Jesienne sadzenie rozsady | - | 185 | 784 | 567 | 262 | 1798 |
| Mean – Średnio | | 190 | 798 | 561 | 287 | 1836 |
| Mean for Atonik – Średnio dla Atoniku | | 124 | 838 | 869 | 447 | 2106 |
| Mean without Atonik – Średnio bez Atoniku | | 102 | 768 | 595 | 361 | 1826 |
| Source of variation – Źródło zmienności | | | | | | |
| Method of plantation establishment – Metoda zakładania plantacji | | ** | ** | ** | ** | ** |
| Atonik application – Stosowanie Atoniku | | ** | ** | ** | ** | ** |
| Interaction – Interakcja | | ** | ** | ** | ** | ** |

NS, **, * – non significant or significant at $P \leq 0.05$ or 0.1 – nieistotne lub istotne przy $P \leq 0,05$ lub $0,1$

Generally, in the first year of goldenrod cultivation plants formed rosette of leaves and only 10–25% – stems with inflorescence, therefore yield of raw material was extremely low (especially on plots with spring or autumn achenes sowing) (tab. 1, 2). In the next three years almost all of plants were blooming, forming several flowering stems, which resulted in the highest herb yields. Raw material yields were comparable with the ones obtained by Lück et al. [2000], Galambosi et al. [1993] and Gruszczyk

Table 2. Air dry weight of aboveground parts of single plant (in g ·plant⁻¹) and leiocarposide content (in %) in goldenrod herb
Tabela 2. Powietrznie sucha masa części nadziemnej (w g·roślina⁻¹) i zawartość lejojarpozydu (w %) w ziele nawłoci

| Plantation establishment method Metoda zakładania plantacji | Atonik application Stosowanie Atoniku | Air dry weight of aboveground part of plant (g ·plant ⁻¹) Powietrznie sucha masa części nadziemnych roślin (g·roślina ⁻¹) | | | | Laiocarposide content Zawartość lejojarpozydu % | | | | |
|---|--|--|-------|-------|-------|---|-------------|-------------|--|--|
| | | year of plant vegetation – rok wegetacji roślin | | | | | | | | |
| | | I | II | III | IV | I | II | III | | |
| Spring sowing Siew wiosenny | + | 1.65 | 38.85 | 52.71 | 45.22 | 0.899±0.06 ^z | 1.100±0.008 | 0.990±0.02 | | |
| | - | 1.51 | 36.48 | 53.60 | 43.41 | 1.028±0.006 | 1.120±0.008 | 1.070±0.017 | | |
| Mean – Średnio | | 1.58 | 37.66 | 52.90 | 44.32 | 0.964 | 1.110 | 1.030 | | |
| Spring transplanting Wiosenne sadzenie rozsady | + | 5.78 | 64.24 | 51.25 | 49.63 | 1.058±0.007 | 1.200±0.008 | 1.130±0.017 | | |
| | - | 4.77 | 45.89 | 35.54 | 34.63 | 1.502±0.0008 | 1.240±0.008 | 1.300±0.16 | | |
| Mean – Średnio | | 5.28 | 55.07 | 43.39 | 42.23 | 1.280 | 1.220 | 1.215 | | |
| Autumn sowing Siew jesienny | + | 2.64 | 41.30 | 43.35 | 39.74 | 1.441±0.04 | 1.030±0.008 | 1.240±0.026 | | |
| | - | 1.41 | 37.88 | 39.29 | 37.04 | 1.636±0.004 | 1.260±0.008 | 1.440±0.016 | | |
| Mean – Średnio | | 2.02 | 39.59 | 41.32 | 38.39 | 1.539 | 1.145 | 1.340 | | |
| Autumn transplanting Jesiennie sadzenie rozsady | + | 6.09 | 57.39 | 57.14 | 50.19 | 1.000±0.008 | 1.140±0.008 | 1.000±0.008 | | |
| | - | 6.70 | 57.26 | 54.95 | 47.45 | 0.776±0.008 | 1.230±0.008 | 1.030±0.012 | | |
| Mean – Średnio | | 6.39 | 57.33 | 56.05 | 48.82 | 0.888 | 1.135 | 1.015 | | |
| Mean for Atonik – Średnio dla Atoniku | | 4.04 | 52.95 | 51.11 | 46.19 | 1.099 | 1.118 | 1.090 | | |
| Mean without Atonik – Średnio bez Atoniku | | 3.60 | 46.88 | 45.85 | 40.63 | 1.236 | 1.213 | 1.210 | | |
| Source of variation – Źródło zmienności | | | | | | | | | | |
| Method of plantation establishment Metoda zakładania plantacji | | ** | ** | ** | ** | ** | ** | ** | | |
| Atonik application – Stosowanie Atoniku | | * | ** | ** | * | ** | ** | ** | | |
| Interaction – Interakcja | | * | ** | * | * | ** | ** | ** | | |

^zData are means ±SE – dane są średnimi ±SE;

NS, **, * – non significant or significant at at P ≤ 0.05 or 0.1 – nieistotne lub istotne przy P ≤ 0,05 lub 0,1

and Kiełtyka [2005]. The highest yields of raw material were obtained in the second and third years of cultivation, whereas in the fourth year a considerable yield decrease was observed. Thus, in order to ensure satisfying yields commercial plantations should last two or three years.

Independently from the plantation establishment method, Atonik application caused significant (on an average by 15%) raw material yields increase. Similar relationship was observed by Zahradniček et al. [1998] and Černý et al. [2002] in the case of sugar beets and Kołodziej [2004] in ginseng. Application of this biomaterial increases yield probably through the stimulation of plant metabolism. This results in better nutrient intake, assimilate flow and quicker synthesis of enzymes, membrane stress protectors, and other indispensable substances. It induces stimulation of these processes in plant thereby improving flowering and fertilization, increases resistance to stress and accelerates plants recovery after adverse environmental conditions.

The highest yields of goldenrod raw material were collected from plots with spring planting of seedlings or autumn achenes sowing. It is in agreement with common herbs production practice, where autumn seeds sowing is considered as the best method of plantation establishment (especially in the case of species with unknown biology or requiring seeds stratification). Spring planting of seedlings resulted in five-weeks-lasting of the first vegetation period prolongation, assuring better growth conditions for young goldenrod's plants. So, these two plantation establishment methods should be recommended on commercial goldenrod plantations.

In the experiment goldenrod herb contained relatively high amount of leiocarposide – its content ranged from 0.77% to 1.63% (tab. 2) and was higher than the one reported by Lück et al. [2000] or Gruszczyk and Kiełtyka [2005]. Similarly as in the case of aboveground parts of plants yields, higher active compound content was stated on plots with plants obtained from autumn diaspores sowing or spring seedlings transplanting. Moreover, contrary to Gruszczyk and Berbeć [2004] results, a slight decrease in leiocarposide content in goldenrod raw material gathered from the plots additionally sprayed with Atonik was observed (tab. 2).

CONCLUSIONS

1. The highest yields of goldenrod herb were obtained from plots with autumn achenes sowing or spring planting of seedlings, so these plantation establishment methods could be recommended on field plantations.

2. Commercial plantation should not last more than three years; further cultivation results in a considerable decrease of raw material yields and morphological parameters deterioration.

3. In order to increase raw material yields goldenrod could be sprayed with 0.1% Atonik.

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EFEKTY METODY ZAKŁADANIA PLANTACJI I STOSOWANIA ATONIKU W UPRAWIE NAWŁOCI POSPOLITEJ (*Solidago virgaurea* L. ssp. *virgaurea*)

Streszczenie. W czteroletnim doświadczeniu polowym badano wpływ różnych metod zakładania plantacji oraz stosowania naturalnego regulatora wzrostu Atoniku na plonowanie i skład chemiczny ziela nawłoci pospolitej (*Solidago virgaurea* L. ssp. *virgaurea*). W eksperymencie porównywano następujące metody zakładania plantacji nawłoci: A. wiosenny siew bezpośredni nasion, B. wiosenne sadzenie rozsady, C. jesienny siew bezpośredni nasion, D. jesienne sadzenie rozsady oraz efekty wykonywanego dwukrotnie w okresie wegetacji oprysku 0,1% roztworem Atoniku. Nasiona wysiewano wprost do gruntu w rzędy co 40 cm, natomiast rozsadę produkowano w tunelu w paletach wielokomórkowych przez okres 5 tygodni, a potem wysadzano na pole w rozstawie 40×15 cm.

Surowiec nawłoci zbierano każdego roku na początku kwitnienia roślin, następnie oznaczono w nim zawartość lejoکارپozydu (metodą HPLC). Najwyższe plony surowca otrzymywano w drugim i trzecim roku uprawy, podczas gdy w czwartym roku obserwowano znaczną obniżkę plonowania roślin, wskazującą, że plantacja produkcyjna tej rośliny winna trwać przez dwa lub trzy lata. Wyższe plony ziela charakteryzujące się większą zawartością lejoکارپozydu zebrano z poletek z wiosennym wysadzeniem uprzednio wyprodukowanej rozsady lub jesiennym wysiewem nasion wprost do gruntu, zatem te dwie metody zakładania plantacji mogą być polecane w polowej uprawie nawłoci. Dodatkowo, w celu zwiększenia plonów surowca rośliny powinny być opryskiwane 0,1% Atonikiem.

Słowa kluczowe: nawłóć pospolita (*Solidago virgaurea* L. ssp. *virgaurea*), metody zakładania plantacji, Atonik, leioکارپozyd

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