Effect of agrotechnical factors on the yield of goldenrod (*Solidago virgaurea* L. ssp. *virgaurea*)

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S u m m a r y

In four-year-lasting field experiment yielding of goldenrod herb depending on different methods of plantation establishment and row spacing were analysed. In the experiment different methods of goldenrod plantation establishment were compared: I. direct spring diaspores sowing, II. spring seedlings planting, III. direct autumn diaspores sowing, IV. autumn seedlings planting. Diaspores were sown directly onto the field in rows of 30 cm, 40 cm, and 50 cm spacing at the amount of 500 g· ha^{-1}, whereas seedlings were produced in multicell trays in plastic tunnel throughout 5 weeks and than transplanted onto the field in the same rows spacing (with 15 cm in-rows spacing). Raw material (herb) was harvested every year at the beginning of blooming stage (at a height of 10-15 cm above the ground). The highest herb yield was obtained in the second and third year of plant vegetation. Due to the fact that in the fourth year a considerable decrease of raw material yield was noted, for pharmaceutical purposes the plantation should be cultivated for three years. Cultivation with 30 and 40 cm row spacing resulted in the highest yields of raw material, whereas in that of 50 cm rows spacing a significant decrease of yields was stated. Direct autumn achenes sowing or spring planting of seedlings could be recommended as the best methods of commercial plantation establishment.

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

INTRODUCTION

Solidago virgaurea is a well known medicinal plant of diuretic, spasmolytic, anti-inflammatory, antiphlogistic, antimycotic, antihypertensive, immunostimulating

and antioxidant activity. The pharmacological activity of *Soliadaginis virgaureae Herba* is caused by the presence among others of leiocarposide, flavonoids, saponins and essential oil [1-5]. European goldenrod is the only species native to Poland of four commonly occurring [4]. Its raw material is being collected mainly from natural habitats, but in recent years trials were carried out with cultivation of this species [6-12]. However, there are a very few data regarding different row spacing or plantation establishment methods on goldenrod's growth and yielding.

MATERIALS AND METHODS

The aim of four-year-lasting field experiment was to compare effects of four methods of plantation establishment and different row spacing on goldenrod yielding. Investigations were carried out on experimental fields in the University of Life Sciences in Lublin, located on slightly loamy sand in Trzciniec (51°7'46"N, 22°10'59"E) in Lubelski region. The soil was characterized by mean humus (1.53%), very low phosphorus (12.2 mg $\cdot kg^{-1}$ of soil), potassium (24.9 mg $\cdot kg^{-1}$ of soil) and magnesium (2.0 mg $\cdot kg^{-1}$ 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 (17 April), II. spring seedlings planting (20 April), III. direct autumn diaspores sowing (10 September), IV. autumn seedlings planting (12 September). For plantation establishment goldenrod (*Solidago virgaurea* L. ssp. *virgaurea*) [13] diaspores obtained from local populations growing in Lubelski region in natural state were used. Diaspores were sown directly onto the field (at the amount of 500 g$\cdot$ ha^{-1} on 0.5-1 cm depth) in rows 30 cm, 40 cm, or 50 cm apart. Seedlings were produced in multicell trays in plastic tunnel for 5 weeks and then planted into the field also in rows 30 cm, 40 cm, and 50 cm apart (with 15 cm in-rows spacing).

Every spring before the beginning of plants' vegetation the following mineral fertilization was applied: 40 kg N $\cdot$ ha^{-1} – in a form of ammonium nitrate, 30.3 kg P $\cdot$ ha^{-1} – in a form of a single superphosphate and 24.1 kg K $\cdot$ ha^{-1} – in a form of potassium salt. 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). Before the harvest, 5 randomly chosen plants per plot were measured and dried in the temperature of 35^0C. A randomized complete block design with three replications (plots 6 m^2) was used. All data were subjected to analysis of variance using GLM procedure (SAS, version 8.2 SAS Institute, Cary, N.C.) with mean separating performed by the LSD test ($p<0.05$).

RESULTS AND DISCUSSION

The experimental factors significantly affected the yield of herb (tab. 1-2, fig. 1).

Table 1.

Yields of goldenrod herb (air-dry matter, g·m^{-2}) depending on the experimental factors

plantation establishment method	row spacing	year of plants' vegetation				total yield
		1st	2nd	3rd	4th	
spring sowing	30 cm	19	740	530	407	1696
	40 cm	17	670	486	355	1528
	50 cm	16	560	397	269	1242
mean		18	657	471	344	1490
spring seedlings planting	30 cm	170	942	742	406	2260
	40 cm	161	898	646	361	2066
	50 cm	61	508	563	280	1412
mean		131	783	650	349	1913
autumn sowing	30 cm	51	752	793	593	2189
	40 cm	45	720	681	465	1911
	50 cm	40	655	671	365	1731
mean		45	709	715	474	1943
autumn seedlings planting	30 cm	196	932	616	313	2057
	40 cm	185	784	567	262	1798
	50 cm	160	780	390	156	1486
mean		180	832	524	244	1780
source of variation						
method of plantation establishment		**	**	**	**	**
row spacing		**	**	**	**	**
interaction		**	**	**	**	**

NS, **, * – non significant or significant at $p \leq 0.01$ or 0.05s, respectively (Tukey test)

Table 2.

Air dry weight of aboveground parts of single goldenrod plant (in g ·plant^{-1}) and number of stems per plant (in units · plant^{-1}) depending on the experimental factors

Plantation establishment method	Row spacing	air dry weight of aboveground parts of plant (g ·plant^{-1})				number of stems per plant (units · plant^{-1})			
		year of plants' vegetation				year of plants' vegetation			
		1st	2nd	3rd	4th	1st	2nd	3rd	4th
spring sowing	30 cm	1.80	33.54	45.90	32.08	1	8.7	4.5	4.8
	40 cm	1.51	36.48	53.60	43.41	1.5	9.2	4.7	5.5
	50 cm	1.30	38.81	57.23	46.38	2	10.0	4.7	6.3
mean		1.54	36.28	52.24	40.62	1.5	9.3	4.6	5.5

spring seedlings planting	30 cm	3.46	33.42	42.07	37.77	1.5	8.0	7.7	5.0
	40 cm	4.77	45.89	35.54	34.63	2.5	9.0	8.3	6.3
	50 cm	5.21	57.05	48.51	48.31	3.0	10.0	8.5	7.2
mean		4.48	48.79	42.04	40.24	2.3	9.0	8.2	6.2
autumn sowing	30 cm	1.04	37.38	38.86	35.89	1.0	5.8	5.0	5.0
	40 cm	1.41	37.88	39.29	37.04	1.0	7.8	5.7	6.0
	50 cm	2.96	45.31	49.16	41.08	1.8	8.8	6.5	7.3
mean		1.80	40.19	42.44	38.00	1.3	7.4	5.7	6.1
autumn seedlings planting	30 cm	6.19	56.09	46.90	38.50	2.17	9.8	5.3	5.0
	40 cm	6.70	57.26	54.95	47.45	2.5	10.3	6.7	5.8
	50 cm	7.36	64.50	50.94	52.38	3.5	11.4	6.5	7.5
mean		6.75	59.28	50.93	46.11	2.7	10.5	6.2	6.1
source of variation									
method of plantation establishment		**	**	*	*	**	*	**	*
row spacing		**	**	**	**	**	**	*	*
interaction		**	**	*	*	**	**	*	*

NS, **, * – non significant or significant at $p \leq 0.01$ or 0.05, respectively (Tukey test)

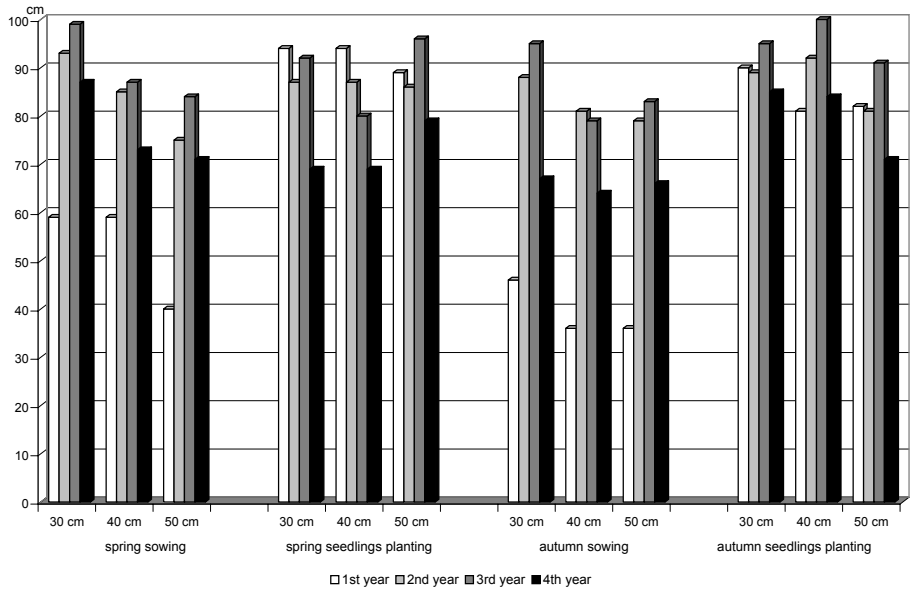

Figure 1. Average height of goldenrod plant (in cm) depending on the experimental factors

In general, in the first year of vegetation, the rosette leaves were observed and only 10–25% of plants born fertile shoots. Thus, the yield of raw material was extremely low (especially on plots with direct diaspores sowing) (tab. 1-2, fig. 1).

In following years of cultivation almost all of plants were blooming, so herb yields were distinctly higher. In the second year of cultivation plants formed the greatest number (from 7 to 11) of the longest stems, whereas in the third year goldenrod was characterised by the smaller number (from 5 to 8) of lower stems with short inflorescences (fig. 1, tab. 2). That is why the raw material yield obtained during the third year of vegetation was on an average 10% lower than those from the second year. In the fourth year of goldenrod vegetation there was observed a considerable decrease of yields. Due to that fact, commercial goldenrod cultivation assuring satisfying yields obtaining should last at the most two or three years. In general, herb yield was at the same level as obtained by Lück et al. [12], but higher than stated by Galambosi et al. [7], Gruszczyk and Kiełtyka [8] as well as Jokela and Galambosi [9].

Along with plants density increase a tendency to decrease number of stems and air dry weight of single plant is observed. Although, the increase of a raw material yields from the unit area at the same time was noted (tab. 1-2). Similar relationship was observed by Jokela and Galambosi [9] as well as Borkowska and Wardzińska [14].

Goldenrod growing in 30 cm row spacing was characterized with the highest total yields of raw material (2050 g $\cdot$ m^{-2} on average). Cultivation in 40 cm row spacing resulted in 11% decrease of total herb yield, while on plots with 50 cm rows spacing – 28% decrease in comparison to the highest density.

Irrespectively of the row spacing, the highest air dry weight of single plants and those collected from the unit area were stated on plots with autumn or spring planting of seedlings (tab. 1, 2). On the other hand, the lowest herb yield (especially during two first years of vegetation) was observed on plots with direct spring diaspores sowing (1490 g $\cdot$ m^{-2} on average). Autumn sowing and spring transplanting were connected with almost 30% yield increase in comparison to spring achenes sowing. It is in agreement with common herbs production practise, where autumn seeds sowing is considered to be the best method of plantation establishment [15]. Spring planting of seedlings resulted in prolongation of the first vegetation period (five-weeks-lasting), assuring better growth conditions for young goldenrod's plants. Thus, autumn seeds sowing or spring planting of seedlings should be recommended for commercial goldenrod plantations.

CONCLUSIONS

Direct autumn achenes sowing or spring planting of seedlings could be recommended for goldenrod commercial field plantation establishment. The highest yields of raw material were obtained at 30 and 40 cm row spacing. Commercial plantation of goldenrod can be exploited for three years. In the fourth year a considerable decrease of herb yield is observed.

REFERENCES

1. Wichtl M. Herbal drugs and Phytopharmaceuticals. A handbook for practice on a scientific basis. London 1994:530-3.
2. Blumethal M, Busse WR, Goldberg A. The complete German Commission E monographs: Therapeutic guide to herbal medicines. Boston 1998:139-40.
3. Melzig M. Echtes Goldrutenkraut – ein Klassiker in der urologischen Phytoterapie. Wien Med Wochenschr 2004; 154:523-7.
4. Budzianowski J, Skrzypczak L, Wesołowska M. Flavonoids and leiocarposide in four *Solidago* taxa. Sci Pharm 1990; 58:15-23.
5. Kalemba D. Constituents of the essentials oil of *Solidago virgaurea* L. Flavour Fragr J 1998; 13:373-6.
6. Bohr Ch, Plescher A. Empfehlungen für den Anbau von Echler Goldrute (*Solidago virgaurea* L.) in Thüringen. Drogenreport 1997; 10:24-7.
7. Galambosi B, Honkala Y, Jokela K. Production potential of wild and cultivated golden-rod (*Solidago virgaurea* L.) populations in Finland. Acta Hort 1993; 344:249-55.
8. Gruszczyk M, Kiełtyka A. Yields and raw material quality of *Hypericum perforatum* L. and *Solidago virga aurea* L. from one-year and two-year plantations. Herba Pol 2005; 51:5-9.
9. Jokela K, Galambosi B. Effect of ridge cultivation and plant density on growth and yield of some medicinal plants in Finland. Z Arzn Gew Pfl 1998, 3:139-45.
10. Kołodziej B. The effect of NPK fertilisation on goldenrod (*Solidago virgaurea* L. ssp.*virgaurea*) yields and quality parameters. Herba Pol 2007, 53:129-34.
11. Kucharski W, Mordalski R. Optimalisation of nitrogen fertilization in goldenrod (*Solidago virgaurea* L.) cultivation for raw material. Herba Pol 2006; 52:119.
12. Lück L, Schenk R, Weber K, Bader G, Abel G. Wildherkünfte von *Solidago virgaurea* L. – Erträge und Variabilität morphologischer und phytochemische Merkmale. Z Arzn Gew Pfl 2000; 1:20-7.
13. Rutkowski L. Klucz do oznaczania roślin naczyniowych Polski niżowej. Warszawa 1998:462.
14. Borkowska H, Wardzińska K. Biomass yield of *Sida hermaphrodita* R. in relation to the manners of establishing a plantation and plant density. Annales UMCS, sec. E. 1997; 48:107-14.
15. Rumińska A. Poradnik plantatora ziół. Poznań 1991.

WPŁYW WYBRANYCH CZYNNIKÓW AGROTECHNICZNYCH NA PLONOWANIE NAWŁOCI POSPOLITEJ (*SOLIDAGO VIRGAUREA* L. SSP. *VIRGAUREA*)

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S t r e s z c z e n i e

W czteroletnim doświadczeniu polowym porównywano plony ziela nawłoci pospolitej (*Solidago virgaurea* L. ssp. *virgaurea*) w zależności od metody zakładania plantacji i rozstawy rzędów. W doświadczeniu zastosowano następujące metody zakładania plantacji:

I. wiosenny siew bezpośredni niełupek, II. wiosenne wysadzanie rozsady, III. jesienny siew bezpośredni niełupek, IV. jesienne wysadzanie rozsady. Niełupki wysiewano wprost do gruntu w rozstawie rzędów co 30 cm, 40 cm i 50 cm w ilości 500 g· ha^{-1}, natomiast rozsadę wyprodukowaną uprzednio w paletach wielokomórkowych w tunelu foliowym (przez 5 tygodni) wysadzano co 15 cm w rzędzie. Ziele zbierano co roku na początku kwitnienia roślin, ścinając pędy na wysokości 10–15 cm nad ziemią.
Najwyższe plony surowca otrzymano w drugim i trzecim roku uprawy. Ponieważ w czwartym roku stwierdzono znaczną obniżkę plonów surowca, uprawa na plantacjach produkcyjnych z przeznaczeniem do celów farmaceutycznych powinna trwać najwyżej trzy lata. Największe plony surowca uzyskano przy odległości między rzędami od 30 cm do 40 cm. Jesienny wysiew nasion lub wiosenne wysadzanie rozsady mogą być polecane jako najlepsze metody zakładania plantacji nawłoci pospolitej.

Słowa kluczowe: *nawłoć pospolita (Solidago virgaurea* L. *ssp. virgaurea), metody zakładania plantacji, rozstawa rzędów*