Journal of International Scientific Publications: Agriculture and Food

Volume 2, ISSN 1314-8591 (Online), Published at: http://www.scientific-publications.net

EFFECT OF PLANT DENSITY ON GROWTH, DEVELOPMENT AND QUALITY OF RIBWORT PLANTAIN (*PLANTAGO LANCEOLATA* L.)

Ewa Osińska, Wiesława Rosłon, Anna Geszprych, Aneta Morawska, Łukasz Gontar

Department of Vegetable and Medicinal Plants, Warsaw University of Life Sciences – SGGW, Poland

Abstract

The aim of the studies carried out in 2012-2013 was to evaluate the influence of plant density (sowing rate) on the growth, development, and accumulation of biologically active compounds in the leaves of plants representing three populations of ribwort plantain (Plantago lanceolata L.). The experiment was established in the third decade of April. Seeds were sown at the rate of 3 and 6 kg/ha. Plants were harvested at three stages of development: vegetative growth, blooming, and seed maturity. Plant weight, root length, leaf length and width, number and length of seed stalks were determined. In the air-dry leaves the content of iridoid glycosides, tannins, flavonoids, and phenolic acids were determined. Sowing rate did not significantly affect the yield of leaves. Plants growing at higher density were characterised by higher content of biologically active compounds.

Key words: *cultivation, populations, sowing rate, time of harvest, morphological traits, iridoid glycosides, tannins, flavonoids, phenolic acids*

1. INTRODUCTION

High popularity of herbal medicine and the growing demand for herbal medicinal products called the attention of phytopharmaceutical industry to the plant raw materials. Many medicinal plants, including those representing the genus *Plantago*, are collected from natural sites (Pons & van der Toorn 1988, Ożarowski 1990). High interest in medicinal usage of plantains (*Plantago* spp.) has recently been observed, which results from the promising results of phytochemical and ethnopharmacological studies confirming anti-inflammatory, spasmolytic, and protective effects of the raw materials obtained from these plants (Bowers & Stamp 1992; Meyer et al. 2006). Special attention is paid to the presence of mucilages in different organs of plantains. These compounds show protective activity on mucous membranes in the digestive tract, which is important in the prevention and treatment of ulcers caused by excessive production of hydrochloric acid. Other important groups of biologically active compounds include iridoid glycosides, tannins, and flavonoids showing anti-inflammatory, bacteriostatic, antiviral, and other effects (Fons et al. 1999; Andrzejewska-Golec 1995; Long et al. 1995). The studies carried out on the species of *Plantago* genus indicate high intraspecific variability. It seems that in order to obtain the raw materials of high and uniform quality, easy for standardisation, it is necessary to introduce the selected populations into cultivation. Ribwort plantain (*Plantago lanceolata* L.) is a plant of Euro-Asiatic origin, well known and commonly occurring in Poland. It grows in meadows, pastures, roadsides, and wastelands. It has been used medicinally since ancient times (Skrzypczak, Budzianowski & Budzianowska 2009). Leaves of this plant have been used for the production of expectorant and antitussive sirups. They also show bacteriostatic and immunotropic action (Fleer & Verspohl 2007). The content of biologically active compounds in the raw material and thus its pharmacological activity is affected by numerous endo- and exogenic factors, including genetic and ontogenetic variation, climatic and soil conditions and agrotechnical treatments (Darrow & Bowers 1997; Coelho, Deboni & Lopes 2005). The aim of this study was to determine the effect of plant density (sowing rate) and stage of plant development on morphological traits of plants representing three populations of ribwort plantain and on the quality of raw material obtained thereof.

2. MATERIALS AND METHODS

The studies were carried out in 2012-2013 in the experimental field and laboratories of the Department of Vegetable and Medicinal Plants, WULS-SGGW in Warsaw.

2.1. Plant material

For establishing the experiment the seeds obtained from 3 populations of ribwort plantain from natural sites in Poland were used:

P1 – Ernestynów – Lubelskie area (N 51º41.484', E 22º11.025')

P2 – Srebrna – Podlasie area (N 52º52.759', E 22º07.648')

P3 – Zalesie Dolne – Mazowsze area (N 52º02.801', E 21º03.663')

Seeds were sown in the third decade of April, at the rate of 3 kg/ha and 6 kg/ha. The experiment was established in the randomised block design with 4 replications. The single plot area was 10 m^2.

Plants were harvested at 3 stages of development: I – vegetative growth, II – blooming, and III – seed maturity. Each time plants were cut from 1 m^2 of each plot. The leaves were dried in a drying chamber at 30-35ºC. The yield of air-dry leaves was determined. The raw material was kept in paper bags till the time of chemical analyses.

Moreover, at each of the 3 developmental stages, 5 randomly selected plants from each combination were evaluated in respect of biometrical traits (plant weight, root length, leaf length and width, number and length of seed stalks).

2.4. Chemical analyses

In the air-dry leaves the contents of iridoid glycosides, tannins, flavonoids, and phenolic acids were determined, according to the methods described in the Polish Pharmacopoeia (Farmakopea Polska VIII 2008).

2.5. Statistical analysis

The results concerning the yield of leaves and the content of biologically active compounds in the leaves were subjected to statistical analysis in Statgraphics PlusV.4.1 programme using a 3-factor analysis of variance and Tukey's HSD test at the significance level 0.05.

3. RESULTS

3.1. Morphological diversity of plants

Plants of the investigated populations differed in respect of morphological traits, such as plant weight, leaf size, root length, number and length of seed stalks. These parameters were affected by the sowing rate and stage of plant development (Tables 1-6).

Plant weight increased during plant development. At the stage of vegetative growth it ranged from 4.91 g (population P2, sowing rate 6 kg/ha) to 12.70 g (population P3, sowing rate 3 kg/ha), at the stage of blooming – from 12.34 g (population P2, sowing rate 3 kg/ha) to 21.87 g (population P3, sowing rate 6 kg/ha), and at the stage of seed maturity – from 31.49 g (population P1, sowing rate 3 kg/ha) to 62.64 g (population P2, sowing rate 3 kg/ha). There was no clear relation between the sowing rate and plant weight. The highest individual variability (expressed as a coefficient of variation) in respect of plant weight was characteristic for the population P1 (Table 1).

Root length ranged from 6.90 to 11.38 cm at the stage of vegetative growth of the plants, from 6.40 to 12.19 cm at the stage of blooming, and from 9.72 to 14.47 cm at the stage of seed maturity. At the stage of seed maturity slightly longer roots were characteristic for the plants grown at higher density (sowing rate 6 kg/ha) (Table 2).

There was no clear relation between the sowing rate and the leaf size (length and width). Leaf length was increasing during plant development (Tables 3-4).

Plants grown at higher density (sowing rate 6 kg/ha) produced higher number of seed stalks (Table 5). Their length ranged from 55.82 to 89.93 cm and was not clearly related to the sowing rate. Relatively low variation in respect of this parameter was found within the investigated populations (Table 6).

Table 1. Plant weight (g)

Stage of plant development	Population	Sowing rate (kg/ha)	Min.	Max.	Mean (n=5)	Standard deviation	Coefficient of variation (%)
Vegetative growth	P1	3	1.20	17.40	11.12	4.70	42.43
		6	1.20	12.80	8.55	3.83	44.80

	P2	3	2.35	9.35	5.46	2.14	39.21
		6	2.20	6.95	4.91	1.38	28.10
	P3	3	4.50	20.70	12.70	5.49	43.27
		6	2.10	9.80	5.17	2.59	50.09
Blooming	P1	3	11.30	40.90	19.98	9.69	48.47
		6	10.20	31.80	21.93	14.71	67.07
	P2	3	7.80	24.10	12.34	5.34	44.00
		6	11.60	28.10	20.61	6.53	31.68
	P3	3	16.30	37.10	21.87	6.86	31.39
		6	15.50	47.70	29.91	13.93	46.57
Seed maturity	P1	3	17.30	72.40	31.49	20.03	63.63
		6	19.30	97.90	51.13	31.12	60.86
	P2	3	17.70	96.60	62.64	30.00	48.74
		6	17.70	62.05	43.14	16.25	37.66
	P3	3	16.30	75.10	36.82	20.60	55.94
		6	16.30	75.10	42.21	23.23	55.03

Table 2. Root length (cm)

Stage of plant development	Population	Sowing rate (kg/ha)	Min.	Max.	Mean (n=5)	Standard deviation	Coefficient of variation (%)
Vegetative growth	P1	3	4.20	12.00	8.50	2.43	28.56
		6	7.00	10.50	8.84	1.06	11.90
	P2	3	4.50	11.00	6.90	2.05	29.76
		6	4.00	16.00	11.38	3.58	31.45
	P3	3	4.50	12.00	8.90	2.70	30.45
		6	6.00	13.00	8.99	2.02	22.46
Blooming	P1	3	7.00	17.00	11.84	3.33	28.15
		6	7.20	11.00	9.33	1.40	15.00
	P2	3	7.50	12.00	9.76	1.41	14.45
		6	3.00	16.00	6.40	2.99	46.71
	P3	3	6.00	14.80	9.81	2.60	26.54
		6	6.50	15.00	12.19	2.94	24.18
Seed maturity	P1	3	10.00	15.00	12.02	1.54	12.84
		6	12.00	18.00	13.80	1.02	7.36
	P2	3	7.50	12.00	9.72	1.65	17.01

		6	9.00	12.00	10.48	0.99	9.54
	P3	3	9.00	12.00	10.41	1.00	9.63
		6	12.00	17.00	14.47	1.67	11.57

Table 3. Leaf length (cm)

Stage of plant development	Population	Sowing rate (kg/ha)	Min.	Max.	Mean (n=5)	Standard deviation	Coefficient of variation (%)
Vegetative growth	P1	3	12.00	24.00	18.60	4.26	22.83
		6	15.10	19.60	16.92	1.18	6.97
	P2	3	12.00	29.00	21.00	5.29	25.16
		6	17.00	26.00	20.58	2.36	11.47
	P3	3	16.00	28.00	19.80	3.71	18.68
		6	13.50	21.00	16.57	2.83	17.07
Blooming	P1	3	23.00	37.00	28.77	5.13	17.81
		6	30.00	38.00	34.01	2.88	8.46
	P2	3	18.00	27.00	22.37	2.78	12.46
		6	24.00	34.00	28.89	3.32	11.49
	P3	3	18.50	40.00	28.95	7.55	26.08
		6	24.00	40.00	30.23	6.55	21.66
Seed maturity	P1	3	33.20	44.50	38.71	4.37	11.29
		6	27.00	40.00	31.96	3.84	12.02
	P2	3	8.50	36.00	21.79	9.96	45.72
		6	28.00	39.00	32.30	3.51	10.86
	P3	3	31.00	42.00	35.69	4.87	13.64
		6	24.00	38.00	34.47	4.52	13.11

Table 4. Leaf width (cm)

Stage of plant development	Population	Sowing rate (kg/ha)	Min.	Max.	Mean (n=5)	Standard deviation	Coefficient of variation (%)
Vegetative growth	P1	3	2.30	5.40	3.50	1.10	31.61
		6	1.90	4.20	2.92	0.63	21.50
	P2	3	1.80	3.00	2.08	0.34	16.27
		6	1.70	2.80	2.18	0.34	15.59
	P3	3	1.70	3.80	2.60	0.68	26.57
		6	1.50	3.00	2.23	0.55	24.66
Blooming	P1	3	1.90	3.00	2.19	0.37	17.01

		6	2.00	4.10	2.85	0.89	31.22
	P2	3	1.70	3.70	2.48	0.66	26.76
		6	1.00	4.00	2.36	0.82	46.57
	P3	3	1.70	3.50	2.36	0.61	26.01
		6	1.60	3.50	2.42	0.60	21.66
Seed maturity	P1	3	1.90	2.90	2.25	0.31	13.61
		6	2.00	3.50	2.46	0.50	20.43
	P2	3	2.00	2.80	2.24	0.43	20.20
		6	1.90	2.50	2.15	0.19	8.78
	P3	3	1.80	3.20	2.22	0.48	21.07
		6	1.80	4.00	2.99	0.67	22.35

Table 5. Number of seed stalks

Stage of plant development	Population	Sowing rate (kg/ha)	Min.	Max.	Mean (n=5)	Standard deviation	Coefficient of variation (%)
Seed maturity	P1	3	2.00	6.00	4.00	1.28	31.47
		6	2.00	20.00	12.40	6.48	52.25
	P2	3	7.00	15.00	10.80	2.86	26.51
		6	2.00	18.00	10.93	5.19	47.46
	P3	3	1.00	8.00	4.00	2.15	43.65
		6	5.00	10.00	7.93	1.58	19.91

Table 6. Length of seed stalks (cm)

Stage of plant development	Population	Sowing rate (kg/ha)	Min.	Max.	Mean (n=5)	Standard deviation	Coefficient of variation (%)
Seed maturity	P1	3	55.00	71.00	62.12	6.12	9.84
		6	49.00	70.00	60.90	8.40	13.75
	P2	3	57.00	90.00	74.20	11.90	16.04
		6	49.00	62.00	56.86	6.78	11.93
	P3	3	47.00	68.00	55.82	8.38	15.00
		6	47.00	120.00	89.93	26.36	29.31

3.2. Yield of leaves

Yield of air-dry leaves was significantly affected by the time of harvest (stage of plant development). The highest yield was obtained from the plants harvested at the stage of seed maturity (1.35 kg/m^2, on average). No significant differences in the leaf yield were found between populations. There was no significant effect of the sowing rate on this parameter, although at the stage of seed maturity slightly higher yield was obtained from the plantation characterised by higher plant density (Table 7)

Table 7. Yield of air-dry leaves (kg/m^2)

Stage of plant development	Population	Sowing rate (kg/ha)		Mean
		3	6	
Vegetative growth	P1	0.09	0.06	0.08
	P2	0.07	0.06	0.07
	P3	0.05	0.04	0.05
	Mean	0.07	0.05	0.06
Blooming	P1	0.31	0.27	0.29
	P2	0.30	0.28	0.29
	P3	0.20	0.35	0.28
	Mean	0.27	0.30	0.29
Seed maturity	P1	1.46	1.55	1.51
	P2	1.13	1.44	1.29
	P3	1.18	1.32	1.25
	Mean	1.26	1.44	1.35
Mean	P1	0.62	0.63	0.63
	P2	0.50	0.59	0.55
	P3	0.48	0.57	0.53
Mean		0.53	0.60	

A – sowing rate, B – stage of plant development, C – population

$LSD_{0.05}$ B=0.16

3.3. Content of biologically active compounds in the leaves

The content of iridoid glycosides in the leaves was significantly affected by the sowing rate and stage of plant development. Higher content of iridoid glycosides was found in the leaves collected from the plantation established by sowing seeds at the rate of 3 kg/ha (2.08 g/100g, on average). The content of these compounds in the leaves was increasing during plant development. However, the interactions between all factors of the experiment were observed (Table 8).

Table 8. Content of iridoid glycosides in the leaves (g/100g)

Stage of plant development	Population	Sowing rate (kg/ha)		Mean
		3	6	
Vegetative growth	P1	2.88	0.81	1.85
	P2	1.22	1.14	1.18
	P3	1.06	0.79	0.93
	Mean	1.72	0.91	1.32
Blooming	P1	1.50	1.44	1.47

	P2	2.10	1.22	1.66
	P3	2.18	2.18	2.18
	Mean	1.93	1.61	1.77
Seed maturity	P1	2.79	2.54	2.67
	P2	2.80	2.50	2.65
	P3	2.22	2.70	2.46
	Mean	2.60	2.58	2.59
Mean	P1	2.38	1.59	1.99
	P2	2.03	1.62	1.83
	P3	1.82	1.89	1.86
Mean		2.08	1.70	

A – sowing rate, B – stage of plant development, C – population

$LSD_{0.05}$ A=0.08	$LSD_{0.05}$ B=0.14	$LSD_{0.05}$ A/B=0.05	$LSD_{0.05}$ A/C=0.06
$LSD_{0.05}$ B/A=0.08	$LSD_{0.05}$ B/C=0.29	$LSD_{0.05}$ A/BC=0.11	$LSD_{0.05}$ B/AC=0.05
$LSD_{0.05}$ ABC=0.04	$LSD_{0.05}$ C/B=0.03	$LSD_{0.05}$ C/A=0.05	$LSD_{0.05}$ C/AB=0.05

The content of tannins in the leaves was significantly affected by all three factors of the experiment. The interactions between these factors were found. Higher content of tannins was found in the leaves of plants grown at lower density (sowing rate 3 kg/ha) (1.83 g/100g, on average). The highest content of tannins was characteristic for the leaves of the population P1 grown at lower density and harvested at the stage of blooming (4.34 g/100g) (Table 9).

Table 9. Content of tannins in the leaves (g/100g)

Stage of plant development	Population	Sowing rate (kg/ha)		Mean
		3	6	
Vegetative growth	P1	1.59	0.91	1.25
	P2	1.05	0.82	0.94
	P3	1.12	0.58	0.85
	Mean	1.25	0.77	1.01
Blooming	P1	4.34	1.23	2.79
	P2	2.00	1.09	1.55
	P3	1.14	0.74	0.94
	Mean	2.49	1.02	1.76
Seed maturity	P1	1.73	0.78	1.26
	P2	2.10	0.30	1.20
	P3	1.44	0.99	1.22
	Mean	1.76	0.69	1.23
Mean	P1	2.55	0.97	1.76
	P2	1.72	0.74	1.23

	P3	1.23	0.77	1.00
Mean		1.83	0.83	

A – sowing rate, B – stage of plant development, C – population

$LSD_{0.05}$ A=0.18	$LSD_{0.05}$ B=0.30	$LSD_{0.05}$ C=0.30	$LSD_{0.05}$ A/C=0.35
$LSD_{0.05}$ B/A=0.18	$LSD_{0.05}$ B/C=0.11	$LSD_{0.05}$ A/BC=0.36	$LSD_{0.05}$ B/AC=0.17
$LSD_{0.05}$ ABC=0.35	$LSD_{0.05}$ C/B=0.31	$LSD_{0.05}$ C/A=0.25	$LSD_{0.05}$ C/AB=0.17
$LSD_{0.05}$ A/B=0.27			

The content of flavonoids in the leaves was also affected by all factors of the experiment. The interactions between these factors were significant. Plants grown at the lower density (sowing rate 3 kg/ha) were characterised by slightly higer content of flavonoids in the leaves. The highest content of these compounds was found in the raw material harvested at the stage of plant vegetative growth. At this stage plants of the population P1 were characterised by higher content of flavonoids in the leaves in comparison with two other populations (Table 10).

Table 10. Content of flavonoids in the leaves (g/100g)

Stage of plant development	Population	Sowing rate (kg/ha)		Mean
		3	6	
Vegetative growth	P1	0.63	0.51	0.57
	P2	0.22	0.13	0.18
	P3	0.52	0.45	0.49
	Mean	0.46	0.36	0.41
Blooming	P1	0.26	0.23	0.25
	P2	0.28	0.27	0.28
	P3	0.31	0.27	0.29
	Mean	0.28	0.26	0.27
Seed maturity	P1	0.22	0.19	0.21
	P2	0.19	0.12	0.16
	P3	0.35	0.17	0.26
	Mean	0.25	0.16	0.21
Mean	P1	0.37	0.31	0.34
	P2	0.23	0.17	0.20
	P3	0.39	0.30	0.35
Mean		0.33	0.26	

A – sowing rate, B – stage of plant development, C – population

$LSD_{0.05}$ A=0.06	$LSD_{0.05}$ B=0.01	$LSD_{0.05}$ C=0.01	$LSD_{0.05}$ A/B=0.06
$LSD_{0.05}$ B/A=0.02	$LSD_{0.05}$ B/C=0.02	$LSD_{0.05}$ A/BC=0.03	$LSD_{0.05}$ B/AC=0.03
$LSD_{0.05}$ ABC=0.03	$LSD_{0.05}$ C/B=0.02	$LSD_{0.05}$ C/A=0.02	$LSD_{0.05}$ C/AB=0.03
$LSD_{0.05}$ A/C=0.06			

Volume 2, ISSN 1314-8591 (Online), Published at: http://www.scientific-publications.net

The influence of each factor of the experiment on the content of polyphenolic acids in the leaves was affected by other factors. The highest content of polyphenolic acids was characteristic for the leaves of the plants of the population P2 grown at lower density (sowing rate 3 kg/ha) and harvested at the stage of blooming (0.70 g/100g). In the case of the population P3 the highest content of polyphenolic acids was found in the leaves harvested at the stage of vegetative growth from the plantation established by sowing seeds at the rate 6 kg/ha (0.55 g/100g) (Table 11).

Table 11. Content of polyphenolic acids in the leaves (g/100g)

Stage of plant development	Population	Sowing rate (kg/ha)		Mean
		3	6	
Vegetative growth	P1	0.48	0.39	0.44
	P2	0.51	0.42	0.47
	P3	0.36	0.55	0.46
	Mean	0.45	0.45	0.45
Blooming	P1	0.47	0.39	0.43
	P2	0.70	0.37	0.54
	P3	0.31	0.29	0.30
	Mean	0.49	0.35	0.42
Seed maturity	P1	0.19	0.20	0.20
	P2	0.24	0.22	0.23
	P3	0.33	0.29	0.31
	Mean	0.25	0.24	0.25
Mean	P1	0.40	0.33	0.37
	P2	0.48	0.34	0.41
	P3	0.33	0.38	0.36
Mean		0.40	0.35	

A – sowing rate, B – stage of plant development, C – population

$LSD_{0.05}$ A=0.02 $LSD_{0.05}$ B=0.03 $LSD_{0.05}$ C=0.03 $LSD_{0.05}$ A/B=0.03

$LSD_{0.05}$ B/A=0.02 $LSD_{0.05}$ B/C=0.03 $LSD_{0.05}$ A/BC=0.04 $LSD_{0.05}$ B/AC=0.02

$LSD_{0.05}$ ABC=0.02 $LSD_{0.05}$ C/B=0.03 $LSD_{0.05}$ C/A=0.02 $LSD_{0.05}$ C/AB=0.03

$LSD_{0.05}$ A/C=0.02

4. DISCUSSION

The aim of the studies was to determine whether the sowing rate (plant density) affects growth, development, leaf yield and quality of ribwort plantain. The effect of time of raw material harvesting on its quality was also determined. Three populations of ribwort plantain were compared in respect of morphological traits, yield and content of biologically active compounds in leaves as affected by sowing rate and stage of plant development.

According to Pons & van der Toorn (1988) height of ribwort plantain plants ranges from 40 to 60 cm. In our studies the mean height of plants (length of seed stalks) at the stage of seed maturity ranged from 56 to 90 cm, and the range of individual variability concerning this trait was even wider (47-120 cm). There was no clear relation between the sowing rate and plant height. High individual variability in respect of the number of seed

stalks was noted (from 2 to 20 stalks). Leaf length and width was also highly diverse (8.50-44.50 and 1.00-5.40 cm, respectively). No clear effect of the plant density on these parameters was observed.

According to Kołodziej (2010) the yield of air-dry leaves that can be obtained from one-year-old plantation of ribwort plantain established by sowing seeds at the rate of 6 kg/ha reaches 0.54 kg/m^2. In the present study the yield of air-dry leaves appeared to be significantly affected by the time of plant harvesting (stage of plant development) and ranged from 0.06 kg/m^2 at the stage of vegetative growth, through 0.29 kg/m^2 at the stage of blooming, to 1.35 kg/m^2 at the stage of seed maturity, on average. No significant effect of sowing rate on leaf yield was found.

The usefulness of ribwort plantain leaves as a raw material for phytopharmaceutical industry is related to the content of numerous groups of biologically active compounds. One of the most important are iridoid glycosides. According to Polish Pharmacopoeia (Farmakopea Polska VIII 2008) *Plantaginis lanceolatae folium* should contain not less than 1.5% iridoids, expressed as aucubin. The studies of Raszeja & Gill (1972) and Rymkiewicz (1979) indicate that the content of iridoid glycosides in this raw material may range from 0.2 to 2.1%. Long et al. (1995) reported the highest aucubin content in the leaves collected in July (3.1%). In our study mean content of iridoid glycosides in the leaves ranged from 1.32% at the stage of vegetative growth of plants to 2.59% at the stage of seed maturity. With the exception of the population P3, higher content of iridoid glycosides was found in the raw material obtained from plants growing at lower density (sowing rate 3 kg/ha).

Another group of biologically active compounds in ribwort plantain leaves are tannins. According to Fons et al. (1998) their content reaches 6.5%. The leaves investigated in the present study contained less tannins (0.30-4.34%). Lower plant density (sowing rate 3 kg/ha) resulted in the more intensive accumulation of these compounds. The highest content of tannins was characteristic for the herb harvested at the stage of blooming.

The content of flavonoids and polyphenolic acids in the investigated raw materials ranged from 0.12 to 0.63% and from 0.19 to 0.70%, respectively. Plants grown at the lower density (sowing rate 3 kg/ha) were characterised by slightly higer content of both these groups of phenolic compounds in the leaves. Their content decreased during plant development.

5. CONCLUSIONS

1. Sowing rate does not significantly affect the yield of ribwort plantain leaves but it affects the content of biologically active compounds in the leaves.

2. Lower sowing rate (3 kg/ha), resulting in lower plant density, is favourable for the accumulation of iridoid glycosides, tannins, flavonoids, and polyphenolic acids in the leaves.

3. The highest yield of leaves characterised by the highest content of iridoid glycosides can be obtained at the stage of seed maturity.

4. Taking into consideration the yield of herb and the content of biologically active compounds, especially iridoid glycosides and tannins, population P1 from Lubelskie region seems to be a good source of the raw material.

ACKNOWLEDGEMENTS

The presented research was financially supported by the Ministry of Science and Higher Education, Project No. 7204/B/P01/2011/40.

REFERENCES

Andrzejewska-Golec, E 1995, ‘Babkowate (Plantaginaceae) – rośliny lecznicze’, *Farmacja Polska*, vol. 50, pp. 899-905.

Bowers, MD & Stamp, NE 1992, ‘Chemical variation within and between individuals of *Plantago lanceolata* (Plantaginaceae)’, *Journal of Chemical Ecology*, vol. 18, no. 7, pp. 985-995.

Coelho, FF, Deboni, L & Lopes, FS 2005, ‘Density-dependent reproductive and vegetative allocation in the aquatic plant *Pistia stratiotes* (Araceae)’, *Revista de biología tropical*, vol. 53, no 3-4, pp. 369-376.

Darrow, K & Bowers, MD 1997, 'Phenological and population variation in iridoid glycosides of *Plantago lanceolata* (Plantaginaceae), *Biochemical Systematics and Ecology*, vol. 25, no. 1, pp. 1-11.

Farmakopea Polska VIII 2008, PTFarm, Warszawa.

Fleer, H & Verspohl, EJ 2007, 'Antispasmodic activity of an extract from *Plantago lanceolata* L. and some isolated compounds', *Phytomedicine*, vol. 14, no. 6, pp. 409-415.

Fons, F, Rapior, S, Gargadennec, A, Andary, C & Bessière, JM 1998, 'Volatile components of *Plantago lanceolata* (Plantaginaceae)'. *Acta Botanica Gallica*, vol. 145, pp. 265-269.

Fons, F, Tousch, D, Rapior, S, Gueiffier, A, Roussel, JL, Gargadennec, A & Andary, C 1999, 'Phenolic profiles of untransformed and hairy root cultures of *Plantago lanceolata*', *Plant Physiology and Biochemistry*, vol. 37, no. 4, pp. 291-296.

Kołodziej, B (ed.) 2010, *Uprawa ziół – poradnik dla plantatorów*, PWRiL, Poznań, pp. 113-115.

Long, C, Moulis, C, Stanislas, E & Fourastè, I 1995, 'L'aucuboside et le catalpol dans les feuilles de *Plantago lanceolata* L. *Plantago major* L. et *Plantago media* L.', *Journal de Pharmacie de Belgique*, vol. 50, no. 6, pp. 484-488.

Meyer, SLF, Zasada, IA, Roberts, DP, Vinyard, BT, Lakshman, DK, Lee, J-K, Chitwood, DJ & Carta, LK 2006, '*Plantago lanceolata* and *Plantago rugelii* extracts are toxic to *Meloidogyne incognita* but not to certain microbes', *Journal of Nematology*, vol. 38, no. 3, pp. 333-338.

Ożarowski, A 1990, *Leksykon roślin leczniczych*, PWRiL, Warszawa, pp. 19-22.

Pons, TL & van der Toorn, J 1988, 'Establishment of *Plantago lanceolata* L. and *Plantago major* among grass', Oecologia, vol. 76, no. 3, pp. 341-347.

Raszeja, W & Gill, S 1972, Zawartość aukubiny w nasionach rodzaju *Plantago* L. Rozprawy Wydz. III Gdańskiego Tow. Nauk. 9, pp. 195-200.

Rymkiewicz, A 1979, Badania nad gatunkami z rodzaju *Plantago* L. z uwzględnieniem karpologii i chemotaksonomii. *Monographiae Botanicae*, vol. 57, pp. 71-103.

Skrzypczak, L, Budzianowski, J & Budzianowska, A 2009, 'Babka lancetowata w kulturze *in vitro*'. *Panacea*, vol. 27, no. 2, pp. 12-13.