SCIENTIARUM POLONORUM ACTA Acta Sci. Pol., Hortorum Cultus 11(1) 2012, 171-182

THE EFFECT OF SELECTED CULTIVATION METHODS ON YIELD AND QUALITY OF ARTICHOKE (*Cynara scolymus* L.) RAW MATERIAL

Barbara Kołodziej, Sylwia Winiarska
University of Life Sciences in Lublin

Abstract. Artichoke is known as a valuable vegetable (for its eaten buds), popular in the countries bordering the Mediterranean Sea, in the USA and South America, or medicine with documented hepatoprotective, choleretic, antioxidative, anticancerogenic, cholesterol-reducing and diuretic action. When it is cultivated for pharmaceutical purposes artichoke should be obtained from one-year-old plantations, characterized by high amount of active substances (CQA and flavonoids). The objective of three year field study was to evaluate the effects of different methods of plantation establishment: direct seed sowing, seedlings produced in multicells transplanting, seedlings with 'bare roots' from nursery beds transplanting as well as plant densities: 3.3 and 4.2 units·m^{-2} in artichoke (*Cynara scolymus* L.) cv. Green Globe culture. Additionally, quality of raw material obtained in two following cuts (performed in August and October) was estimated. Generally, traditional method of plantation establishment by direct seed sowing results in lower yields of worse quality of artichoke raw material (characterized by significantly lower active substances content), while, seedlings produced previously in multicell trays in plastic tunnel transplantation could be indicated as better method of artichoke plantation establishment for pharmaceutical purposes. A decrease of artichoke yields and dimensions but at the same time tendency to significant improve its quality (on an average two times higher content of flavonoids and CQA in comparison to direct seed sowing) was noted when seedlings transplantation from plastic tunnel (with 'bare roots') was used as method of plantation establishment. Increasing plant density of 3.3 to 4.2 units·m^{-2} caused a decrease of size and weight (by 13,4%) of individual plant leaves, and at the same time an increase of their numbers, and total yields harvested from the unit area (by 0.2 t·ha^{-1}). Moreover, during the second cut significantly higher (by 27%) yields of better quality artichoke leaves (characterized by higher flawonoid and caffeoylquinic acids content) were obtained.

Key words: plant density, seed sowing, seedlings transplanting, leaf yield, caffeoylquinic acids, flavonoid

---

Corresponding author – Adres do korespondencji: Barbara Kołodziej, Department of Industrial and Medicinal Plants, University of Life Sciences in Lublin, 15 Akademicka Str., 20-950 Lublin; Poland, phone (+48) 81 445 66 79, e-mail: barbara.kolodziej@up.lublin.pl

INTRODUCTION

Artichoke (*Cynara cardunculus* L. *subsp. cardunculus* Wikl. = *Cynara scolymus* L.) from Asteraceae family and has been known since the 4th century as a vegetable or remedy. Nowadays, it is popular especially in Mediterranean Sea region (Italy and Spain being the world's leading producers) as well as North and South America and it plays an important role in human nutrition [Ryder et al. 1983, Wang et al. 2003, Schütz et al. 2004, Sałata 2010].

Various studies have shown the health-promoting potential of artichoke. It was proven that extracts based on artichoke leaves have hepatoprotective, choleretic, hypocholesterolemic, antioxidative, anticancerogenic and diuretic action [Ryder et al. 1983, Brandt 1997, Wang et al. 2003, Eich et al. 2005, EMA 2011, Pandino et al. 2011]. The mechanisms of the raw material action and its active substances are not fully known, caffeoylquinic acids and flavonoids seem to play an important role in its pharmacological properties [Brandt 1997, Häusler et al. 2002, Wagenbreth and Eich 2005, Wittemer et al. 2005]. As Pandino et al. [2011] proved, leaf and inflorescence shoots of artichoke (usually treated as a waste material in vegetable production) possessed antioxidant properties due to phenolic compounds content. Artichoke leaves contained 1–6% mono- and dicaffeoylquinic acids, 0.1–1.2% flavonoid; 0.4% bitter sesquiterpene lactones as well as phytosterols, carbohydrates and volatile oil [Wagenbreth et al. 1996, Brandt 1997, Honermeier et al. 2001, Wang et al. 2003, Wagenbreth and Eich 2005, EMA 2011]. Studies conducted so far indicate that artichoke by-products could be used as an animal feedstuff, for fiber or functional food production. However, if artichoke raw material for pharmaceutical production comes from vegetable crops (being an additional source of income for the producer), a drug characterized by low quality is obtained [Wagenbreth et al.1996, Brandt 1997, Hanning and Eich 2001, Wang et al. 2003, Matthes and Honermeier 2003b, 2004]. Therefore, for pharmaceutical purposes artichoke should be characterized by high content of active substances (CQA, flavonoids), fast vegetative growth in the first year of cultivation and raw material homogeneity [Wagenbreth et al. 1996]. Nowadays, drugs available on the market comes mainly from one-year-old *Cynara scolymus* plantations (mainly in Germany and Poland) [Wagenbreth et al. 1996, Hanning and Eich 2001, Wagenbreth and Eich 2005].

It is very important to determine optimal agricultural conditions (method of plantation establishment, plant density or harvest date) for artichoke. In the case of vegetable artichoke production (in a Mediterranean climate) plantation is always established vegetatively (by stumps, offshoots or ovoli), rarely *in vitro* or seed-propagated cultivars are available [Ryder et al. 1983, Baier et al. 1997]. The use of seeds to propagate artichoke allows for regular crop rotation and decrease of transplanting costs due to mechanized sowing. On the other side, seedlings produced prior in nurseries transplanting could ensure seeds saving, vegetation period extending and as a result better plant development [Kołodziej and Winiarska 2010, Sałata 2010]. Another important problem in artichoke culture is its reaction for different plants density. Usually along with increased plant density yield increase was noted (on vegetable plantation with number of heads per plant decreases, without any noticeable effect on head size) – [Elia et al. 1991]. In the case of artichoke for immature inflorescences production, more than 2.5 plants·m^{-2}

reduced the number of productive plants, indicating that 2.5 plants·m^{-2} appeared to be the upper limit [Ryder et al. 1983, Elia et al. 1991]. While on one year artichoke plantation for pharmaceutical purposes there was noted an increment of leaf yield along with increased plant density on plots [Honermeier et al. 2001, Götman and Honermeier 2003, Matthes and Honermeier 2003b].

The objective of this paper was to evaluate the effects of different plantation establishment method, planting density as well as the date of leaf harvesting on *Cynarae folium* yield and active substances content.

MATERIALS AND METHODS

The experiment was conducted in the years 2004–2006 on experimental field of the University of Life Sciences in Lublin in Chmielnik Kolonia (51˚11'52"N, 22˚12'32"E). The experiment was established in a randomized complete block design with four replications (plots of 12 m^2), located on silt-loam with pH 7.7 and moderate content of macronutrients (11.1 mg P·kg^{-1} of soil, 18.2 mg K·kg^{-1} of soil and 7.2 mg Mg·kg^{-1} of soil). Prior to plantation establishment, plots were fertilized with 17.6 kg P·ha^{-1}, 124.5 kg K·ha^{-1} and 100 kg N·ha^{-1} (divided in two parts: before and during the vegetation season).

In the experiment there were compared also different methods of plantation establishment: 1) direct seed sowing, seedlings produced: 2) in multicell trays, 3) in a nursery bed (with so called 'bare roots') transplantation. Every year, seeds of 'Green Globe' variety were sown in a heated plastic tunnel (in rows 15 cm in the case of 3rd method or one seed was placed in multicells Teku Miniflor JP 3040/80 model with 26 ml volume of each cell filled with peat moss substrate in the middle of March), and seedlings (10 cm high with 3–4 true leaves) were transplanted into the field at the beginning of May, the same time when direct sowing (on 1–1.5 cm depth) took place. Both, seeds and transplants were set at two distances: 60 × 40 cm (respectively 41.6 thousand plants·ha^{-1}) and 60 × 50 cm (corresponding 33.3 thousand plants·ha^{-1}). During vegetation, mechanical loosening of inter rows as well as hand-weeding and irrigation system maintain were ensured.

Artichoke raw material was harvested two times per year (first – in the second decade of August, second – in the second decade of October). Before harvesting, the measurements of number, width and length of all leaves per plant as well as fresh and air dry matter (dried at 40ºC in a drying chamber) of 10 plants randomly chosen from plots (the same plants in the first and second cut) were performed. When artichoke plants formed inflorescences, they were separated from leaves just to share of inflorescences obtain, but further laboratory analyses were performed only on a leafy material.

HPLC analyses. Chemical analyses (by HPLC modified method of Krawczyk [2001] and Schütz et al. [2004], described below) on sum of polyphenolic compounds expressed as caffeoylquinic acids (CQA) and flavonoids (every year obtained as a mean of the four replicates) were performed in PhytoLab Klęka (MB-Holding GmbH and Co. KG). Powdered leaf material (0.1 g) was extracted with 10 ml methanol 80% (v/v) by ultrasonic treatment for 60 min. All solutions were filtered through 0.45 µm cellulose acetate membrane filters (Sartorius, Göttingen, Germany) into HPLC vials before injection. Analysis was performed with a Merck-Hitachi D-7000 chromatograph equipped with a diode-array detector (DAD L-7445), vacuum degasser, column heater and loop dosing 20 µl. A LiChrosher RP-18 column (250 × 4.6 mm; 5 µm particle size) column was used for all separations.

The mobile phase included water containing 0.2% phosphoric acid (solvent A) and acetonitrile (solvent B) in the following gradient system: initial 6%B for 10 min, linear gradient to 30%B in 20 min, hold at 30% for 5 min. The total running time was 35 min. The post running time was 10 min. The flow rate was 1.5 ml min^{-1}, the column temperature 25˚C. The absorption spectra were recorded from 200 to 400 nm for all peaks, quantification was carried out at a single wavelength of 330 nm. Quantification of CQA and flavonoids was achieved by external standard method using chlorogenic acid and luteolin 7-O-glucoside purchased from Roth (Karlsruhe, Germany) and caffeic acid from Fluka (Busch, Switzerland) as standards. Acetonitrile, methanol and phosphoric acid were all of analytical or HPLC grade (from Merck Eurolab; Vienna, Austria). Table 3 contained data which were averages of three years of investigation.

Statistical analyses. 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 on all variables was calculated using ANOVA analysis of variance.

RESULTS AND DISCUSSION

Experimental factors of the study significantly modified yields and quality parameters of one year-old artichoke plants (tab. 1–3). Every year the highest total weight of above ground parts of single *Cynara scolymus* plant, characterised by greater number of the longest leaves were obtained in objects with seedlings produced previously in multicells grown in higher density, whereas the lowest one on plots with direct seed sowing and lower plant density (tab. 1, 2). Dimensions, number and weight of rosette leaves obtained in the experiment were similar to those obtained in earlier studies by Götmann and Honermeier [2003] or Matthes and Honermeier [2003a, 2003b, 2005] or Sałata [2010]. It is worth to emphasize, that air dry matter of artichoke raw material was on an average six times lower than its fresh weight (mean drying rate – 6.18), indicating high costs of raw material maintenance (high volume transportation, the need to evaporate large quantities of water during a chamber drying).

Independently from the experimental factors, it was noted that during the second cut plants were better developed, creating more, longer (by 3.7 cm) leaves and as a result 27% higher biomass than harvested two months earlier (tab. 1, 2). We stated that yields of leaf drug from the first harvest varied between 1.36 and 2.2 t·ha^{-1} and 2.03 and 2.65 t·ha^{-1} from the second cut, similarly as in Eich et al. [2005] and Göttman and Honermeier [2003] as well as Matthes and Honermeier [2003a, 2003b] experiments. Moreover, concentration of phenolic acids and flavonoids in raw material from the second harvest was higher (respectively by 1.47 and 0.21%) than in the first cut, like in Kawala and Żaba [2001] as well as Matthes and Honermeier [2003b] and Eich et al. [2005] studies. This was probably the result of lower air temperature and precipitation

Table 1. Artichoke single plant characteristics depending on the experimental factors (mean from 2004–2006)
Tabela 1. Charakterystyka pojedynczych roślin karczocha w zależności od zastosowanych czynników eksperymentalnych (średnio z 2004–2006)

Metod of cultivation Metoda uprawy	Plant density (plant·m^{-2}) Zagęszczenie roślin (szt.·m^{-2})	Fresh weight (g per plant) Świeża masa (g·roślina^{-1})			Air dry matter (g per plant) Powietrznie sucha masa (g·roślina^{-1})			Number of leaves per plant Liczba liści (szt.·roślina^{-1})			Average length of leaves Średnia długość liści (cm)		Average width of leaves Średnia szerokość liści (cm)	
		I harvest zbiór	II harvest zbiór	I+II	I harvest zbiór	II harvest zbiór	I+II	I harvest zbiór	II harvest zbiór	I+II	I harvest zbiór	II harvest zbiór	I harvest zbiór	II harvest zbiór
From seeds Z siewu	4.2	267	344	611	45.3	56.8	102.0	11.6	15.0	26.6	43.6	44.8	17.7	18,8
	3.3	326	407	733	55.1	65.1	120.0	11.9	15.6	27.4	45.4	47.2	19.5	19.5
Mean from seeds Średnio z siewu		297	375	672	50,2	60.9	111.1	11.7	15.3	27.0	44.5	46.0	18.6	19.1
From multicells Z wielodoniczek	4.2	318	405	723	53.6	64.1	117.8	14.2	14.6	28.8	51.2	55.5	24.6	23.0
	3.3	376	472	847	63.6	77.4	141.0	16.1	16.1	32.2	54.2	56.5	27.1	23.8
Mean from multicells Średnio z wielodoniczek		347	439	785	58.6	70.8	129.4	15.2	15.4	30.5	52.7	56.0	25.8	23.4
From transplants Z rozsady	4.2	204	321	525	34.8	52.0	86.8	8.9	12.8	21.7	37.4	22.8	17.4	9.7
	3.3	223	344	567	40.6	56.3	96.8	9.8	13.7	23.4	40.3	23.3	19.7	9.9
Mean from transplants Średnio z rozsady		214	332	546	37.7	54.2	91.8	9.3	13.2	22.5	38.9	23.1	18.6	9.8
Mean for 4.2 plant·m^{-2} Średnio dla 4.2 szt.·m^{-2}		263.0	356.7	619.7	44.6	57.6	102.2	11.6	14.1	25.7	44.1	41.0	19.9	17.2
Mean for 3.3 plant·m^{-2} Średnio dla 3.3 szt.·m^{-2}		308.3	407.7	715.7	53.1	66.3	119.3	12.6	15.1	27.7	46.6	42.3	22.1	17.7
Source of variation – Źródło zmienności														
Metod of cultivation – Metoda uprawy		**	**	**	**	**	**	**	n.s., r.n.	**	**	**	**	**
Plant density – Zagęszczenie roślin		**	*	**	**	*	**	*	**	*	**	*	**	**
Interaction – Interakcja		*	**	*	*	**	*	*	*	*	*	*	**	**

n.s., *, ** – non significant or significant at $p \geq 0.05$ or 0.1; r.n., *, ** – różnica nieistotna lub istotna przy $p \geq 0.05$ or 0.1

Table 2. The effect of experimental factors on the yields of fresh and air dry weight of artichoke leaves (mean from 2004–2006)
Tabela 2. Wpływ zastosowanych czynników eksperymentalnych na plon świeżej i powietrznie suchej masy liści karczocha (średnio z lat 2004–2006)

Metod of cultivation Metoda uprawy	Plant density ($unit \cdot m^{-2}$) Zagęszczenie roślin ($szt. \cdot m^{-2}$)	Yield of fresh weight of leaves Plon świeżej masy liści ($t \cdot ha^{-1}$)			Yield of air dry matter of leaves Plon powietrznie suchej masy liści ($t \cdot ha^{-1}$)			Share of inflorescences in raw material yield Udział kwiatostanów w plonie surowca (%)	
		I harvest zbiór	II harvest zbiór	I+II	I harvest zbiór	II harvest zbiór	I+II	I harvest zbiór	II harvest zbiór
From seeds Z siewu	4.2	11.2	13.8	25.0	1.86	2.16	4.01	1.17	1.83
	3.3	11.3	13.7	25.0	1.88	2.14	4.01	2.50	2.29
Mean from seeds Średnio z siewu		11.2	13.7	25.0	1.87	2.15	4.01	1.85	2.06
From multicells Z wielodoniczek	4.2	13.5	17.1	30.6	2.20	2.65	4.84	3.17	3.00
	3.3	12.7	16.0	28.7	2.13	2.53	4.65	3.75	2.92
Mean from multicells Średnio z wielodoniczek		13.1	16.5	29.6	2.16	2.59	4.75	3.46	2.96
From transplants Z rozsady	4.2	8.8	14.1	23.0	1.49	2.29	3.78	13.33	7.00
	3.3	8.1	12.3	20.5	1.36	2.03	3.39	15.63	6.25
Mean from transplants Średnio z rozsady		8.5	13.2	21.7	1.42	2.16	3.58	14.48	6.63
Mean for 4.2 $plant \cdot m^{-2}$ Średnio dla 4.2 $szt. \cdot m^{-2}$		11.2	15.0	26.2	1.9	2.4	4.2	5.9	3.9
Mean for 3.3 $plant \cdot m^{-2}$ Średnio dla 3.3 $szt. \cdot m^{-2}$		10.7	14.0	24.7	1.8	2.2	4.0	7.3	3.8
Source of variation – Źródło zmienności									
Metod of cultivation – Metoda uprawy		**	**	**	**	**	**	**	**
Plant density – Zagęszczenie roślin		**	*	**	**	*	**	**	n.s., r.n.
Interaction – Interakcja		*	**	*	*	**	*	*	*

n.s., *, ** – non significant or significant at $p \geq 0.05$ or 0.1; r.n., *, ** – różnica nieistotna lub istotna przy $p \geq 0.05$ or 0.1

Table 3. Effect of experimental factors on caffeoylquinic acid (CQA) and flavonoid content in artichoke leaves as well as theoretical yields of CQA and flavonoids (mean from 2004–2006)

Tabela 3. Wpływ zastosowanych czynników eksperymentalnych na zawartość sumy kwasów kawoilochinowych (CQA) i flawonoidów a także teoretyczny plon CQA i flawonoidów w liściach karczocha (średnio z 2004–2006)

Metod of cultivation Metoda uprawy	Plant density (unit·m^{-2}) Zagęszczenie roślin (szt.·m^{-2})	CQA content (% of air dry matter) Zawartość sumy kwasów kawoilochinowych (% powietrznie suchej masy)		Flavonoids content (% of air dry matter) Zawartość flawonoidów w powietrznie suchej masie (% powietrznie suchej masy)		Theoretical yield of CQA Teoretyczny plon CQA (kg·ha^{-1})	Theoretical yield of flavonoids Teoretyczny plon flawonoidów (kg·ha^{-1})
		I harvest zbiór	II harvest zbiór	I harvest zbiór	II harvest zbiór		
From seeds Z siewu	4.2	1.14±0.84	1.50±0.73	0.63±0.049	0.63±0.26	53.6	25.3
	3.3	0.97±0.64	1.41±0.66	0.42±0.39	0.51±0.17	48.4	18.8
Mean from seeds Średnio z siewu		1.06	1.46	0.52	0.57	51.1	21.9
From multicells Z wielodoniczek	4.2	1.73±1.06	3.45±0.85	0.79±0.69	1.00±0.25	129.6	43.9
	3.3	1.28±0.65	3.18±0.87	0.60±0.55	0.87±0.34	107.7	33.8
Mean from multicells Średnio z wielodoniczek		1.51	3.32	0.70	0.94	118.6	39.5
From transplants Z rozsady	4.2	2.41±1.37	4.69±0.57	0.80±0.73	1.10±0.36	143.3	37.1
	3.3	1.95±1.27	4.07±0.54	0.65±0.46	1.07±0.35	109.1	30.6
Mean from transplants Średnio z rozsady		2.18	4.38	0.73	1.08	125.6	33.7
Mean for 4.2 plant·m^{-2} Średnio dla 4.2 szt.·m^{-2}		1.76	3.21	0.74	0.91	108.83	35.43
Mean for 3.3 plant·m^{-2} Średnio dla 3.3 szt.·m^{-2}		1.40	2.89	0.56	0.82	88.40	27.73
Source of variation – Żródło zmienności							
Method of cultivation – Metoda uprawy		**	**	*	**	**	**
Plant density – Zagęszczenie roślin		*	**	*	**	*	**
Interaction – Iinterakcja		*	n.s., r.n.	n.s., r.n.	*	**	**

n.s., *, ** – non significant or significant at $p \geq 0.05$ or 0.1; r.n., *, ** – różnica nieistotna lub istotna przy $p \geq 0.05$ or 0.1

during artichoke regrowth after the first cut as well as inflorescences emergence before the first harvest (from 1.17 to 15.63% plants per plot), that caused the clear loss of active substances content in raw material (tab. 2, 3), like in Wagenbreth et al. [1996], Brandt [1997] and Matthes and Honermeier [2003a, 2003b, 2004] experiments.

Independently from plant density, the highest yields of raw material were observed when artichoke plantation was started from seedlings produced in multicell trays (on an average 29.6 and 4.75 $t \cdot ha^{-1}$ fresh and air dry matter from two following cuts respectively). Use of the seedlings produced in multicells gives positive results in field cultivation of many species of vegetables and herbs (which were formerly cultivated by so-called "bare root" seedlings), resulting in increased yields, and their better quality [Bodnar and Garton 1996, Andruszczak 2005, Kołodziej and Najda 2007]. In the literature on vegetable artichoke cultivation (especially in countries with temperate climate), method of plantation establishment is recommended as the most effective, allowing the harvest acceleration [Bućan et al. 2005, Sałata 2010]. Generally, artichoke seedlings from multicells transplanting had an effect on an improvement of quality parameters and average weight of single plant, but substance content was lower than in object with seedlings with "bare roots" – Table 1–3, which was in agreement with Jani et al. [2005] results. In temperate climate, direct seeds sowing is usually used for one year plantation establishment [Baier et al. 1997, Hanning and Eich 2001, Wagenbreth and Eich 2005]. Moreover, traditional method of plantation establishment (seeds sowing), was connected with an average 16.5% air dry matter of single plant (totally from I and II cut) decrease in comparison to seedlings produced in multicell trays transplantation and at the same time 21% increase, when plots were established by transplants with 'bare roots'. Plants from direct seeds sowing objects created 5 better developed leaves more and as a result yields of air dry matter of leaves were higher by 0.43 $t \cdot ha^{-1}$ compared to plots with seedlings with "bare roots" transplantation. Similar results in the case of sage were obtained by Czarnecki et al. [1992], in basil by Ziombra et al. [2000] and in lovage and marshmallow case by Andruszczak [2005]. Moreover, plants from direct seed sowing objects weighted 14% less than these from seedlings from multicells, they created also smaller number (by 3 units) of shorter (by on an average 8–10 cm) and narrower (by 4–7 cm) leaves. Different results were obtained by Sałata [2010], who didn't noted any differences in artichoke yielding between direct seeds sowing and seedlings transplanting. Differences obtained in our experiment could be due to longer (by 7 weeks) vegetation period of plants produced in multicells than in the case of direct seeds sowing.

Artichoke cultivated by means of seedlings with 'bare roots' transplantation was characterized by low growth intensity, small number of poor-developed leaves and consequently, in this object significantly low yields of leaves were observed, but at the same time a significant improve of its quality was noted. Although, artichoke negatively reacted the root system damage during seedlings transplanting (responding to the loss of leaves, prolongation of re-rooting and high plant mortality on the field, and later, on described object, plants produced smaller number the shortest and narrowed leaves, and were characterized by the highest share of inflorescences – Table 1, 2), raw material accumulated the highest amount of caffeoylquinic acids and flavonoids. Following, theoretical yields of CQA and flavonoids were the highest (on an average 125.6 kg of

CQA·ha^{-1} as well as 33.7 kg of flavonoids·ha^{-1} respectively). The opposite results in vegetable artichoke production in Albania obtained Jani et al. [2005], who recorded higher yields of heads characterised by better quality in the case of seed-propagated plants. Differences obtained arose probably from distinct climatic and experimental procedure conditions as well as purposes of artichoke cultivation (as a vegetable of for pharmacy). There is worth to emphasize that our studies showed that traditional way of plantation establishment by direct seeds sowing does not create favorite conditions for plant growth in temperate climate, resulting in lower yields of worse quality of artichoke raw material. Seedling transplantation (as a seed saving, vegetation period extending, but more labor requiring method) could be indicated as better method of artichoke plantation establishment for pharmacy.

As far as active ingredients (CQA and flavonoids) are concerned, there was observed a wide variation in content depending on the experimental factors under study (tab. 3). The highest content of caffeoylquinic acids was observed in objects with seedlings produced in a plastic tunnel transplantation (especially from the second cut growing in higher densities) – from 1.95 to 4.69%, when the lowest one – in object with crops from direct seed sowing (from 0.97 to 1.5%). Similar relationship was observed in the case of flavonoid accumulation (tab. 3). Moreover, flavonoid content was positively correlated with CQA content (r = 0.788 – our results), which is in accordance with Wagenbreth et al. [1996] as well as Wagenbreth and Eich [2005] studies. Active substance content in artichoke leaf was comparable with obtained in special culture for pharmaceutical purposes by Wagenbreth et al. [1996], Krawczyk [2001], Hanning and Eich [2001], Häusler et al. [2002], Wang et al. [2003], Matthes and Honermeier [2003a, 2003b, 2004] and Eich et al. [2005] but higher than in Kawala and Żaba [2001] and Sałata [2006, 2010] experiments.

In contrary to Elia et al. [1991] studies, independently from three tested methods of plantation establishment, increasing plant density positively affected artichoke yielding. Average fresh and air dry weight of single plant (together from two cuts) from object with lower plant density was 13.4% higher than with 4.2 plants·m^{-2} (tab. 1). Similarly, number of leaves per plant and leaf length and width were higher on plots with lower plant density. However, along with increased plant density the total yield per unit of area also increased (on an average by 0.2 t·ha^{-1}), like in Matthes and Honermeier [2003a] experiment. As a result, also theoretical yields of caffeoylquinic acids and flavonoids were higher (by 20.4 and 7.7 kg·ha^{-1}). It is worth emphasizing that plants grown in lower densities accumulated a lower amount of determined caffeoylquinic acids and flavonoids (by 0.22% of CQA and 0.095% of flavonoids, respectively), which was similar to the results obtained by Matthes and Honermeier [2003a]. In the experiment there was found a significant interaction between plantation establishment method and row spacing, so sowing artichoke in higher densities and starting from transplants (from multicells or with 'bare roots') significantly increased total active ingredient accumulation and yield.

CONCLUSIONS

Among the three compared methods of plantation establishment the best results gave planting of seedlings produced in multicell trays. When cultivation technology with seedlings produced in multicell trays was used, there was better growth intensity and yielding observed, as well as high content and yields of polyphenols and flavonoids compared to single-grain direct seed sowing. But at the same time, the raw material from seed sowing objects was characterized by the lowest content of CQA and flavonoids. Despite the negative reaction to the damage of artichoke root system during transplanting of seedlings produced in a plastic tunnel (with 'bare roots') expressing the inhibition of growth and the smallest leaves yield, its raw material was characterized by the highest content and the theoretical yield of biologically active compounds. Moreover, during the second harvest (performed in October) there was obtained more than 50% of the total mass of raw material, characterized by a significantly higher content of active substances. Increasing the density of plants from 3.3 to 4.2 units·m^{-2} reduced the size and weight of leaves per single plants, while increased their numbers and also total yield harvested per unit area.

REFERENCES

Andruszczak S., 2005. The effect of plantation establishment method on growth, development and yielding of marshmallow (*Althea officinalis* L.) and lovage (*Levisticum oficinale* Koch.). Doct. Thesis, Univ. of Life Sciences in Lublin.

Baier C., Frankenhausen B., Diekmann W., Müller B., Wegener T., 1997. Propagation of the medicinal herb globe artichoke (*Cynara* spec.). Drogenrep. 10(18), 86–92.

Bodnar J., Garton R., 1996. Growing vegetable transplants in plug trays. OMAFRA. Factsheet, 96–023.

Brandt N., 1997. Der Ekstrakt in artischoken – präparaten. Dtsch. Apoth. Ztg 137(41), 60–75.

Bućan L., Goreta S., Perica S., 2005 Influence of transplant age and type on growth and yield of seed propagated globe artichoke. Acta Hort. 681, 95–98.

Czarnecki M., Dedio I., Krysiuk W., 1992. The effect of sage (*Salvia officinalis* L.) culture on yields and essential oil content. Herba Pol. 38(1), 29–36.

Eich J., Baier C., Grün M., Wagenbreth D., Zimmermann R., 2005. Artichoke leaves used for herbal drug production: influence of nitrogen fertilization on yield on pharmaceutical quality. Acta Hort. 681, 545–551.

Elia A., Paolicelli F., Bianco V., 1991. Effect of sowing date, plant density and nitrogen fertilizer on artichoke (*Cynara scolymus* L.): preliminary results. Adv. Hort. Sci. 5, 119–122.

EMA, 2011. Assessment report on *Cynara scolymus* L., folium. Draft. EMA/HMPC/150209/2009 Committee on Herbal Medicinal Products (HMPC). [Online]. Available at: http://www.ema.europa.eu/ema. Accessed on 20 August 2011.

Götman S., Honermeier B., 2003. Einfluss von bestandesdichte und standraumverteilung der pflanzen auf ertrag und qualität der blattdrogen bei der artischocke (*Cynara scolymus* L.). Mitt. Ges. Pflanzenbauwisse. 15, 211–214.

Haning H., Eich J., 2001. Artischoken – anbau für pharmazeutische zwecke – eine neue anbautechnologie. Z. Arzn. Gew. Pfl. 6, 190–194.

Häusler M., Ganzera M., Abel G., Popp M., Stuppner H. 2002. Determination of caffeoylquinic acids and flavonoids in *Cynara scolymus* L. by high performance liquid chromatography. Chromat. 56, 407–411.

Honermeier B., Göttman S., Bender L., Matthes C., 2001. Die artischocke als arzneimittel. Pflanzenbau und pflanzenzüchtung für eine pharmazeutische nutzung. Spiegel der Forschung 18(2), 42–48.

Jani S., Hoxha S., Papakroni H., 2005. Planting density and management of seed, seedling and offshoot propagated artichoke. Acta Hort. 681, 201– 204.

Kawala Z., Żaba T., 2001. Optimisation of growing, drying and extraction conditions of artichoke leaves. Ann. UMCS, sect. EEE, 9, 65–70.

Kołodziej B., Najda A., 2007. Plantation establishment methods in cultivation of chosen medicinal plants. Herba Pol. 53(3), 268–272.

Kołodziej B., Winiarska S., 2010. The effect of irrigation and fertigation in artichoke (*Cynara cardunculus L ssp. flavescens Wikl.*) culture. Herba Pol., 3, 7–14.

Krawczyk A., 2001. Standarization of raw material and extract of artichoke (*Cynara scolymus* L.). Herba Pol. 47(2), 130–136.

Matthes Ch., Honermeier B., 2003a. Einfluss von bestandesdichte und standraumverteilung der pflanzen auf ertrag and qualität der blattdrogen bei der artischoke (*Cynara scolymus* L.). Mitt. Ges. Pflanzenbauwiss. 15, 211–214.

Matthes Ch., Honermeier B., 2003b. Untersuchungen zum einfluss des erntetermins auf ertrag und qualität der blattdrogen bei der artischoke (*Cynara cardunculus* L. subsp. *flavescens* Wikl.). Mitt. Ges. Pflanzenbauwiss. 15, 336–337.

Matthes Ch., Honermeier B., 2004. Bildung pharmazeutisch relevanter wirkstoffe in der blattdroge der artischoke (*Cynara cardunculus* L. subsp. *flavescens* Wikl.). Mitt. Ges. Pflanzenbauwiss. 16, 237–238.

Matthes Ch., Honermeier B., 2005. Wirkung differenzierter N-Düngung auf inhaltsstoffgehalt und morphologie der artischoke (*Cynara cardunculus* L. subsp. *flavescens* Wikl.) in einem gefäßversuch. Mitt. Ges. Pflanzenbauwiss. 17, 156–157.

Pandino G., Lombardo S., Mauromicale G., Williamson G., 2011. Phenolic acids and flavonoids in leaf and floral stem of cultivated and wild *Cynara cardunculus* L. genotypes. Food Chem. 126, 417–422.

Ryder E., de Vos N., Bari M., 1983. The globe artichoke (*Cynara scolymus* L.) HortSci. 18(5), 646– 653.

Sałata A., 2006. Influence of harvest date on content of phenolic acids and tanninis in herb of artichoke (*Cynara scolymus* L.). Folia Hort. 2, 113–117.

Sałata A., 2010: The influence of agrotechnical treatments on yield and biological value of artichoke (*Cynara scolymus* L.). Rozpr. Nauk. UP Lublin, 343.

Schütz K., Kammerer D., Carle R., Schieber A., 2004. Identification and quantification of caffeoylquinic acids and flavonoids from artichoke (*Cynara scolymus* L.) heads, juice, and pomace by HPLC-DAD-ESI/MS. J. Agric. Food Chem. 52, 4090–4096.

Wagenbreth D., Eich J., 2005. Pharmaceutically relevant phenolic constituents in artichoke leaves are useful for chemical classification of accessions. Acta Hort. 681, 469–474.

Wagenbreth D., Grün M., Wagenbreth A., Wegener T., 1996. Artischoke. qualitätsdroge aus arzneipflanzenbau. Dtsch. Apoth. Ztg. 136(43), 112–121.

Wang M., Simon J., Aviles I., He K., Zheng Q., Tadmor Y., 2003. Analysis of antioxidative phenolic compounds in artichoke (*Cynara scolymus* L.). J Agric Food Chem 51, 601–608.

Wittemer S., Ploch M., Windeck T., Müller S., Drewelow B., Derendorf H., Veit M., 2005. Bioavialability and pharmacokinetics of caffeoylquinic acids and flavonoids after oral administration of Artichoke leaf extracts in humans. Phytomed. 12, 28–38.

Ziombra M., Frąszczak B., Łaszkowska M., 2000. Effect of cultivation method and date of harvest on the field of basil herb. Annales UMCS, sec. EEE, Horticultura 8, 453–458.

WPŁYW RÓŻNYCH METOD UPRAWY NA PLON I JAKOŚĆ SUROWCA KARCZOCHA ZWYCZAJNEGO (*Cynara scolymus* L.)

Streszczenie. Karczoch jest cenną rośliną warzywną (jadalne pąki). Uprawiany jest głównie w krajach przylegających do Morza Śródziemnego, w USA i Południowej Ameryce. Karczoch jest od dawna znaną rośliną zielarską o udokumentowanym działaniu ochronnym na wątrobę, żółciopędnym, antyoksydacyjnym, antykancerogennym, obniżającym poziom cholesterolu i moczopędnym. W uprawie na potrzeby farmaceutyczne, karczoch powinien być pozyskiwany z jednorocznych plantacji, charakteryzujących się wysoką zawartością substancji aktywnych (kwasów kawoilochinowych i flawonoidów). Celem trzyletniego doświadczenia polowego było określenie wpływu różnych metod zakładania plantacji: punktowego siewu nasion, wysadzania rozsady z palet wielokomórkowych lub wysadzania rozsady 'rwanej' wyprodukowanej w tunelu foliowym, a także zagęszczenia roślin: 3,3 i 4,2 rośliny·m^{-2} w uprawie karczoch zwyczajnego (*Cynara scolymus* L.) odmiany Green Globe. Dodatkowo, dokonano oceny surowca zielarskiego zebranego z dwóch terminów zbioru (przeprowadzonych w sierpniu i październiku). Ogólnie, zastosowanie tradycyjnej metody zakładania plantacji z bezpośredniego wysiewu nasion spowodowało otrzymanie niższych plonów gorszej jakości surowca (charakteryzującego się istotnie niższą zawartością substancji aktywnych), podczas gdy wysadzanie rozsady wyprodukowanej w wielodoniczkach w tunelu foliowym może być uznane za lepszą metodę zakładania plantacji karczocha uprawianego na potrzeby farmaceutyczne. W przypadku zastosowania rozsady 'rwanej', wyprodukowanej w tunelu foliowym obserwowano obniżkę plonów karczocha i jednocześnie tendencję do istotnego polepszenia jakości otrzymanego surowca (przeciętnie dwukrotnie większa zawartość flawonoidów i kwasów kawoilochinowych w porównaniu z siewem bezpośrednim). Zwiększenie zagęszczenia roślin z 3,3 do 4,3 sztuk·m^{-2} powodowało zmniejszenie wielkości i masy (o 13,4%) liści z pojedynczych roślin, ale jednocześnie zwiększenie ich liczby i plonów (o 0,2 t·ha^{-1}). Ponadto, surowiec otrzymany z drugiego terminu zbioru charakteryzował się wyższymi (o 27%) plonami i większą zawartością substancji aktywnych (flawonoidów i kwasów kawoilochinowych).

Słowa kluczowe: zagęszczenie roślin, siew nasion, wysadzanie rozsady, plon liści, kwasy kawoilochinowe, flawonoidy

Accepted for print – Zaakceptowano do druku: 22.11.2011