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Effects of Irrigation and Various Plantation Modalities on Production and Concentrations of Caffeoylquinic Acids and Flavonoids of Globe Artichoke Leaves (*Cynara scolymus* L.)

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Summary

Artichoke is a source of caffeolquinic acids and flavonoids for pharmaceutical industry as their concentrations in the leaves tend to be very high. A three-year field experiment was conducted in Poland to estimate the effects of irrigation and various plantation modalities on the concentrations and productions of these substances. In the experiment four methods of plantation establishment (single-grain direct seeds sowing, seeds sowing with covering with nonwoven polypropylene film, seedlings produced in a plastic tunnel transplantation, seedlings produced in multicell trays in a plastic tunnel transplantation) as well as drip irrigation on the background of unwatered plots were used. Generally, supplemental irrigation was connected with better developed plants, that produced greater number of longer leaves and as a result higher above ground parts weight, whereas during the second cut (performed in October) significantly higher yields of better quality artichoke leaves were obtained. Both, with and without irrigation, yield was lower in the case of transplantation of seedlings with bare roots and at a less degree in the case of direct sowing without covering. The concentration of CQA and flavonoids were higher without irrigation and much lower in direct sowing than in transplantation. Thus, studies showed that direct sowing (even though with crops covering) resulting in lower yields of worse quality of artichoke raw material. Seedlings produced previously in plastic tunnel transplantation could be indicated as better method of artichoke plantation establishment for pharmaceutical purposes.

Key words. *Cynara scolymus* L. – drip irrigation – seeds sowing – seedlings transplanting – leaf yield – caffeoylquinic acids content – flavonoids content

Introduction

Artichoke (*Cynara cardunculus* L. *ssp. flavescens* Wikl. = *Cynara scolymus* L.) from *Asteraceae* family, commonly found in southern Europe (Mediterranean region), is cultivated as a vegetable (buds) or medicinal plant (leaves) (Ryder et al. 1983; Brandt 1997). The edible part of the plant is the immature inflorescence, which is harvested when it is still in rapid growth (Bianco 2005). For pharmaceutical purposes dried artichoke leaves (*Cynarae folium*) are used. Artichoke leaf contains up to 2 % phenolic acids, mainly 3-caffeoylquinic acid (chlorogenic acid), 1.3-di-O-caffeoylquinic acid (cynarin), and caffeic acid; 0.1–0.5 % flavonoids; 0.4 % bitter sesquiterpene lactones – cynaropicrin; phytosterols (taraxasterol); sugars; inulin; enzymes, and a volatile oil consisting mainly of the sesquiterpenes β-selinene and caryophyllene (Ema 2011). A high content of caffeoylquinic acids (a minimum 0.8 % of chlorogenic acid) and flavonoids (min. 0.2 %), an exclusively vegetative growth in the first year of cultivation and homogeneity of the drug material are the most important demands on artichoke for pharmacy (Wagenbreth et al. 1996). Various studies have shown that globe artichoke extracts significantly increase choleresis and reduce blood cholesterol. It has been reported also hepatoprotective, antioxidative, anticarcinogenic, antibacterial, anti-HIV and diuretic action. Extracts have also beneficial effects on gastro-intestinal activity, irritable bowel syndrome, blood-clotting time, capillary resistance, heart activity, as well as a neutralizing effect on certain toxic substances (Ryder et al. 1983; Brandt 1997; Wang et al. 2003; Eich et al. 2005; Ema 2011). Although the mechanisms of the raw material action and its active substances are not fully known, caffeoylquinic acids and flavonoids seem to play important roles in its pharmacological properties (Brandt 1997; Häusler et al. 2002; Wagenbreth and Eich 2005). In recent years, an increasing demand for functional foods with added value has led to a renewed interest in

this crop. When artichoke raw material for pharmaceutical production comes from vegetable crops, being an alternative source of income for the producer (mainly in Mediterranean basin), a drug of low quality parameters is obtained (Brand 1997; Hannig and Eich 2001). Studies carried out so far, clearly indicate that one-year cultivation of this plant and the acquisition of raw leaf contributes to a significant improvement in the quality of raw material (Hannig and Eich 2001; Honermeier et al. 2001; Göttman and Honermeier 2003). This is why nowadays, raw material available on the market comes first of all from vegetative *Cynara cardunculus* ssp. *flavescens* plantations (mainly from Germany and Poland) (Hannig and Eich 2001; Wagenbreth and Eich 2005). Therefore, it is very important to determine optimal agricultural conditions (a.a. plantation establishment methods) for this species.

One of important problem in artichoke culture is its reaction for supplemental irrigation during vegetation period. Based on studies conducted in Europe and the USA (Boari et al. 2000; Mansour et al. 2005; Shinohara 2008), artichoke appears to be a high water requirement crop compared to other vegetable crops, in part due to its large foliage biomass and longer production cycle, which can be up to 6–7 months when grown as an annual production cycle. As Shinohara et al. (2011) reported irrigation was more effective than N management to optimize artichoke yields, however as in other crops was connected with phenolics content decrease (Pandjaitan et al. 2005). The most efficient system of watering is drip irrigation, resulting in significant herb yields increase (Koszański et al. 2006).

The aim of three-year field experiment conducted in Poland was to assess the effects of the cultural techniques used for the artichoke crop on CQA and flavonoids of the artichoke leaves. In this study the effects of supplemental irrigation (on the background of unwatered plots) as well as different plantation establishment methods (possible to use in temperate climate in annual culture) on *Cynarae folium* yields and quality were determined.

Materials and Methods

An experiment lasting three years was conducted on experimental fields at the University of Life Sciences in Lublin, 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 different methods of plantation establishment: A) single-grain direct seeds sowing, B) direct seeds sowing followed by covering the seeds with nonwoven polypropylene film (black agrotextile) for 6 weeks, C) seedlings produced in a plastic tunnel (with „bare root“) transplantation, D) seedlings produced in multicell trays in a plastic tunnel transplantation. Every year, seeds of 'Green Globe' variety were sown in a plastic tunnel (in rows 15 cm in the case of C 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 – method D) and after 7 weeks seedlings (10 cm high with 3–4 true leaves) were transplanted. Both, seeds and transplants were set at 60×40 cm distance. In the case of B method, just after the sowing, plots were covered with nonwoven polypropylene film for 6 weeks.

In the experiment there were also compared effects of supplemental drip irrigation with T-Tape 508-20-250 (emitters were located on tapes lying along the rows, spaced every 20 cm, designed for 4.2 l of water per hour per 1 m^2) on the background of unwatered plots. Time of irrigation treatments were determined on the base of indications of soil moisture sensors ThetaProbe type ML2x (Delta-T Devices Ltd., U.K.), placed in each block (every four plots) on the 20 cm depth, in interrows, 30 cm from plants, connected with HH2 moisture meter measured volumetric soil moisture content. Device senses moisture content by responding to the dielectric properties of the soil and according to Hanson and Peters (2000) was the most accurate of six instruments over a wide range of soils. After calibration, irrigation treatments was begun when soil moisture content dropped under the 60 % of maximum water holding capacity (pF 2.7) – dates of irrigation marked in Table 1. Single water doses were 10 mm, whereas summary doses were as follows: in the first year – 130 mm, in the second – 90 mm, and in the third one – 150 mm (Table 1). Average air temperature during three vegetation periods under study and precipitation was diverse, which resulted in necessity for supplemental watering (especially in the first and third year of vegetation) – Table 1. In the first and the second growing season mean air temperature was almost at the same level as in long-term observations, whereas in the third vegetation period was 1.7 °C higher. In the last year there was reported the least favorable weather conditions for the artichoke plants (rainless decades with very high air temperatures alternating with those with precipitation values exceeding several times the long-term observations). During vegetation, mechanical cultivation of inter rows as well as hand-weeding and irrigation system maintain were ensured.

Artichoke leaf was harvested two times per year (I – in the second decade of August, II – in the second decade of October). At the harvesting, the measurements determined number and length as well as fresh and air dry matter of 10 plants randomly chosen from plots and yields of fresh and air dry weight (dried at 40 °C in a drying chamber) per plot were performed. Chemical analyses (by HPLC method modified by Krawczyk (2001) and Schütz et al. (2004), on sum of polyphenolic compounds expressed as caffeoylquinic acids and flavonoids obtained as a mean of the four replicates were performed.

Table 1. Total irrigation doses and ▼ – single water dose (10 mm) application dates against a background of average total precipitation (1951–2006) and total precipitation in the individual decades of the following months of growing seasons according to Agrometeorological Observatory of University of Life Sciences in Lublin (mean from 2004–2006).

Year	Decade	Months						Total precipitation (mm)	Total irrigation dose (mm)
		V	VI	VII	VIII	IX	X		
Average total precipitation		58.3	65.8	78.0	69.7	52.1	40.3	364.2	–
2004	I decade	10.1	3.7 +▼▼	4.7 +▼	14.7 +▼	1.2 +▼	7.4 +▼		
	II decade	11.3 +▼	25.9	27.5	9.1 +▼	0.4 +▼	11.3		
	III decade	16.6 +▼	20.3 +▼	58.3	24.7 +▼	12.6 +▼	0.4		
	Sum	38.0	49.9	90.5	48.5	14.2	19.1	260.2	130
2005	I decade	32.8	47.1	0.0	103.9	0.0 +▼	0.4 +▼		
	II decade	65.0	7.4 +▼	22.4 +▼	3.2 +▼	8.9 +▼	2.7 +▼		
	III decade	0.2 +▼	1.4 +▼	87.4	1.6	9.1	5.5		
	Sum	98.0	55.9	109.8	108.7	18.0	8.6	399.0	90
2006	I decade	9.0	28.4 +▼	0.0 +▼	73.0	11.0	4.4 +▼		
	II decade	18.4 +▼	0 +▼	6.8 +▼▼	79.7	0 +▼▼	0.9 +▼		
	III decade	32.1 +▼	9.5 +▼	0 +▼	45.6	0 +▼▼	8.9		
	Sum	59.5	37.9	6.8	198.3	11.0	14.2	327.7	150

HPLC analysis

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 acetonitryle (solvent B) in the following gradient system: initial 6 % B, 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 was 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. Acetonitryle, methanol and phosphoric acid were all of analytical or HPLC grade (from Merck Eurolab; Vienna, Austria).

Statisctics

The experimental was a randomized complete block design with four replications (as blocks) of 50 plants each and a total plot area of 12 m^2 (3 × 4 m). 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

The experimental factors tested significantly affected morphological features, yields and accumulation of flavonoids and caffeoylquinic acid in one year-old artichoke plants.

Every year the highest total (from two cuts) weight of above ground parts of single *Cynara scolymus* plant, characterised by greater number of the best developed leaves were obtained in treatment with additional irrigation treatment from seedlings produced previously in multicells, whereas the lowest one on plots without supplemental watering with seedlings produced in plastic tunnel transplanting (Table 2). Dimensions, number and weight of rosette leaves obtained in the experiment were similar to those obtained in earlier studies by Göttman and Honermeier (2003) or Matthes and Honermeier (2004).

Independently from the experimental factors studied, during the second cut plants were better developed, creating more, longer (by 3 cm) leaves and as a result 23 % higher biomass than harvested two months earlier (Table 2). Like in Eich et al. (2005) and Göttman and Honermeier (2003) studies we stated that yields of leaf drug from the first harvest varied between 1.49 and 2.91 t ha^{-1} and 2.16 and 3.47 t ha^{-1} from the second cut.

Both, on control and irrigated plots, the lowest yields of single plant and obtained from the area unit were harvested in the case of seedlings produced in a plastic tunnel (with „bare roots“) transplantation. The negative reaction of artichoke has been reported on the root system damage during seedlings transplanting. Artichoke plants badly tolerate this treatment, responding to the loss of leaves and prolongation of re-rooting (as a result 10–20 % of the plants died, requiring second transplanting on the field). Later on, it was expressed by the fact that plants produced in the following cuts respectively: ten and fourteen the shortest and narrowed leaves, that were characterized by the highest share inflorescences (8 %) in artichoke raw material (Table 2). At the same time, however, they accumulated the highest amount of caffeoylquinic acids (from 1.52 % in the first cut to 4.69 % in the second one) and flavonoids (from 0.72 to 1.1 % respectively) in harvested raw material. Following, theoretical yields of CQA and flavonoids of the described plots was the highest (on an average of 137.9 kg ha^{-1} CQA as well as 39.1 kg ha^{-1} flavonoids). The traditional method of plantation establishment (seeds sowing) without irrigation was connected with on an average 17.5 % air dry matter of single plant increment in comparison to seedlings produced in a plastic tunnel transplantation and 28.6 %, when plots were covered with nonwoven polypropylene film for 6 weeks after sowing. Plants obtained from that two plots created respectively 5 or 8 better

Table 2. The effect of experimental factors on the yields of dry matter mass as well as average number and length of artichoke leaves (mean from 2004–2006).

Irrigation	Method of plantation establishment	Dry matter mass (t ha^{-1}) in following cuts and total yield from two cuts expressed in %			Number of leaves (units per plant)		Average length of leaves (cm)	
		I harvest	II harvest	total yield	I harvest	II harvest	I harvest	II harvest
0[a]	A[b]	1.86 ± 0.1	2.16 ± 0.2	100.0	11.6 ± 0.6	15.0 ± 1.6	43.6 ± 2.8	44.8 ± 3.7
	B	2.05 ± 0.1	2.59 ± 0.4	115.7	14.0 ± 0.7	16.0 ± 0.7	51.3 ± 0.8	52.1 ± 3.6
	C	1.49 ± 0.4	2.29 ± 0.3	94.3	8.9 ± 1.0	12.8 ± 2.1	29.5 ± 5.6	33.5 ± 8.4
	D	2.20 ± 0.1	2.65 ± 0.2	120.7	14.2 ± 0.9	14.6 ± 0.5	51.3 ± 2.9	55.5 ± 2.2
I[a]	A	2.50 ± 0.1	2.99 ± 0.2	136.9	13.0 ± 0.7	15.8 ± 0.6	45.5 ± 1.9	49.4 ± 2.2
	B	2.77 ± 0.2	3.47 ± 0.2	155.6	16.0 ± 0.6	18.1 ± 0.4	54.2 ± 1.3	56.5 ± 1.6
	C	2.43 ± 0.1	2.81 ± 0.1	130.7	11.3 ± 0.4	15.4 ± 0.5	34.6 ± 1.7	41.0 ± 0.9
	D	2.91 ± 0.1	3.40 ± 0.3	157.4	15.0 ± 0.3	17.3 ± 0.5	55.9 ± 0.7	57.1 ± 2.1
Source of variation								
Irrigation (I)		***	***	***	**	*	*	***
Method of plantation establishment (M)		**	**	**	**	*	**	***
Years (Y)		NS	*	NS	NS	*	NS	***
Blocks effect (R)		*	NS	*	*	NS	NS	NS
Interaction (I × M)		***	**	***	**	NS	**	NS

[a] 0 – without irrigation; I – with drip irrigation; [b] A – direct seeds sowing; B – direct seeds sowing with covering; C – seedlings produced in plastic tunnel transplantation; D – seedlings from multicells trays transplantation; [z] Data are means ± SE from three following years; NS, ***, **, * – non-significant or significant at $P \leq 0.01$, 0.05 or 0.1

developed leaves more and as a result yields of air dry matter of leaves were higher by 0.23 and 0.86 t ha^{-1} respectively compared to plots with seedlings with „bare roots" transplantation. The same trends were observed on irrigated plots. Similar results in the case of sage were obtained by Czarnecki et al. (1992). When cultivation technology with nonwoven polypropylene film left for 6 weeks after sowing was used, there was observed earlier (about 12 days compared to A treatment), equalized sprouting and better growth intensity and yielding compared to single-grain seeds sowing without covering. In the available literature on artichoke culture for pharmaceutical purposes, there are no studies on the use of agrotextile. However, experiments indicate that it is used in the cultivation of other plant species, with beneficial influence on their growth and development as well as quality characteristics (Halter et al. 2005). But at the same time, the raw material from seeds sowing plots was characterized by the lowest content of CQA and flavonoids (especially when crops were covered for 6 weeks after sowing). Artichoke cultivated in a traditional way, that is by means of direct seeds sowing without additional irrigation was characterized by low growth intensity, small number poor-developed leaves compared to B method (that could be explained partially by higher temperatures in the first period of artichoke growth and development under agrotextile film). Consequently, in this treatment significantly low yields of leaves as well as active substance content and theoretical yields were observed.

Seedlings transplantation was connected with the increase of yields and plant dimensions (seedlings with „bare roots" was an exception) and tendency to significant improvement its quality. The opposite results in vegetable artichoke production in Albania obtained Jani et al. (2005), who recorded higher yields of heads characterising 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 cultivation. The highest yields of raw material were observed when artichoke plantation was started from seedlings produced in multicell trays (on an average 4.84 and 6.31 t ha^{-1} air dry matter). It could be partially explained by different age of plants at the date of harvest (plants from seedlings transplanting were about 7 weeks older than that from sowing). Use of the seedlings produced in multicells give positive results in field cultivation of many species of vegetables (which were formerly cultivated by so-called „bare root" seedlings e.g. cabbage, cauliflower, broccoli, leek, etc.), resulting in increased yields, and improve their quality (Bodnar and Garton 1996). In the literature on the artichoke cultivation in order to gain immature buds (especially in countries with cooler climates) that 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 at the beginning of May was connected with an improvement of quality parameters and average weight of single plant, however, active substances content noted was slightly lower than in treatment C (seedlings with „bare roots") – Table 2–3, which was in agreement with Jani et al. (2005) results.

The artichoke is a demanding crop, particularly in water. Compared to control we recorded improvements of yield as well as single plant dimensions for localised water supply. Independently from four tested methods of plantation establishment, additional water application positively affected artichoke development and yielding (causing on an average 34 % yields increment). Generally, plants from irrigated plots created two to five better developed leaves more than on control plots and produced smaller number of inflorescences (2.9 versus 4.8 % on control plots). However, water factor adversely affected analyzed active substances content and their theoretical yields were significantly lower than on control plots.

Our examination of active ingredients (CQA and flavonoids) resulted in a wide variation in content depending on the method of plantation establishment, irrigation treatment as well as their interaction (Table 3). In the second cut, similarly as in Kawala and Żaba (2001) studies concentration of phenolic acids and flavonoids in raw material from the second swath was higher (respectively by 1.05 and 0.12 %) than in the first cut. This could be explain by the fact, that just before the first cut there was observed the emergence of inflorescences, which probably caused the loss of active substances content in raw material (as in Göttman and Honermeier 2003 studies). On the other side, Wang et al. (2003), Shinohara et al. (2011) as well as Pandjaitan et al. (2005) stated that phenolic content increase with plant maturity. What is more, as Ibrahim et al. (2011) observed, probably more carbon was available for these substances in the second cut relatively to the structural carbon used for plant building before the first cut. As Pandino et al. (2011) proved, leaf and floral stem of artichoke, usually treated as a waste material in vegetable production, possessed antioxidant property and contained a wide range of phenolic compounds. However caffeolyquinic acids and flavonoids content in such a raw material was much smaller than obtained from one-year culture (Wagenbreth et al. 1996; Brandt 1997; Hanning and Eich 2001). In our experiment the highest content of caffeoylquinic acids was observed in plots with seedlings produced in a plastic tunnel transplantation (especially from the second cut) – from 1.52 to 4.69 %, when the lowest one – in plots with crops from direct seeds sowing covering (from 0.43 to 0.92 %). Similar relationship was observed in the case of flavonoids accumulation (Table 3), and flavonoids content was positively correlated with CQA ($r = 0.788$). Probably, as Ibrahim et al. (2011) observed, more carbon was available for these substances in the transplanted plants relatively to the sowed plants, which could be explained by their age (plants from transplanted plots were older by 7 weeks) or differences in temperature and water balance. As in Shinohara (2008) and

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

Irrigation	Method of plantation establishment	CQA content (%)		Flavonoids content (%)		Theoretical yields of CQA (kg ha^{-1})	Theoretical yields of flavonoids (kg ha^{-1})
		I harvest	II harvest	I harvest	II harvest	I + II harvest	I + II harvest
0[a]	A[b]	0.97 ± 0.3[z]	1.50 ± 0.3	0.42 ± 0.1	0.51 ± 0.1	50.3	18.4
	B	0.57 ± 0.1	0.92 ± 0.3	0.39 ± 0.1	0.53 ± 0.2	35.7	21.5
	C	2.41 ± 0.3	4.69 ± 0.6	0.80 ± 0.2	1.10 ± 0.3	142.2	36.5
	D	1.28 ± 0.3	3.45 ± 0.5	0.79 ± 0.2	0.87 ± 0.3	119.7	40.2
I[a]	A[b]	0.93 ± 0.2	0.84 ± 0.2	0.40 ± 0.1	0.52 ± 0.1	48.6	25.8
	B	0.43 ± 0.1	0.43 ± 0.1	0.38 ± 0.1	0.24 ± 0.1	27.1	19.5
	C	1.52 ± 0.4	3.44 ± 0.6	0.72 ± 0.2	0.86 ± 0.3	133.7	41.7
	D	1.12 ± 0.5	2.37 ± 0.4	0.74 ± 0.2	1.00 ± 0.3	114.9	56.1
Source of variation							
Irrigation (I)		***	***	***	***	***	***
Method of plantation establishment (M)		**	**	**	**	**	**
Years (Y)		*	*	NS	*	NS	NS
Blocks effect (R)		NS	*	*	NS	*	*
Interaction (I × M)		**	**	**	**	**	**

[a] 0 – without irrigation; I – with drip irrigation; [b] A – direct seeds sowing; B – direct seeds sowing with covering; C – seedlings produced in plastic tunnel transplantation; D – seedlings from multicells trays transplantation; [z] Data are means ± SE from three following years; ***, **, * – non-significant or significant at P ≤ 0.01, 0.05 or 0.1

Shinohara et al. (2011) experiments, we observed that it is possible to enhance phenolic contents in raw material by deficit water, but at the cost of significant yield losses. In such conditions the structural carbon is in excess and, as Ibrahim et al. (2011) reported, secondary metabolites production increase. This effect could be easily observed in Fig. 1a, showing relation between dry mass of single plant and CQA content on unwatered plots. On irrigated plots such strong relation was not observed (Fig. 1b). Active principles content in artichoke leaf was comparable with obtained in special culture for pharmaceutical purposes by Wagenbreth et al. (1996), Wagenbreth and Eich (2000), Krawczyk (2001), Häusler et al. (2002); Wang et al. (2003) and Eich et al. (2005) but higher than in Sałata (2010) and Kawala and Żaba (2001) experiments.

There is worth to emphasize that our studies showed that traditional way of plantation establishment by direct seeds sowing (even though with crops covering) does not

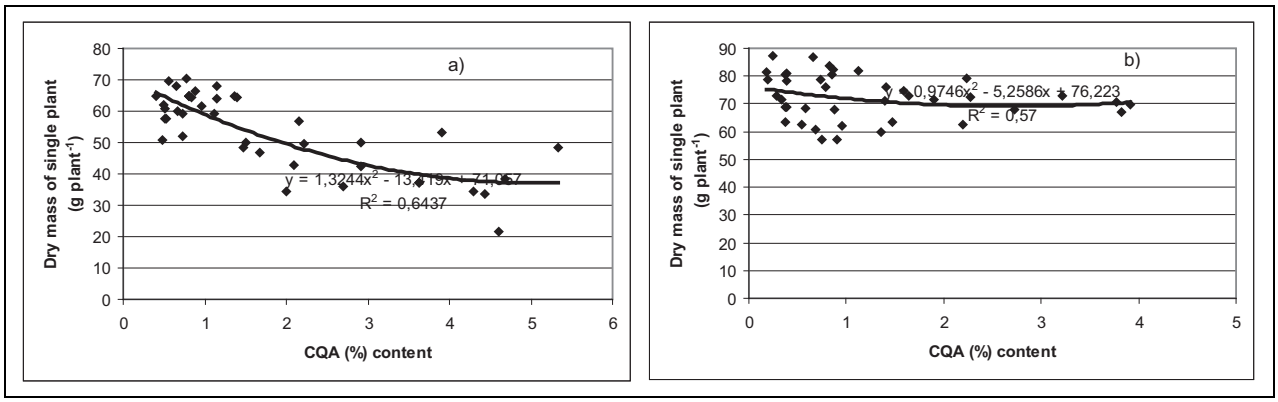


Fig. 1. Relation between the dry mass of single plant and CQA content in the artichoke raw material from a) nonwatered plots and b) irrigated plots

create favorite conditions for plants growth in temperate climate, resulting in lower yields of worse quality of artichoke raw material. Seedlings transplantation (as seeds saving, vegetation period extending, but more labor-requiring method) could be indicated as better method of artichoke plantation establishment for pharmacy. Thus, it seems that all the factors negatively affecting growth and development of artichoke as the damage the root system during transplantation or unfavorable thermal and water conditions caused an increase of active substances concentration in the raw material. This may indicate a significant role (particularly polyphenols) in the reactions of plants to increase resistance to stress, which is in agreement with SHINOHARA (2008) and SHINOHARA et al. (2011) findings. Thus, if the pharmaceutical industry would be interested in the highest quality artichoke raw material, in temperate climates artichoke should be produced under conditions of water deficit. What is more, to establishing annual plantations seedlings transplanting could be recommended.

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