The effect of irrigation and fertigation in artichoke (*Cynara cardunculus* L. *ssp. flavescens* Wikl.*)* culture

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Summary

Artichoke for pharmaceutical purposes should be characterized by high yield and content of active substances (CQA, flawonoids), an exclusively vegetative growth in the first year of cultivation and homogeneity of raw material. Drugs available on the market comes mainly from vegetative artichoke plantations.

The objective of this study was to evaluate the effects of additional drip irritation with spreading fertilization and fertilizing drip irrigation (fertigation) applied to artichoke. The experiment was conducted on silt-loam in 2004-2006 on experimental fields at the University of Life Sciences in Lublin. In the experiment effects of supplemental drip irrigation with T-Tape and additional fertigation with 0.2% solution of Universol Green on the background of unwatered object were compared. Terms of irrigation and the soil moisture were tested with ThetaProbe device according to the dielectric properties of soil. Seeds of 'Green Globe' variety were sown in May and leaves were harvested two times a year (1^{st} – in the second decade of August, 2^{nd} – in the second decade of October). Chemical analyses comprised sum of polyphenolic compounds (caffeoylquinic acids) and flavonoids content by HPLC and FC method.

Higher yields of artichoke were obtained with use of fertigation mode, with an increase higher than 20% and 50% as compared to drip irrigation and control plots. Generally, supplemental irrigation or fertigation was connected with better developed plants that produced greater number of longer and wider leaves and, as a result, higher raw material weight in both terms of harvest. Artichoke raw material obtained from plots with additional water or water with nutrients supply was characterized by smaller caffeoylquinic acids content in two following harvest dates studied, whereas flavonoids content remained higher than control. At the same time recalculated flavonoids and CQA yields were the highest after both irrigation and fertigation.

Key words: *artichoke, Cynara cardunculus L. ssp. flavescens Wikl., irrigation, fertigation, leaves yield, CQA content, flavonoids content*

INTRODUCTION

Artichoke is widely known as a vegetable (buds), containing moderate amounts of vitamins, minerals and carbohydrates, low protein and fat, very popular in the Mediterranean region, North and South America [1]. For pharmaceutical purposes artichoke should be characterized by high content of active substances (CQA, flavonoids), an exclusively vegetative growth in the first year of cultivation and homogeneity of raw material [2]. It was proven that standardized extracts on the basis of artichoke leaves have choleretic, hepatoprotective, cholesterol-reducing and diuretic properties. Extracts have also beneficial effects on gastro-intestinal activity, blood-clotting time, capillary resistance, heart activity as well as a neutralizing effect on certain toxic substances [1, 3, 4]. Nowadays, drugs available on the market are produced mainly from vegetative *Cynara cardunculus* ssp. *flavescens* plantations [5]. Therefore, it is very important to determine optimal agricultural conditions (a.a. additional irrigation or harvest date) for this species. One of an important problems in artichoke culture is its response to supplemental irrigation during vegetation. The most efficient system of watering is drip irrigation, resulting in significant herb yields increase [6, 7]. Recently, drip irrigation combined with fertiliser feeding of fruit and vegetables that allows for a precise matching of fertilization with plants requirements has been more and more often used [8-10].

The objective of this research was to study the effects of supplemental irrigation and fertigation as well as the date of harvesting on artichoke *Cynarae folium* yields and quality.

MATERIALS AND METHODS

A three-year-lasting experiment (2004–2006) was conducted on experimental fields at the University of Life Sciences in Lublin (Chmielnik Kol., Lublin district), located on silt-loam of pH 7.7 and moderate content of macroelements (11.1mg $P \cdot kg^{-1}$ of soil, 18.3 mg $K \cdot kg^{-1}$ of soil and 7.2 mg $mg \cdot kg^{-1}$ of soil). In early spring, before plantation establishment, mineral fertilization was applied: 17.6 kg $P \cdot ha^{-1}$, 124.5 kg $K \cdot ha^{-1}$ and 100 kg $N \cdot ha^{-1}$ (in two parts before sowing and during the vegetation season). In the experiment the effects of supplemental drip irrigation with T-Tape (drippers were located on tapes lying along the rows, spaced by 20 cm, designed for 4.2 l of water per hour per 1 m^2) and additional fertigation with solution of Universol Green on the background of unwatered object were compared. The experimental was a randomized complete block design with four replications (plots of 2 m^2).

Time of irrigation and fertigation treatments were determined on the base of indications of soil moisture sensor ThetaProbe type ML2x (Delta-T Devices Ltd., U.K.) placed on the 20 cm depth 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 [11] was the most accurate of six instruments over a wide range of soils. After calibration, irrigation was begun when field water capacity of soil dropped under 60%. Single water doses were 10 mm, whereas summary doses were as follows: in the first year – 130 mm (V–20 mm, VI–30 mm, VI–10 mm, VII–30 mm, IX–30 mm, X–10 mm), in the second – 90 mm (V–10 mm, VI–20 mm, VII–10 mm, VIII–10 mm, IX–20 mm, X–20 mm), and in the third one – 150 mm (V–20 mm, VI–30 mm, VII–40 mm, IX–40 mm, X–20 mm). Through the irrigation system we applied additionally 0.2% solution of Universol Green (23–6–10–2MgO, by Scotts, UK). Every year seeds of 'Green Globe' variety (purchased from Germany) were sown 2nd of May in 40 x 60 cm distance. During vegetation a hand-weeding (in rows) and cultivation between rows were ensured. *Cynarae folium* was harvested twice a year (I – in the second decade of August, II – in the second decade of October). Before harvesting, number, length and air dry matter of leaves of 10 plants randomly chosen from plots were measured. After that yields of fresh and air dry weight (dried at 40°C in a drying chamber) of leaves per area units were performed. Chemical analyses (by HPLC method described by Krawczyk [12] and Schütz *et al*. [13]) for sum of polyphenolic compounds (caffeoylquinic acids) and flavonoids (by the Folin-Ciocalteau method [14]) were performed in the phytochemical laboratory of Phytopharm Klęka S.A. 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

Irrigation, fertigation and the date of artichoke harvesting significantly modified yields and quality parameters of one-year-old plants. Additional water or water with nutrient application positively affected artichoke development and yielding. Every year the highest total (form the first as well as from the second cut) weight of herb of single *Cynara cardunculus* ssp. *flavescens* plant characterised by greater number the longest and the widest leaves were obtained in objects with additional irrigation or fertigation treatments, whereas the lowest one on plots without supplemental watering (tab. 1, 2).

Table 1.

Artichoke single plant characteristics depending on the irrigation treatment (mean from 2004–2006)

treatment	fresh weight of single plant (g per plant)			air dry matter of single plant (g per plant)			number of leaves (units per plant)			average length of leaves [cm]		average width of leaves [cm]	
	1st harvest	2nd harvest	1st + 2nd	1st harvest	2nd harvest	1st + 2nd	1st harvest	2nd harvest	1st + 2nd	1st harvest	2nd harvest	1st harvest	2nd harvest
control	267	344	611	45.3	56.8	102.0	11.6	15.0	26.6	43.6	44.8	17.7	18.8
irrigation	362	448	809	59.3	72.9	132.2	13.0	15.8	28.8	45.5	49.5	21.3	23.9
fertigation	401	520	920	67.0	86.4	153.4	14.4	14.7	28.2	48.7	53.4	23.5	26.6
source of variation													
irrigation treatment			**			**			**				
harvest date			**			**			*				
interaction			*			*			NS				

NS, **, * – non-significant or significant at $p \leq 0.05$ or 0.1

In general, during the second cut plants were better developed, produced higher number of longer leaves and as a result higher herb yield. Share of the first cut varied from 43.7% (plots with fertigation) to 44.8% (irrigated plots) of the total air dry matter of single plant. Average fresh weight of single plant (from both cuts) from object with supplemental irrigation was 32.4% higher than on control plots, whereas fertigation caused the 50.5% increase in artichoke leaves weight (tab. 2). Plants from irrigated or fertigated plots created only two or three leaves more than on control, but they were better developed. Leaves from two following cuts were 1.9 and 4.7 or 5.1 and 8.6 cm longer, respectively, in objects irrigated and fertigated as compared with plots without additional watering. At the same time they were 3.6 and 5.1 or 5.8 and 7.8 cm wider, respectively, in objects irrigated and fertigated in comparison to control plots (tab. 2).

Table 2.

The effect of experimental factors on the yields of fresh and air dry weight of artichoke leaves (mean from 2004–2006)

treatment	yields of fresh weight of leaves [kg·m^{-2}]			yields of air dry weight of leaves [kg·m^{-2}]		
	1st harvest	2nd harvest	1st + 2nd	1st harvest	2nd harvest	1st + 2nd
control	11.2	13.8	25.0	1.86	2.16	4.01
irrigation	14.9	18.3	33.2	2.50	2.99	5.49
fertigation	16.7	21.2	37.9	2.81	3.52	6.33
source of variation						
irrigation treatment			**			**
harvest date			*			*
interaction			NS			*

NS, **, * – non-significant or significant at $p \leq 0.05$ or 0.1

Plant dimensions, number of leaves per plant as well as single plant weight were similar as in Götmann and Honermeier [15] studies.

The artichoke is a demanding crop, both in water and fertiliser. The fertigation objects supplying fertiliser in available form and uniformly spread caused an improvement of yield as well as single plant dimensions. The highest fresh and air dry yields of raw material were obtained on plots from the first cut fertigated during the vegetation period, while the lowest one on control from the second date of leaves harvesting. At two following cuts additional irrigation caused the average increase by 32.8% in raw material yields, whereas fertigation alone increased yields by 51.6%. Similarly, Mansour *et al.* [10] proved superior effect of fertigation causing 16% increase in artichoke heads yields in comparison to drip irrigation. Regardless of the water supply treatment during the first harvesting (in August) artichoke produced 17% smaller biomass than harvested two months later (tab. 2), which was similar to Götmann and Honermeier [15] experiments. Yields of leaves from the first harvest varied between 1.9 and 2.8 $t \cdot ha^{-1}$ and 2.2 and 3.5 $t \cdot ha^{-1}$ from the second cut and was comparable to obtained in Eich et al. [4] studies.

As far as active substances content is concerned, in general artichoke raw material obtained from plots with additional water or water with nutrients supply were characterized by smaller caffeoylquinic acids content in two following harvest dates studied, whereas flavonoids content remained higher than in control. Flavonoids content in artichoke drug material varied from 0.4% (irrigated object from the first cut) to 0.65% (object with fertigation, second cut) and was higher than stated by Häusler *et al*. [16]. At the same time, artichoke leaves contained from 0.71% (first cut, plots with fertigation) to 1.5% (second cut, control) of caffeoylquinic acids (CQA) and was comparable to Götmann and Honermeier [15] but smaller than in Häusler *et al*. [16], Schütz *et al*. [13] as well as Wagenbreth and Eich [5] experiments. Similarly as in Häusler *et al*. [16] study concerning a comparison of different methods of caffeoylquinic acids and flavonoids content in artichoke raw material there was no correlation observed between the two active substances examined. In general, raw material gathered during the second cut was characterised by higher content of active substances; that was in agreement with previous Götmann and Honermeier [15] concerning the effect of some agronomical factors on yields and raw material quality of artichoke as well as Sałata [17] studies estimating yields and quality of raw material depending on the age of plant.

Flavonoids and CQA content and artichoke leaves yields enable theoretical calculation of flavonoids and CQA yields. It significantly depended on the experimental factors: in the case of flavonoids the highest yields were obtained after both irrigation and fertigation treatment (on an average by 7.4 and 16.8 kg, respectively, compared to control), whereas CQA yields were the highest in the fertigated object (by 28 kg, on average, compared to control) as it was shown in table 3.

Table 3.

The 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)

treatment	flavonoids content (%)		CQA content (%)		theoretical yields of flavonoids [kg·ha^{-1}]	theoretical yields of CQA [kg·ha^{-1}]
	1st harvest	2nd harvest	1st harvest	2nd harvest	1st + 2nd	1st + 2nd
control	0.42a*	0.51a	0.97a	1.50a	18.4 a	50.3a
irrigation	0.40a	0.52a	0.93b	0.84b	25.8b	48.6b
fertigation	0.45b	0.65b	0.71c	0.80b	35.2c	78.0c

*different letters indicate significant differences between the treatments ($p \leq 0.05$)

CONCLUSIONS

Irrigation and fertigation, despite of high costs, positively affected yields of artichoke plants. Supplemental irrigation and particularly fertigation was connected with better developed plants that produced greater number of longer and wider leaves and as a result higher yields of aboveground parts (by 32.8% and 51.6%, respectively, as compared to control). Regardless of the water supply treatment, during the second harvesting (in August) artichoke produced 17% higher biomass with higher caffeoylquinic acids and flavonoids content than those harvested two months earlier.

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EFEKTY NAWADNIANIA I FERTYGACJI W UPRAWIE KARCZOCHA (*CYNARA CARDUNCULUS* L. *SSP. FLAVESCENS* WIKL.)

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Streszczenie

Karczoch uprawiany z przeznaczeniem do celów farmaceutycznych powinien charakteryzować się wysokimi plonami i wysoką zawartością substancji czynnych (kwasów kawoilochinowych, flawonoidów), wytwarzać dużą ilość biomasy już w pierwszym roku wegetacji i charakteryzować się jednorodnością surowca. Surowiec do produkcji preparatów leczniczych pochodzi z plantacji jednorocznych.
Celem badań była ocena efektów dodatkowego nawadniania kroplowego z wprowadzeniem nawozów do gleby oraz nawożenia poprzez system nawadniający (fertygacji) karczocha. Doświadczenie przeprowadzono na glebie typu pył ilasty w latach 2004–2006 na polach doświadczalnych należących do Uniwersytetu Przyrodniczego w Lublinie. Porównywano w nim wpływ nawadniania kroplowego za pomocą taśm T-Tape i fertygacji 0,2% roztworem Universol Green w porównaniu z obiektem bez nawadniania. Terminy nawodnień i wilgotność gleby określano za pomocą miernika objętościowej wilgotności gleby Theta-Probe na podstawie zmian jej właściwości dielektrycznych. Nasiona karczocha odmiany

Green Globe wysiewano co roku w maju, a liście zbierano dwukrotnie (1. – w drugiej dekadzie sierpnia, 2. – w drugiej dekadzie października). W suchym surowcu oznaczono zawartość związków polifenolowych (kwasów kawoilochinowych) metodą HPLC oraz flawonoidów metodą FC.
Największe plony karczocha otrzymano przy zastosowaniu fertygacji: były one odpowiednio o ponad 20% i 50% większe w stosunku do tych zebranych z poletek nawadnianych oraz kontrolnych. Generalnie dodatkowe nawadnianie lub fertygacja plantacji wpływały na lepszy rozwój roślin, które wytwarzały większą liczbę dłuższych i szerszych liści, a w rezultacie większe plony surowca. Surowiec z obiektów dodatkowo nawadnianych lub fertygowanych charakteryzował się niższą zawartością kwasów kawoilochinowych z dwóch kolejnych zbiorów, podczas gdy zawartość flawonoidów była wyższa niż z plantacji kontrolnej. Jednocześnie teoretyczny plon CQA i flawonoidów był największy po zastosowaniu zarówno nawadniania, jak i fertygacji.

Słowa kluczowe: *karczoch, Cynara cardunculus L. ssp. flavescens Wikl., nawadnianie, fertygacja, plon liści, zawartość CQA , zawartość flawonoidów*