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EVALUATION OF THE YIELD AND BIOLOGICAL VALUE OF TARRAGON (*Artemisia dracunculus* L.) IN THE BUNCH HARVEST CULTIVATION

Grażyna Zawiślak, Renata Nurzyńska-Wierdak
University of Life Sciences in Lublin

Abstract. The biological value of fresh and dried spice material is strongly influenced by climatic and agronomic conditions as well as by genetic and ontogenetic factors. In the available scientific literature, few publications present the problems of growing herbal plants for direct consumption and discuss the biological value of fresh herbal material. Therefore, the aim of the present study was to evaluate the yield and quality of tarragon herb grown for bunching depending on plant density (20 × 20 cm and 30 × 30 cm) and harvest date (beginning of July and beginning of September). This study was conducted during the period 2010–2012 at the Experimental Station of the Department of Vegetable Crops and Medicinal Plants, University of Life Sciences in Lublin, in south-east region of Poland (51º14'N 22º34'E). In fresh plant material, the contents of L-ascorbic acid, chlorophyll, carotenoids and essential oil were determined, while the contents of essential oil, tannins and flavonoids were determined in leaf herbage. The yield of tarragon herb grown for bunching was dependent on the plant density and harvest date as well as their interaction. Plants grown at lower density and harvested during the early summer period were characterized by better yield parameters compared to the other treatments. Tarragon herb harvested at the beginning of July was characterized by higher concentrations of L-ascorbic acid, chlorophyll a, b and a + b, flavonoids and essential oil as well as a lower content of tannins than the plant material harvested at the beginning of September. The carotenoid content in tarragon herb was not dependent on the factors studied, with their significant interaction. In growing tarragon for bunching, lower plant density can be recommended, since it contributes to high herb and essential oil yields. The beginning of July proved to be a more favourable time for harvesting tarragon grown for bunching than the beginning of September due to the quantity and biological value of tarragon yield and essential oil yield.

Key words: fresh herbs, chemical composition, plant density, harvest date, essential oil yield

Corresponding author: Grażyna Zawiślak, Department of Vegetable Crops and Medicinal Plants, University of Life Sciences in Lublin, Leszczyńskiego 58, 20-068 Lublin, Poland, e-mail: grazyna.zawislak@up.lublin.pl

INTRODUCTION

Spice plants, due to the presence of various chemical constituents, improve the flavour and aroma of food products and dishes. They are a source of vitamins and mineral nutrients [Grzeszczuk and Jadczak 2008, Zawiślak and Dzida 2012] necessary for proper functioning of the organism. The essential oils synthesized by spice plants are considered to be important biologically active substances with a wide spectrum of action. Their aromatic qualities and biological activity result from their rich chemical composition and the activity of dominant compounds [Lopes-Lutz et al. 2008, Miguel 2010]. Spices are used fresh and dried and their biological quality as well as flavour and aromatic properties can vary. Some fresh spices are more valuable than dried or frozen, because they contain more vitamin C [Grzeszczuk and Jadczak 2008]. Both vegetable plants [Mysiak and Tendaj 2008] and herbal plants [Jadczak 2007, Jadczak and Grzeszczuk 2008, 2009] are recommended to be cultivated for bunching. The biological value of fresh and dried spice material is strongly influenced by climatic and agronomic conditions as well as by genetic and ontogenetic factors [Mysiak and Tendaj 2008, Sawilska and Mielczarek 2009, Mannan et al. 2011]. Climatic conditions of cultivation differentiated the contents of some macronutrients and essential oil in summer savoury herb; moreover, sowing time had an effect on essential oil biosynthesis [Jadczak 2007]. Similarly, the contents of some mineral nutrients and essential oil in tarragon herb [Jadczak and Grzeszczuk 2008, Zawiślak and Dzida 2012] as well as the antioxidant activity of raw material varied between years [Jadczak and Grzeszczuk 2008]. Nitrogen fertilization, plant density and climatic conditions also modified the quantity and quality of cumin yield [Azizi and Kahrizi 2008]. Damtew et al. [2011] obtained the maximum yields of *Artemisia annuaa* herb, essential oil and artemisinin at a high density of 27.8 plants ha^{-1} when the harvest was carried out, respectively, 5, 4 and 7 months after planting.

Mugwort (*Artemisia* L.) is one of the most important species of the family Asteraceae, widespread mainly in the northern hemisphere. Among these species, there are annual and perennial plants as well as shrubs; they are usually aromatic and bitter. Some mugworts are medicinal and spice plants, such as tarragon or absinthium. Tarragon (*Artemisia dracunculus* L.) is widely cultivated across the world, mostly in southern Europe, Russia and the United States [Obolskiy et al. 2011], for culinary and medicinal purposes. *A. dracunculus* is characterized by great morphological and phytochemical variation, which primarily results from the origin and cultivation conditions of plants [Mir et al. 2012, Eisenman et al. 2013]. *A. dracunculus* is valued for its cool, sweet, licorice aroma with a slightly bitter undertone. This species is distinguished by a delicate, herbal, anise-basil flavour. It is used as an aromatic seasoning for meats, sauces, seafood (dried or fresh herb), salads, and vinegar (fresh leaves). Tarragon herb and its constituents exhibit antimicrobial, anti-inflammatory, hepatoprotective, antihyperglycemic, antioxidative, sedative, and gastroprotective activity [Lopes-Lutz et al. 2008, Obolskiy et al. 2011, Obistioiu et al. 2014]. Moreover, tarragon leaves show a high content of artemisinin which is helpful in the treatment of malaria [Mannan et al. 2011].

In the available scientific literature, few publications present the problems of growing herbal plants for direct consumption and discuss the biological value of fresh herbal

material. Therefore, the aim of the present study was to evaluate the yield and quality of tarragon herb grown for bunching depending on plant density and harvest date.

MATERIAL AND METHODS

This study was conducted during the period 2010–2012 at the Experimental Station of the Department of Vegetable Crops and Medicinal Plants, University of Life Sciences in Lublin (51º14'N 22º34'E). Seed material of Russian tarragon (*Artemisia dracunculus* L.) was obtained from the company PNOS Ożarów Mazowiecki. Tarragon seedlings were produced in a greenhouse. Seeds, sown in germination boxes filled with a peat substrate, germinated after two weeks. Seedlings were transplanted into plug trays and then planted in the field in the middle of May at a spacing of 20 × 20 cm and 30 × 30 cm, in a randomized block design in 4 replicates. The plot area was respectively 1.6 m^2 and 2.52 m^2. Plants were grown on grey-brown podzolic soil derived from loess deposits on chalky marl. The crop stand was prepared in accordance with agricultural practice recommendations for the studied species. Mineral fertilization was applied at the following rates and in the following forms: 70 kg $N \cdot ha^{-1}$ ascalcium nitrate, 26 kg $P \cdot ha^{-1}$ as granulated triple superphosphate, 83 kg $K \cdot ha^{-1}$ as potassium sulphate. Crop management operations involved hand weeding and soil loosening. No chemical crop protection was used and no presence of diseases and pests was found, either. Climatic conditions during the study period did not differ from the average multi-annual and foster the growth and development of tarragon plants (tab. 1).

Table 1. Average air temperature and total rainfall during the study period* relative to and the long-term mean

	Month	Year			1951–2005
		2010	2011	2012	
Air temperature (ºC)	May	14.5	14.3	15.0	13.0
	June	18.0	18.6	17.3	16.2
	July	21.6	18.4	21.4	17.8
Total rainfall (mm)	May	156.7	42.2	56.3	57.7
	June	65.6	67.8	62.8	65.7
	July	101.0	189.0	52.3	83.5

*according to Agro-meteorological laboratory at University of Life Sciences in Lublin

Tarragon herb was harvested by cutting stems 5 cm above ground when plants reached a height of 30 cm (beginning of July – the first harvest time). The second harvest was carried out at the beginning of September by cutting plants at a height of 8 cm above ground. Tarragon herb was dried in a drying oven at a temperature of 35ºC and subsequently passed through 5 mm mesh sieves, in this way obtaining leaf herbage. In fresh plant material, the contents of L-ascorbic acid, chlorophyll, carotenoids and essen-

tial oil were determined, while the contents of essential oil, tannins and flavonoids were determined in leaf herbage.

L-ascorbic acid content was determined by the spectrophotometric method according to J.H. Roe with a modification of Ewelin [Korenman 1973]. 2 g portions of fresh plant material were homogenized in 2% oxalic acid, filtered into a volumetric flask and the mixture was made up to 100 ml with 2% oxalic acid. 10 ml of 2,6-dichlorophenolindophenol solution was added to 2 ml of the test solution and absorbance was measured at 520 nm, relative to the control sample (2 ml of 2% oxalic acid and 10 ml of 2,6-dichlorophenolindophenol solution, bleached with L-ascorbic acid). The turbidity of the test solution was removed by adding pure L-ascorbic acid and then the second measurement was performed.

Chlorophyll and carotenoids were extracted with 80% acetone. 1 g of fresh plant material was ground in a mortar with a small amount of 80% acetone, filtered into a volumetric flask, washing the sediment with 80% acetone several times. Next, the solution was made up to 50 ml with 80% acetone. Absorbance was measured on a spectrophotometer at a wavelength of λ = 662 nm (chlorophyll a) and λ = 645 nm (chlorophyll b) as well as λ = 470 nm for carotenoids. The chlorophyll and carotenoid contents were given according to Lichtenthaler and Wellburn [1983].

The essential oil was hydrodistilled according to Polish Pharmacopoeia VII [2006] in a glass distillation apparatus made of low expansion glass, fitted with a 1000 ml round-bottom flask. To determine the amount of essential oil, 20 g of dry tarragon herb and 400 ml of distilled water were used. The liquid in the flask was heated to boiling, adjusting the rate of distillation to obtain 2–3 ml of distillate per minute. The distillation time was three hours. Once the distillation was completed, the oil was collected in a calibrated tube and after 30 minutes the volume of the essential oil was read.

The content of tannins, expressed as pyrogallol equivalents, was determined according to Polish Pharmacopoeia VII [2006]. Tannins were determined spectrophotometrically after their extraction from dried plant material. 5 g of finely powdered plant material was weighed and placed into a 250 ml volumetric flask, 150 ml of water was added and the mixture was kept in a boiling water bath for 30 min. Then, the mixture was cooled down, transferred quantitatively to a 250 ml volumetric flask, made up with water and left for sediment to settle. Subsequently, the liquid was filtered through filter paper, rejecting the first 50 ml. To determine the total polyphenol content, 5 ml of this filtrate was made up with water, 1 ml of phosphorus-molybdate-tungsten reagent was added to 25 ml of this solution and then 10 ml of water, and the volume was made up to 25 ml with sodium carbonate solution (290 $g \cdot l^{-1}$). After 30 minutes absorbance was measured at 760 nm, using water as a reference (A_1). To determine polyphenols not bound to hide powder, 0.1 g of hide powder was added to 10.0 ml of the filtrate and the mixture was vigorously shaken for 1 hour and then filtered. 5 ml of the filtrate was made up to 25 ml with water and subsequently 1 ml of phosphorus-molybdate-tungsten reagent was added to 2 ml of the solution, and then 10 ml of water, and the volume was made up to 25 ml with sodium carbonate solution (290 $g \cdot l^{-1}$). After 30 minutes absorbance was measured at 760 nm, using water as a reference (A_2). A reference solution was prepared in the following way: immediately before the determination, 50 mg of pyrogallol was dissolved in water and the volume was made up to 100 ml with water. 5 ml of

the solution obtained was made up to 100 ml with water, 1 ml of phosphorus-molybdate-tungsten reagent was added to 2 ml of this solution, and then 10 ml of water, and the volume was made up to 25 ml with sodium carbonate solution (290 $g \cdot l^{-1}$). After 30 minutes absorbance was measured at 760 nm, using water as a reference (A_3). The tannin content (%) was expressed as pyrogallol ($C_6H_6O_3$), according to the following formula:

$$X = \frac{62.5 \cdot (A_1 - A_2) \cdot m_2}{A_3 \cdot m_1},$$

where:

A_1 – absorbance of polyphenols in the test solution;
A_2 – absorbance of polyphenols not bound to hide powder in the test solution;
A_3 – absorbance of the reference solution of pyrogallol;
m_1 – weighed amount of plant material in g;
m_2 – weighed amount of pyrogallol in g.

Flavonoids were determined spectrophotometrically after their extraction from leaf herbage [Polish Pharmacopoeia VI 2002]. The total flavonoid content was expressed as quercetin equivalents. 10 g of moderately powdered plant material was weighed and placed into a round-bottom flask, then 20 ml of acetone, 2 ml of HCl (281 $g \cdot l^{-1}$) and 1 ml of methenamine solution (5 $g \cdot l^{-1}$) were added and the mixture was kept for 30 min. in a boiling water bath under a reflux condenser. The hydrolysate was filtered through cotton wool to a 100 ml volumetric flask, the sediment was placed into the flask, together with the cotton wool, 20 ml of acetone was added and again the mixture was kept boiling for 10 min. Etching was repeated once again. The obtained extracts were filtered into the same volumetric flask, making up the volume with acetone. Next, 20 ml of the solution was measured to the separator, 20 ml of water was added and the mixture was extracted with ethyl acetate in 15 ml portions and 3 times in 10 ml portions. The combined organic layers were washed twice with 40 ml of water, filtered into a 50 ml volumetric flask and the volume was made up with ethyl acetate. Two samples were prepared for determination: 2 ml of aluminium chloride solution (20 $g \cdot l^{-1}$) was added to 10 ml of the stock solution and the volume was made up to 25 ml with a mixture (1:19) of acetic acid (1.02 $kg \cdot l^{-1}$) and methanol. To prepare a reference solution, 10 ml of the stock solution was made up to 25 ml with a mixture (1:19) of acetic acid (1.02 $kg \cdot l^{-1}$) and methanol. After 45 minutes, the absorbance of the solutions was measured at 425 nm, using the reference solution as a reference. The total flavonoid content (%) was expressed as quercetin equivalents according to the following formula:

$$X = \frac{A \cdot k}{m},$$

where:

A – absorbance of the test solution;

k – conversion factor for quercetin $k = 0.875\left(a\frac{1\%}{1\text{cm}} = 714\right)$;

m – weighed amount of plant material in g.

All chemical analyses were performed in four replicates. The essential oil yield was given according to Farahani et al. [2009]: essential oil yield = essential oil percentage × flowering shoot yield. The obtained results were statistically analysed by two-way cross-classification analysis of variance ANOVA. Intervals of confidence were determined with the Tukey's test at the level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

Tarragon herb and essential oil yield

The yield of tarragon herb grown for bunching was dependent on the following investigated factors: plant density and harvest time as well as their interaction (tab. 2). A significantly higher herb yield was obtained when tarragon was grown at lower density compared to higher density (row spacing, respectively: 30 × 30 cm and 20 × 20 cm). The sum of the fresh herb yields from plants harvested on the first and second time, grown at lower density, was 160.75 kg·100 m^{-2}, which was higher by 9.23% than the fresh herb yield of tarragon grown at a spacing of 20 × 20 cm. A similar relationship was shown for dry herb yield and leaf herbage yield. The dry herb yield from plants grown at a spacing of 30 × 30 cm was higher by 23.77%, while the leaf herbage yield by 35.75% compared to these yields obtained from tarragon grown at a spacing of 20 × 20 cm. Plant density is one of the agronomic factors that modify the quantity and quality of crop yield [Azizi and Kahrizi 2008, Nurzyńska-Wierdak and Dzida 2009, Damtew et al. 2011]. The lowest plant density in marjoram herb crops contributed to obtaining the highest fresh and dry herb yield [Nurzyńska-Wierdak and Dzida 2009]. In turn, the biological yield of cumin was highest at medium plant density per unit area [Azizi and Kahrizi 2008]. On the other hand, the dry leaf yield of *Artemisia* increased with increasing plant density [Damtew et al. 2011]. The above differences result most probably from different cultivation conditions, but they are also caused by the morphological characters of plants. Analysing the relationship between harvest time and tarragon yield, it was found that the fresh herb, dry herb and leaf herbage yields from plants harvested at the beginning of July (first harvest date) were significantly higher than the yields from the harvest at the beginning of September (second harvest time). The average fresh herb yield obtained at the first harvest time was shown to be higher 1.5 times from the yield at the beginning of September (second harvest time) (tab. 2). The study showed a significant interaction of plant density and harvest with the tarragon yield parameters studied.

The average fresh herb yield from plants grown for bunching was 76.66 kg·100 m^{-2} (tab. 2). The study of Jadczak and Grzeszczuk [2008] demonstrated that a much higher yield of fresh herb (359.6 kg·100 m^{-2}) can be obtained in the cultivation of tarragon for bunching using direct sowing. In an earlier study [Zawiślak and Dzida 2012], a higher yield of fresh tarragon herb was achieved when it was grown from seedlings, with the harvest at the beginning of April (138.7 kg·100 m^{-2}), but the herb was characterized by a high proportion of stems and was not suitable for direct consumption. The differences in the tarragon herb yields can be explained by agronomic conditions (plantation estab-

lishment method, plant density, harvest time and stage of maturity when harvested) and climatic conditions.

Analysing the dry herb yield and leaf herbage yield depending on harvest time, the yields obtained at the first harvest time (beginning of July) were shown to be higher by 67% compared to the dry herb yield and leaf herbage yield from the second harvest (beginning of September). It was found that the percentage of stems in the herb harvested at the beginning of July and at the beginning of September was at a similar level: 46.82% and 47.33%, respectively (tab. 2). Crop yields are largely determined by harvest time, which is conditioned by the stage of plant maturity: physiological or commercial maturity. The presented results show that it is better to harvest tarragon grown for bunching in early summer time rather than in early autumn. The dry leaf yield of *A. annua* increased in plants harvested after 4 and after 5 months and subsequently it decreased after 6 and 7 months from planting [Damtew et al. 2011]. These relationships are caused by the nature of morphological changes during ontogenesis.

Table 2. The yield of tarragon in the bunch harvest cultivation (2010–2012)

Plant spacing (cm)	Harvest term	Yield of			Share of herb without stems in dry herb (%)	Yield of essential oil of dry herb (kg·100 m^{-2})
		fresh herb	dry herb	herb without stems		
		kg · 100 m^{-2}				
20 × 20	first time of harvest	93.35	40.55	18.71	46.14	0.31
	second time of harvest	52.55	13.63	6.25	45.85	0.08
	mean	72.95	27.09	12.48	45.99	0.19
30 × 30	first time of harvest	93.62	54.28	25.70	47.34	0.42
	second time of harvest	67.13	16.80	8.15	48.51	0.10
	mean	80.37	35.54	16.92	47.92	0.26
Mean	first time of harvest	93.48	47.41	22.20	46.82	0.36
	second time of harvest	59.84	15.21	7.20	47.33	0.09
	mean	76.66	31.31	14.70	47.07	0.22
$LSD_{0.05}$						
plant spacing		4.391	3.397	1.714	–	0.024
harvest term		4.391	3.397	1.714	–	0.024
interaction		8.230	6.366	3.212	–	0.045

The essential oil yield was significantly dependent on plant spacing and herb harvest time (tab. 2). Plants grown at lower density (30 × 30 cm) were characterized by a higher essential oil yield (0.26 kg·100 m^{-2}) compared to the other plant density treatment (0.19 kg·100 m^{-2}). The total oil content obtained from plants grown at a spacing of 30 × 30 cm and at the spacing of 20 × 20 cm was similar (tab. 3). Otherwise, Khorshidi et al. [2009] found the highest essential oil content in fennel plants grown at the lowest

density. Rao [2002] showed opposite relationships stating that the highest plant density was the best for obtaining the maximum yield of geranium oil. The present study demonstrated that the essential oil yield from plants cut at the beginning of July was 75% higher than the oil yield from plants harvested at the beginning of September (tab. 2). Climatic and agronomic conditions have different effects on essential oil yield of plants. The research of Farahani et al. [2009] showed the lemon balm oil yield to be reduced under the influence of water deficit stress. Omobolanle Ade-Ademilua et al. [2013] demonstrated a significant effect of light and moisture conditions on essential oil content and yield in basil. In turn, Bowes and Zheljazkov [2004] proved that genetic variability had a greater influence on basil oil yield than agronomic variability. Oil yield is a function of the synthesis of major physiologically active substances, which leads to an increase in biomass and in consequence to increased oil yield. Therefore, most frequently climatic conditions and agronomic modifications have a significant contribution to determining oil yield in aromatic plants.

Biological value of tarragon

The analysis of the chemical composition of fresh tarragon herb did not show a significant correlation between plant density and the contents of L-ascorbic acid, chlorophyll a, carotenoids and essential oil (tab. 3). On the other hand, tarragon plants grown at higher density were characterized by a significantly higher concentration of chlorophyll b and chlorophyll a + b than plants grown at lower density. The study found significantly more L-ascorbic acid, chlorophyll a, chlorophyll b, chlorophyll a + b and oil in the herb harvested on the first date – the beginning of July. The average L-ascorbic acid content in tarragon herb investigated was 6.77 mg·100 g^{-1} FW. In the herb cut at the beginning of July, the content of this compound was significantly higher by 2.34 mg·100 g^{-1} FW than in the herb obtained at the later harvest time. Tarragon grown for bunching can contain from 9.8 to 10.08 mg·100 g^{-1} FW of L-ascorbic acid [Martyniak-Przybyszewska and Wojciechowski 2004, Jadczak and Grzeszczuk 2008]. Comparing the L-ascorbic acid content in various spice plants, its higher content, in relation to the tarragon herb studied, has been found in the herb of hyssop [Zawiślak 2011], marjoram, thyme, savoury and basil [Martyniak-Przybyszewska and Wojciechowski 2004]. Thus, tarragon herb cannot be considered to be the best source of L-ascorbic acid, though the presence of this constituent increases the biological value of herbal material, in particular of fresh herb. Grzeszczuk and Jadczak [2008] showed that as a result of freezing tarragon herb for a period of 6 months, the vitamin C content decreased to 4.08 mg·100 g^{-1} FW. That is why it is advisable to use tarragon herb also for direct consumption.

The present study demonstrated a significant correlation between harvest time and chlorophyll content in tarragon herb (tab. 3). More chlorophyll a + b (by 40%) was found in the herb cut at the beginning of July than in the herb harvested at the beginning of September. Furthermore, plants grown at higher density accumulated significantly more chlorophyll a and a + b than those grown at lower density. Taking into consideration the quantity of tarragon herb yield and the chlorophyll content, it was noted that the lower density of plants and the harvest time at the beginning of July resulted in an in-

crease in herb yield, with a reduction/increase in chlorophyll content (respectively: plant density/harvest time). These relationships can be explained by certain modifications in the climatic conditions (light, moisture) under two different plant density regimes and harvest times. Similarly, in the study of Kadam et al. [2013] climatic conditions during the growing season of the plants studied modified the chlorophyll and carotenoid content. Hassan et al. [2013] also showed that the yield of rosemary herb and the chlorophyll content in it decreased with the progressive deficit of irrigation.

Table 3. Biological value of tarragon's fresh herb yield (2010–2012)

Plant spacing (cm)	Harvest term	L-ascorbic acid	Chlorophyll a	Chlorophyll b	Chlorophyll a + b	Carotenoids	Essential oil ml·100 g^{-1}
		mg·100 g^{-1} f.m.					
20 × 20	first time of harvest	7.79	59.25	32.42	91.67	39.00	0.60
	second time of harvest	5.76	40.58	17.50	58.08	36.17	0.45
	mean	6.77	49.91	24.96	74.87	37.58	0.52
30 × 30	first time of harvest	8.09	54.66	28.83	82.49	37.83	0.60
	second time of harvest	5.45	34.50	13.00	47.50	47.33	0.42
	mean	6.77	44.58	20.91	65.49	42.58	0.51
Mean	first time of harvest	7.94	56.95	30.62	87.57	38.41	0.60
	second time of harvest	5.60	37.54	15.25	52.79	41.75	0.43
	mean	6.77	47.24	22.93	70.18	40.08	0.51
$LSD_{0.05}$							
plant spacing		n.s.	n.s.	3.658	9.262	n.s.	n.s.
harvest term		0.923	6.937	3.658	9.262	n.s.	0.057
interaction		n.s.	n.s.	n.s.	n.s.	9.896	n.s.

n.s. – not significant

The present study did not show a significant effect of plant density and harvest time on the carotenoid content, but it found a significant interaction of the experimental factors with the trait in question (tab. 3). Plants grown at lower density (30 × 30 cm) harvested at the beginning of September (second harvest time) were characterized by a significantly higher concentration of carotenoids than plants from the first harvest time grown at a spacing of 20 × 20 cm. The average carotenoid content in the plant material was 40.08 mg·100 g^{-1}, much exceeding the content of this constituent in all herbs studied, including tarragon [Veeru et al. 2009, Daly et al. 2010]. Both chlorophyll and carotenoids belong to important nutrients that have an antioxidant character [Veeru et al. 2009] and hence their presence in spice material increases its health-enhancing qualities.

The essential oil content in fresh and dry tarragon herb was dependent on harvest time (tabs 3 and 4). Plants harvested at the beginning of July accumulated significantly more essential oil. These differences appear to be caused by more favourable thermal

and light conditions of the summer period of cultivation and harvest compared to the autumn period. An earlier study [Zawiślak and Dzida 2012] showed significant variations in the tarragon essential oil concentration between years depending on weather conditions during the study period. Climatic conditions also modified essential oil biosynthesis in cumin plants [Azizi and Kahrizi 2008]. In the present study, the average essential oil content in dry tarragon herb was 1.56 ml·100 g^{-1}, exceeding the values given by other authors [Lopez-Lutz et al. 2008, Haghi et al. 2010, Zawiślak and Dzida 2012]. In turn, Kowalski et al. [2007] found twice more essential oil in tarragon herb. These differences can result not only from the origin of plant material, but also from the oil extraction method.

Table 4. Chemical composition of tarragon's dry herb (2010–2012)

Plant spacing (cm)	Harvest term	Essential oil ml·100 g^{-1}	Tannins	Flavonoids
			%	
20 × 20	first time of harvest	1.71	0.09	0.77
	second time of harvest	1.34	0.14	0.64
	mean	1.52	0.11	0.70
30 × 30	first time of harvest	1.68	0.08	0.75
	second time of harvest	1.33	0.13	0.64
	mean	1.50	0.10	0.69
Mean	first time of harvest	1.69	0.08	0.76
	second time of harvest	1.33	0.13	0.64
	mean	1.59	0.10	0.70
$LSD_{0.05}$				
plant spacing		n.s.	n.s.	n.s.
harvest term		0.059	0.017	0.058
interaction		n.s.	n.s.	n.s.

n.s. – not significant

The present experiment did not show plant density to be correlated with the content of flavonoids and tannins (tab. 4). But herb harvest time differentiated the concentration of the above-mentioned constituents. The tannin content was more than 1.5 higher in the herb obtained at the beginning of September (0.13%) than in the case of harvest at the beginning of July (0.08%). Nevertheless, with such a low content of these compounds (on average 0.10%), tarragon herb cannot be considered to be tanning material. In turn, the flavonoid content was higher in tarragon herb harvested at the beginning of July compared to that harvested at the beginning of September (tab. 4). The average flavonoid content was at a level of 0.70%. The flavonoid concentration in various herbal plant species is subject to genetic variability [Atanassova et al. 2011, Zhang et al. 2011, Zawiślak 2011, Sulaiman et al. 2012] and environmental variability. The flavonoid content in inflorescences of cultivated dwarf everlast plants was higher than in the plant

material collected from natural stands [Sawilska and Mielcarek 2009]. The positive correlation between the antioxidative activity and the content of phenolic compounds and flavonoids should be noted [Zhang et al. 2011]; this shows that these components are most probably the main antioxidants responsible for this activity.

According to the present research results and the literature data, tarragon is a suitable species to be grown for bunching, which is evidenced by the intensive growth of tarragon plants as well as by the quantity and quality of yield. The biological value of tarragon harvested during the vegetative stage is determined not only by the presence of L-ascorbic acid, chlorophyll, carotenoids, flavonoids, tannins and essential oil, but also of artemisinin, the concentration of which decreases at the flowering stage [Manan et al. 2011].

CONCLUSIONS

1. Plant density and harvest time significantly differentiated the fresh and dry herb yield, leaf herbage yield and essential oil yield in tarragon. The percentage proportion of stems in tarragon herb was comparable between treatments. Plants grown at lower density and harvested during the early summer period were characterized by better yield parameters compared to the other treatments.

2. The biological value of tarragon grown for bunching, as expressed by the contents of L-ascorbic acid, chlorophyll, carotenoids, flavonoids, tannins and essential oil, was largely affected by the investigated cultivation factors. Plants grown at higher density accumulated significantly more chlorophyll b and chlorophyll a + b than those grown at lower density.

3. Tarragon herb harvested at the beginning of July was characterized by higher concentrations of L-ascorbic acid, chlorophyll a, b and a + b, flavonoids and essential oil as well as a lower content of tannins than the plant material harvested at the beginning of September. The carotenoid content in tarragon herb was not dependent on the factors studied, with their significant interaction.

4. Plant density affected to a greater extent the quantity of tarragon yield than its biological value. In growing tarragon for bunching, lower plant density can be recommended, since it contributes to high herb and essential oil yields. The beginning of July proved to be a more favourable time for harvesting tarragon grown for bunching than the beginning of September due to the quantity and biological value of tarragon yield and essential oil yield.

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OCENA PLONOWANIA I WARTOŚCI BIOLOGICZNEJ ESTRAGONU (*Artemisia dracunculus* L.) W UPRAWIE NA ZBIÓR PĘCZKOWY

Streszczenie. Wartość biologiczna świeżego i wysuszonego surowca przyprawowego pozostaje pod silnym wpływem warunków klimatycznych, agrotechnicznych oraz czynników genetycznych i ontogenetycznych. W dostępnej literaturze naukowej nieliczne publikacje przedstawiają problematykę uprawy roślin zielarskich na bezpośrednie spożycie oraz omawiają wartość biologiczną świeżego surowca. Dlatego też celem podjętych badań była ocena plonowania oraz jakości ziela bylicy estragonu w uprawie na zbiór pęczkowy, w zależności od gęstości roślin (20 × 20 cm i 30 × 30 cm) i terminu zbioru (początek lipca i początek września). Badania przeprowadzono w latach 2010–1012 w Stacji Doświadczalnej Katedry Warzywnictwa i Roślin Leczniczych Uniwersytetu Przyrodniczego w Lublinie (51º14'N 22º34'E). W świeżym materiale roślinnym określono zawartość kwasu L-askorbinowego, chlorofilu, karotenoidów oraz olejku eterycznego. Natomiast w zielu otartym określono zawartość olejku eterycznego, garbników i flawonoidów. Wielkość plonu ziela estragonu w uprawie na zbiór pęczkowy była zależna od gęstości roślin oraz terminu zbioru, a także ich współdziałania. Rośliny rosnące w mniejszym zagęszczeniu oraz zbierane w okresie wczesnoletnim charakteryzowały się lepszymi parametrami plonu w porównaniu z pozostałymi. Ziele estragonu zbierane na początku lipca charakteryzowało się większą koncentracją kwasu L-askorbinowego, chlorofilu a, b i a + b, flawonoidów oraz olejku eterycznego oraz mniejszą zawartością garbników, niż surowiec zbierany na początku września. Zawartość karotenoidów w surowcu estragonu nie była zależna od badanych czynników, przy ich istotnym współdziałaniu. W uprawie estragonu na zbiór pęczkowy można polecić mniejsze zagęszczenie roślin warunkujące wysoki plon surowca oraz plon olejku. Początek lipca okazał się korzystniejszym terminem zbioru estragonu na pęczki niż początek września, z uwagi na wielkość i wartość biologiczną plonu oraz plon olejku.

Słowa kluczowe: świeże ziele, skład chemiczny, gęstość sadzenia, termin zbioru, plon olejku eterycznego

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