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THE EFFECT OF NITROGEN FERTILIZATION ON YIELDING AND ANTIOXIDANT ACTIVITY OF LAVENDER (*Lavandula angustifolia* Mill.)

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Abstract. The aim of the experiment conducted in 2003–2006 was to estimate the effect of dose of nitrogen on yielding and antioxidant activity of lavender. The experiment was established in one factorial design in four replications and plot area 3.0 m^2. Nitrogen was supplied in three different rates: as a preplant dose 50 kg $N \cdot ha^{-1}$, or split application 100 (50 + 50) and 200 kg $N \cdot ha^{-1}$ (100 + 100) with one top dressing provided on first week of May. Results obtained from two years of the study indicate that the most suitable for lavender yielding appeared to be nitrogen fertilization at the rate of 100 kg $N \cdot ha^{-1}$. The results of the study also demonstrated that heavy nitrogen fertilization decreased concentration of phenolic compounds and have negligible effect on chlorophyll and carotenoids concentration in lavender flowers and increased content of phenolics, total carotenoids and chlorophyll a + b in leaves. The antioxidant activity of lavender flowers was higher in treatment fertilized with nitrogen in dose of 50 kg $N \cdot ha^{-1}$ and decreased at the rates of 100 and 200 kg $N \cdot ha^{-1}$.

Key words: *Lavandula angustifolia*, yield, carotenoids, phenolics, chlorophyll, antioxidant activity

INTRODUCTION

Oxidation is one of major causes of chemical spoilage, resulting in rancidity and deterioration of the nutritional quality, colour, flavour, texture and safety of foods [Antolovich et al. 2002]. At present there is increasing interest both in industry and in scientific research for spices and aromatic herbs because of their strong antioxidant and antimicrobial properties, which exceeded many commonly used natural and synthetic antioxidants. These properties are due to many substances, including some vitamins,

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carotenoids, chlorophyll, catechins, phytoestrogens, minerals, etc. and render spices and some herbs or their antioxidant components as preservative agents in food [Parejo et al.2002]. The antioxidant properties of seven dessert spices were compared with those of the common food antioxidants butylated hydroxyanisole, butylated hydroxytoluene and propyl gallate [Murcia et al. 2004]. Mint and cinnamon had a higher percentage of inhibition than the other spices analyzed and also than food antioxidants. Leafy spices like thyme, marjoram, basil, sage showed pro-oxidative activity for food exposed to light, while the same food stored in the dark confirmed the antioxidative effect of the spices [Pokorny et al. 2001]. Use of natural antioxidants for inactivating free radicals receives a lot attention because they are natural, non-synthetic products, and their appreciation by consumers is very favourable. Antioxidant activity of the selected plants was poorly investigated, therefore testing of their antiradical properties is being interested, primarily in order to find new promising sources for natural antioxidants, functional foods, neutraceuticals and cosmeceuticals.

Lavender is best known for its flowers contained essential oil which is used medicinally, in balms, salves, perfumes, cosmetics. Essential oil of lavender has antiseptic and anti-inflammatory, analgesic, antifungal and bactericidal properties because it is rich in terpenes [Rumińska 1983, Worwood 1991, Schnaubelt 1998, Kohlmünzer 2000, Yusufoglu et al., 2004]. Lavender is frequently used as an aid to sleep and relaxation. Extract of lavender is claimed to heal acne, it is also used in treatment of skin burns and inflammatory conditions.

Lavender has also the other bioactive constituents such as polyphenols, antocyanins, carotenoids, chemicals that act as antioxidants in the human body, but little information on antioxidant properties of this plant can be found in the literature [Dapkevicius et al. 1998, Miliauskas et al 2004].

Chemical and biological diversity of medicinal plants are depending on such factors, as cultivation area, climatic conditions, vegetation phase as well as genetic modifications [Miliauskas et al. 2004]. There are lack information on effect of fertilization on antioxidant activity of these plants. Aromatic plants are cultivated and commercialized from centuries, nevertheless, little is known about cultural techniques and recommendation for fertilization which are available for growers. The aim of the experiment conducted in 2003–2006 was to estimate the effect of dose of nitrogen on yielding and antioxidant activity of lavender.

MATERIAL AND METHODS

Field experiment was conducted in 2003–2006 on a fine clay soil with 1.8% organic matter and pH 6.8, with high content of phosphorus (90–125 mg $P \cdot dm^{-3}$) and potassium (220–240 mg $P \cdot dm^{-3}$). The experiment was established in one factorial design in four replications and plot area 3.0 m^2. Nitrogen was supplied in three different rates: as a preplant dose 50 kg $N \cdot ha^{-1}$, or split application 100 (50 + 50) and 200 kg $N \cdot ha^{-1}$ (100 + 100) with one top dressing provided on first week of May. The source of nitrogen was ammonium nitrate. Transplants of lavender were produced in greenhouse and planted out in spacing of 50×50 cm in the plots on mid July 2003.

The harvest was done in the second week of July in 2005 and 2006, when 25% flowers were fully developed. The fresh and dry weight of flowers was noticed. One week before harvest date there was estimated stage of development of pants (weight, width as well as mean number of flowers on one plant).

In samples of flowers and leaves chlorophyll, carotenoids, polyphenolics and antioxidant activity were determined. Fresh flowers and leaves were blended with BOSCH blender and extracted with 100 cm^3 of methanol (80%). Radical scavening activity of plant extracts against stable DPPH was determined according to Yen et al. [1995], ABTS according to Re et al. [1999] and FRAP test according to Benzie and Strain [1996]. The content of total phenolic compounds was determined by Folin-Ciocalteu method [Slinghart and Singleton 1977], chlorophyll a + b and total carotenoids was determined spectrophotometrically according to Rumińska et al. [1990].

The plants measurements, yields and chemical analyses were elaborated by standard statistical procedure with one factorial design and the least significant differences calculated at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Dose of nitrogen influenced on the growth and development of lavender plants particularly in third year after transplant planting (tab. 1). The plants fertilized with nitrogen at the rate of 200 kg N·ha^{-1} were taller and more wide than those cultivated on plots with total nitrogen dose of 50–100 kg N·ha^{-1}, and in 2005 year produced higher number of flowers per plant, whilst in 2006 more flowers was noticed on plants from plots fertilized with nitrogen at the rate of 100 kg N·ha^{-1}.

Results obtained from two years of the study indicate that the most suitable for lavender yielding appeared to be nitrogen fertilization at the rate of 100 kg N·ha^{-1} (tab. 2). The significantly lowest yield of flowers was achieved from plots fertilized with nitrogen at the rate of 50 kg N·ha^{-1}. Heavy fertilization at the rate of 200 kg N·ha^{-1} caused decrease in the yield of lavender flowers in 2006. The recommended by Rumińska et al. [1991] and Kordana et al. [1991] dose of nitrogen for lavender fertilization is 40–50 kg N·ha^{-1}. They stated that intensive nitrogen soil fertilization in total rates of 100–200 kg N·ha^{-1}decreased the yield of lavender as well as had detrimental effect on overwintering of plants in the field. There was not observed the worse overwintering of plants intensive fertilized with nitrogen in experiment.

The rate of nitrogen had the significant effect on chemical composition of lavender flowers and leaves (fig. 1). The level of chlorophyll a + b in leaves increased from 4.36 to 5.48 mg · 1 g^{-1} d.m. respectively at the rates of nitrogen 50 and 200 kg N·ha^{-1}, but in flowers there was not observed the positive effect of enhanced doses of nitrogen on its amounts. The results of the study also demonstrated that heavy nitrogen fertilization decreased concentration of phenolic compounds in lavender flowers and increased content of total carotenoids and phenolics in leaves. The level of phenolic compounds in leaves of lavender at the rate of 50 kg N·ha^{-1} was lower than in flowers but when dose of nitrogen increased content of this bioactive substances in flowers decreased and was similar to obtained in leaves of this plant.

Table 1. The effect of dose of nitrogen on growth and development of lavender
Tabela 1. Wpływ dawki azotu na wzrost i rozwój lawendy

Dose of nitrogen Dawka azotu kg N·ha^{-1}	Height of plant Wysokość roślin cm			Width of plant Zasięg roślin cm			Number of flowers per plant Liczba kwiatostanów na roślinie		
	2005	2006	mean średnia	2005	2006	mean średnia	2005	2006	mean średnia
50	42.7	55.2	48.9	77.0	79.9	78.4	145.0	198.1	171.5
100	44.0	58.2	51.1	78.2	82.3	80.2	156.7	297.7	227.2
200	44.7	65.1	54.9	81.0	89.3	85.1	181.2	222.4	201.8
Mean – Średnia	43.7	59.5	51.6	78.7	83.8	81.3	161.0	239.4	200.2
LSD (NIR) α = 0.05	ns	4.1	6.2	ns	5.2	6.8	11.8	18.3	21.8

Table 2. The effect of dose of nitrogen on yield of fresh and dry inflorescence of lavender
Tabela 2. Wpływ dawki azotu na plon świeżej i suchej masy kwiatostanów lawendy

Dose of nitrogen Dawka azotu kg N·ha^{-1}	Yield of fresh inflorecsence Plon świeżych kwiatostanów kg·m^{-2}			Yield of dry inflorescence Plon suchych kwiatostanów kg·m^{-2}			Share of flowers in total yield of dry inflorescence Udział kwiatów w plonie suchych kwiatostanów, %		
	2005	2006	mean średnia	2005	2006	mean średnia	2005	2006	mean średnia
50	5.08	6.36	5.72	0.98	1.34	1.16	58.4	56.3	57.3
100	6.25	7.99	7.12	1.09	1.67	1.38	59.5	58.4	58.9
200	6.35	7.61	6.98	1.26	1.50	1.38	57.2	56.4	56.8
Mean – Średnia	5.89	7.32	6.60	1.17	1.50	1.33	58.4	57.0	57.7
LSD (NIR) α = 0.05	0.17	0.34	0.20	0.12	0.09	0.15			

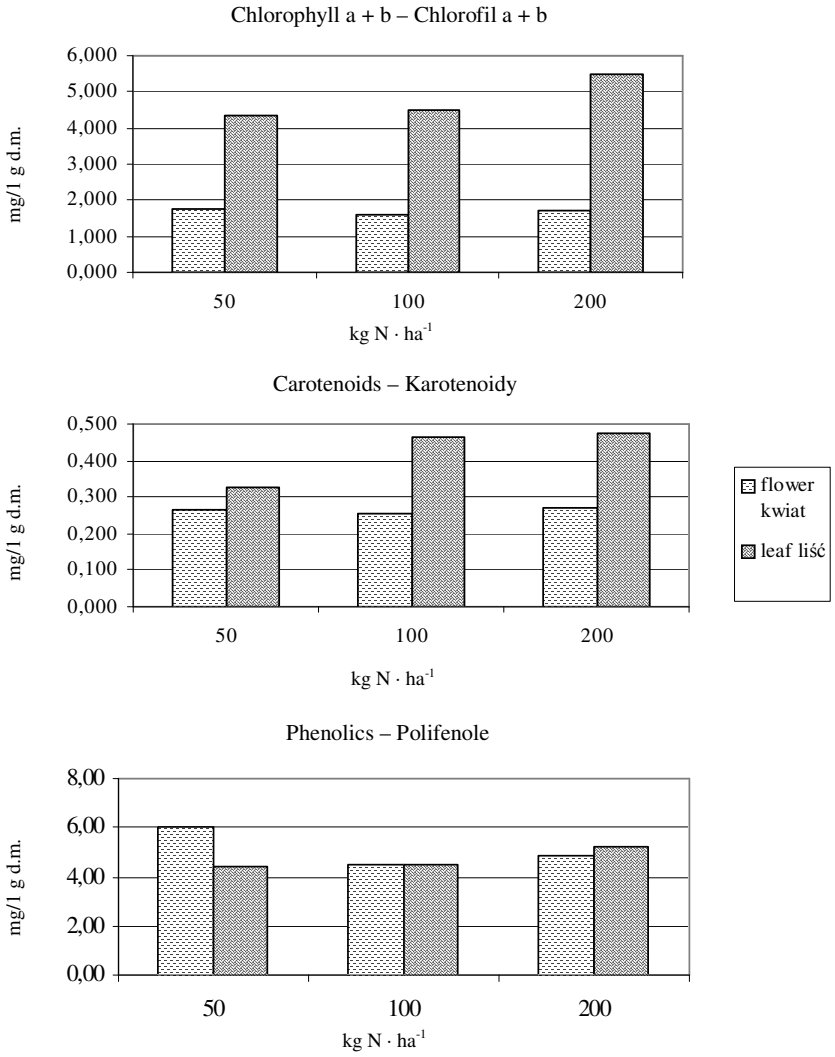

Fig. 1. The effect of nitrogen dose on the content of chlorophyll, carotenoids and phenolics in lavender (2005)

Rys. 1. Wpływ dawki azotu na zawartość chlorofilu, karotenoidów i polifenoli w lawendzie (2005)

The antioxidant activity of lavender flowers was higher in treatment fertilized with nitrogen in dose of 50 kg N·ha^{-1} and decreased at the rates of 100 and 200 kg N·ha^{-1} (tab. 3). There was observed correlation between free radical scavenging tests used in experiment. In all tests there was noticed the decrease of antioxidant activity of flowers

obtained from plots fertilized with heavy rates of nitrogen whilst in leaves this activity was rather stable (FRAP test) or slightly increased with rising of nitrogen rates (DPPH and ABTS test).

According to Cetkovic et al. [2004] antioxidant properties of medicinal plants were in correlation with the contents of total phenolic compounds and flavonoids in extracts. Also Miliauskas et al. [2004] observed a correlation between radical scavening capacities of extracts with the total phenolic compounds content in tested plants. Partly it is in agreement with results obtained in this experiment.

Table 3. Antioxidant activity of lavender at different rates of nitrogen (2005)
Tabela 3. Aktywność antyoksydacyjna lawendy przy zróżnicowanym nawożeniu azotem (2005)

Dose of nitrogen Dawka azotu kg N·ha^{-1}	FRAP µM Trolox /1 g d.m. µM Troloxu /1 g s.m.		DPPH µM DPPH /1 g d.m. µM DPPH /1 g s.m.		ABTS µM Trolox /1 g d.m. µM Troloxu /1 g s.m.	
	flower	leaf	flower	leaf	flower	leaf
50	63.02 a*	54.99 a	0.44 a	0.07 b	13.84 a	10.25 b
100	47.16 c	57.06 a	0.21 b	0.10 ab	10.35 b	11.04 b
200	50.19 b	59.66 a	0.24 b	0.12 a	10.79 b	12.50 a
Mean – Średnia	53.45	57.23	0.29	0.09	11.66	11.26

*Values marked with the same letters in column do not differ significantly
*Wartości oznaczone w kolumnach tymi samymi literami alfabetu nie różnią się istotnie

Antioxidant properties of lavender are rather less documented. According to numerous reports antioxidant properties of this plant are rather contradictory, probably because of differences in the assessment methodology. Dapkevicious et al. [1998] did not detect antioxidant activity of various plant extracts in the linoleic acid-β-carotene system, but according to Hohmann et al. [1999] aqueous methanolic extracts of lavender were effective in lipid peroxidation media.

According to Miliauskas et al. 2004, among thirteen tested species methanol extracts of *Geranium macrorrhizum* and *Potentilla fruticosa* had higher antioxidant activity than *Salvia officinalis*, while *Calendula officinalis*, *Lavandula angustifolia* and *Matricaria recutita* were relatively weak antioxidants. Also Lee and Shibamoto [2002] observed low antioxidant activities of volatile extracts of lavender in comparison to thyme, basil and rosemary.

CONCLUSIONS

1. Results obtained from two years of the study indicate that the most suitable for lavender yielding appeared to be nitrogen fertilization at the rate of 100 kg N·ha^{-1} .

2. Heavy nitrogen fertilization decreased concentration of phenolic compounds and have negligible effect on chlorophyll and carotenoids concentration in lavender flowers and increased content of phenolics, total carotenoids and chlorophyll a + b in leaves.

3. The antioxidant activity of lavender flowers was higher in treatment fertilized with nitrogen in dose of 50 kg N·ha^{-1} and decreased at the rates of 100 and 200 kg N·ha^{-1}. The antioxidant activity of leaves increased with intensive nitrogen fertilization.

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WPŁYW NAWOŻENIA AZOTEM NA PLONOWANIE I AKTYWNOŚĆ ANTYOKSYDACYJNĄ LAWENDY (*Lavandula angustifolia* Mill.)

Streszczenie. Celem doświadczenia przeprowadzonego w latach 2003–2006 była ocena wpływu dawki azotu na plonowanie lawendy wąskolistnej. Doświadczenie jednoczynnikowe założono czterech powtórzeniach, powierzchnia jednego poletka do zbioru wynosiła 3,0 m^2. Azot stosowano w następujących dawkach: 50 kg N·ha^{-1} oraz w dawkach dzielonych stosowanych przedwegetacyjnie wczesną wiosną i pogłównie: 100 (50 + 50) kg N·ha^{-1} i 200 (100 + 100) kg N·ha^{-1}. Wyniki uzyskane w doświadczeniu wskazują, że optymalną dawką azotu dla lawendy jest 100 kg N·ha^{-1}. Wykazano również, że intensywne nawożenie azotem obniża zawartość polifenoli i ma niewielki wpływ na poziom karotenoidów i chlorofilu w kwiatach lawendy, podnosi zaś zawartość tych składników w jej liściach. Aktywność antyoksydacyjna kwiatów lawendy była największa w obiekcie nawożonym azotem w ilości 50 kg N·ha^{-1} i zmniejszyła się przy dawkach 100 i 200 kg N·ha^{-1}.

Słowa kluczowe: *Lavandula angustifolia*, plon, karotenoidy, polifenole, chlorofil, aktywność antyoksydacyjna

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