Specific way of controlling yield and quality of crops of rocket (*Eruca sativa* Mill.) and tailoring some of its functional properties

Specyficzna modulacja kontroli wydajności i jakości plonów rukoli (*Eruca sativa* Mill.) oraz niektórych jej właściwości funkcjonalnych

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Słowa kluczowe: arugula, *Eruca vesicaria*, olejki eteryczne, plazma jarzeniowa, sensoryka

Summary

Plantations of rocket were watered with water treated for 30 min with low temperature, low-pressure glow plasma of low frequency (LPGP) either in the air (LPGPA), under nitrogen (LPGPN) or carbon dioxide (LPGPC). Watering with LPGPN offered the lushest plants. The kind of the plasma treated water had a minor effect on rooting of the plants. Always watering rocket provided higher yield of crops and watering with LPGPN was the most beneficial in this respect. The watering with the LPGP treated water, regardless its kind, decreased the level of fat in the crops by approximately 14%. Simultaneously, it was meaningless for the level of carbohydrates and slightly increased the level of proteins. All kinds of the LPGP-treated water increased the level of chlorophyll *a* but LPGPA and LPGPC decreased the level of chlorophyll *b*. The watering provided crops of a higher level of carotenoids, ascorbic acid and sulphur containing compounds. Watering with LPGPN was the most beneficial in this respect. Such watering influenced also composition of the essential oils extracted from the leaves. No novel components were found in the extracts but the yield of some components was essentially influenced. Therefore, functional properties of the essential oil suitable as either a spice, flavoring agent and a cure useful in herbal medicine and aromatherapy could be tailored.

Streszczenie

Plantację rukoli nawadniano wodą traktowaną przez 30 min niskotemperaturową, niskociśnieniową plazmą jarzeniową o niskiej częstości pod powietrzem, azotem i ditlenkiem węgla. Stosowanie wody plazmowanej pod azotem wpłynęło na zwiększenie biomasy rośliny. Rodzaj używanej wody miał niewielki wpływ na ukorzenienie roślin. Każdy rodzaj wody zwiększał wydajność plonów, a stosowanie wody plazmowanej pod azotem było pod tym względem najkorzystniejsze. Zastosowanie któregokolwiek rodzaju plazmowanej wody obniżało zawartość tłuszczu w roślinach o około 14%, nie miało wpływu na zawartość węglowodanów i minimalnie zwiększało zawartość białka. Podlewanie upraw którymkolwiek rodzajem plazmowanej wody podnosiło poziom chlorofilu *a*, ale woda plazmowana pod powietrzem lub ditlenkiem węgla obniżała poziom chlorofilu *b*. Każdy rodzaj plazmowanej wody zwiększał zawartość karotenoidów, kwasu askorbinowego i związków siarkowych, a podlewanie wodą plazmowaną pod azotem dawało najlepsze rezultaty. Nawadnianie upraw plazmowanymi rodzajami wody wpływało na skład olejków eterycznych ekstrahowanych z liści i ich wydajność. W żadnym przypadku nie stwierdzono nowych składników w składzie olejków. Nawadnianie upraw różnymi rodzajami plazmowanej wody pozwala na kontrolowanie właściwości olejków stosowanych jako przyprawy, środki nawadniające lub lecznicze wykorzystywane w ziołolecznictwie i aromatoterapii.

Introduction

Rocket (*Eruca vesicaria*, *Eruca sativa* Mill.) known also as arugula is commonly known edible leaf vegetable of a pungent, bitter flavour. Its seeds are also edible [1, 2]. The plant is consumed in form of salads and component of additive to various dishes. In West Asia an edible taramira oil is pressed of rocket seeds [3]. Essential oil from the plant leaves is also available [4, 5]. Rocket is appreciated for its high level of vitamins and such bioelements as potassium, calcium, magnesium, iron, manganese, copper and zinc [6]. The pungent flavour of the plant is generated by sulphur containing glucosinolates which decompose into thiocyanates and finally into dialkylsulfides and dialkyldisulfides. These transformations are assisted by microorganisms either residing in the plant or these infecting plants on their storage [4, 5, 7–9].

Recently [10, 11], a new kind of plasma was invented. That plasma generated at 38°C at $5x10^{-3}$ mbar, 800 V, 50 mA and 10 KHz frequency (LPGP) did not break valence bonds of the compounds exposed to it. Thus, for instance, water exposed to LPGP in the presence of air was solely declusterized into smaller $(H_2O)_n$ units and neither perhydrol nor ozone were generated. Molecules of atmospheric oxygen

dissolved in water were excited from its ground triplet state into excited singlet state. Resulting small $(H_2O)_n$ units were stabilized by building aqueous clathrates hosting the excited oxygen molecules [12]. Further papers on the preparation and physicochemical properties of water treated with LPGP either in under ammonia [13], nitrogen [14], carbon dioxide [15], methane [16] or oxygen [17] revealed that these kinds of water better solubilize mineral and organic compounds and corresponding solutions better permeate the cell membranes. Therefore, the LPGP-treated kinds of water became a good vector for various solutes beneficial for processes occurring inside the plant and animal cells [18, 19].

This paper presents an influence of watering rocket (*Eruca sativa* Mill.) with water treated with LPGP in the air, under nitrogen or carbon dioxide upon the yield of crops and their biological and functional properties including composition of corresponding extracted essential oils.

Materials and Methods

Materials

Rocket (*Eruca sativa* Mill.): Seeds only for hobby gardening manufactured by W. Legutko Breeding and Seed Company, Jutrosin, Poland, BK 1007-08302-MON, 2020 were used.

Water

Tap water from Częstochowa municipal supply system had pH 7.6, EMF = 351.8 ± 0.3 mV and conductivity g = 0.444 ± 0.004 mS, It contained totally 672.28 mg minerals/L (193.27 mg Ca^{2+}/L, 46.21 mg Mg^{2+}/L, 23.18 mg Na^{+}/L, 5.27 mg K^{+}/L, 351.90 mg HCO_3^{-}/L, 51.20 mg SO_4^{-}/L, 6.52 mg Cl^{-}/L, 40 μg Fe/L).

Gases

Nitrogen: Nitrogen from a tank (AIR-PRODUCTS, Warsaw, Poland) was deoxygenated by passing through an absorber filled with an alkaline solution of resorcinol
Carbon dioxide: pure (100%) CO_2 (AIR-PRODUCTS, Warsaw, Poland)

Substrate

Substrate was composed of medium size turf fraction Florabalt® Pot Medium-Coarse (Floragard, Oldenburg, Federal Republic of Germany). The medium of pH 5.6, contained 1.2 g/L total salts including 210 mg N/L, 120 mg P_2O_5/L, 260 mg K_2O/L and 0.258% S. It was supplemented with multicomponent PG-Mix 18-10-20 fertilizer (1.20 kg/m^3) (Yara, Oslo, Norway).

Methods

Rocket cultivation

The monofactorial experiment was carried out from July 4th (sowing) till August 30th (harvesting) 2021 in a greenhouse. Temperature in the greenhouse was set for 22 and 18°C during the day and night, respectively. The daytime took 16 h since the sunup. The passing from the day into the night regime was controlled with computer. The automatic additional 16h illumination with sodium lamps was used when natural light intensity decreased below 100 W/m^2. The experiment involved three sets of trays with 24 pots each. Ten seeds of the plant were sown into every pot. In one series of experiments 2 multiplates hosted 300 plants. In order to eliminate parietal effect 60 plants on the edge of trays were left apart and, therefore, only 240 plants were harvested. Since the experiments were run in triplicates maximum 720 plants were collected for a given series. Plants watered with tap, non-plazmed water served as control samples.

The watering was adjusted according to tensiometer readings (Irrometer model SR 150 mm) when soil water tension was < - 40 kPa. The plants were watered by hand to avoid the accidental contact of water with leaves. Initially, plants consumed totally 3L water, that is 1L per each replication in the 5 day period until March 24th. In the subsequent 1 month period the watering was intensified and the same amount of water was administered to the plants in 3 day periods. In the final period of breading plants were watered daily consuming the same amount of water. In such manner the watering consumed totally 40 mL each kind water daily. The experiment terminated on May 18th when the plants were collected. The plants were then dried at 105°C for 4 hours to determine dry mass of the crops.

Saturation of water with a gas

Through either deionized or tap water was a stream of a given gas was bubbled for 15 min. Its flow rate depended on the volume of the water sample. In case of the 200 mL sample it was 10 mL/min).

Treating water with LPGP

Water (200 mL) saturated with a corresponding gas was placed in 250 mL glass bottles and free space over the liquid was additionally filled with corresponding gas. The whole was placed in the chamber of the reactor [14] and exposed to GP for 30 min. Plasma of 38°C was generated at 5×10^{-3} mbar, 800 V, 50 mA and 10 KHz frequency. The produced water was stored at ambient temperature in 100 mL closed teflon containers.

Estimation of crop yield

.000 1g. Weights of samples were measured with Analytical laboratory scale RADWAG AS 220.R2 (Radom, Poland) with precision of ± 0.0001 g.

Estimation of dry mass

Samples were 24 h dried at 100–105°C. Weights of samples were measured with Analytical laboratory scale RADWAG AS 220.R2 (Radom, Poland) with precision of ± 0

Estimation of ash

In a vessel weighed with the 0.0002 g precision a substance was weighed with the same precision and the whole was inserted for 10 min into a front of an oven heated to 815°C. Subsequently, the vessel with the sample was shifted (2 cm/min) into the central region of the chamber. After returning the temperature of the oven to 815°C the analysed sample was maintained inside the chamber for further 25 min. After that time the sample was left in the open for cooling to room temperature than weighed with the 0.0002 g precision.

Fat content

A sample thoroughly disintegrated in a mortar was weighed (5 g ± 1 mg) then blended with anh. Na_2SO_4 (5 g) and transferred into extracting casing filling it in no more in 3/4th its height. The filled casing was closed with a fat-free cotton wool. The 3 h extraction with n-hexane (200 mL) was carried out in an Soxhlet apparatus equipped in a flask for collecting extract weighed with the ± 1 mg precision. After that time, acetone (2 mL) was added to the flask with the extract cooled to room temperature. On blowing a stream of nitrogen the whole was slowly heated to remove acetone and n-hexane. The flask with extract was heated for 10 min in a drying box at 103°C then left in a desiccator for cooling to room temperature followed by weighing. The fat content (H) [g/100 g or %] was estimated using Eq. (1)

$$H = [(m_2 - m_1)/m_0]. 100 \quad (1)$$

where
m_0 – mass of the sample,
m_1 – mass of empty extracting flask and
m_2 – mass of extracting flask with extract.

Protein content

The Kjeldahl method [20] was applied for the estimations.

Carbohydrate content

Mass of carbohydrates (M) was determined from Eq. (2)

$$M = 100 \text{ g} - \text{mass of fat} - \text{mass of proteins} \quad (2)$$

Chlorophyll content

Leaves of cress (200 mg) were homogenized for 2 min in a cooled mortar then homogenized for further an additional 2 min with the acetone/ammonia (0.05 mol/dm^3) 8/2 blend (5 cm^3) cooled to 0–5°C. The extraction was continued for 2 more min. by addition of a subsequent 5 cm^3 of extracting acetone/ammonia blend. The resulting suspension of well disintegrated sample was transferred into 25 cm^3 measuring cylinder, the mortar was washed with extracting blend (10 cm^3) and the wash was combined with the extract. The extract was then centrifuged for 10 min at 5000 rpm, and decanted. The volume of the extract was increased to 25 cm^3 by adding the extracting blend. The experiments wererun in triplicates.

The absorbance (A) of resulting extract was taken at 470, 647 and 664 nm. The content of chlorophylls a and b in mg/g was estimated from the Eqs. (3) and (4), respectively.

$$\text{chl.a} = 25a/m \tag{3}$$

where
a = 11.78 A664-2.29 A647
and m denotes the weight (mg) of the fresh plant material.

$$\text{chl.b} = 25b/m \tag{4}$$

where
b = 20.05 A647 – 4.77 A664
and m denotes the weight (mg) of the fresh plant material.

Carotenoids content

The content of carotenoids (β-carotene and xanthophyll) was calculated from Eq. (5).

$$\text{car} = 25c//229m \tag{5}$$

where
c = 1000 A470-3.27
a – 104b and m denotes the weight (mg) of the fresh plant material.

Determination of ascorbic acid

Sample of the dried plant (1g) was disintegrated in a mortar 50 cm3 distilled water and 5 cm 3 of 0.1M aqueous solution of potato starch added. This solution was titrated with a iodine solution following paper by Al Majidi and Al Qubury [21]. The estimations were triplicated.

Analyses for cations

Samples were mineralized in a microwave oven (MarsXpress CEM Company, Matthews, NC USA). Samples (0.5 g) were digested with nitric acid 65% analytical grade (10 cm^3). Determination of metals content was performed with atomic absorption spectrometry with electrothermal device (AA Varian 240 instrument). A palladium standard solution (1000 mg/dm^3) was used as a modifier.

Anion analyses with ion chromatography

A DX500 micropore (2 mm) ion chromatograph with a CD20 conductivity detector and GP40 gradient pump (Dionex, California) was used for ion separation and detection. Commercially available Ionpac CG12A guard and CS12A analytical columns (Dionex, California, USA) with carboxylic-phosphonic acid functional groups were used for cation analysis. Ionpac AG14 guard and AS14 analytical columns (Dionex, California) with quaternary ammonium functional groups were used for anion separation. Eluents were stored in vessels pressurized at 8 p.s.i. using high purity argon (BOC gases), and flow-rates were maintained at 0.45 ml/min for anions and 0.40 cm^3/min for cations using a GP40 gradient pump (Dionex, California, USA). Samples were loaded from an AS40 automated sampler (Dionex, California, USA).

Estimation of total sulphur

The sulfur content was determined using a CHNS/O FlashSmart Thermo Scientific analyser (Waltham, MA USA).

Preparation of samples for separation of essential oil

Leaves (1.0 – 1.5 g) were placed in 15 mL vials made of dark glass and hexane (10 mL) was added to each vial. Extraction on ultrasonicated bath at room temperature lasted 10 min. After centrifugation at 4000 rpm the samples were filtered through a syringe PVDF 0.2 μm filter.

Separation of essential oils for determination of their yield

Samples of the plant (100 g) were steam distilled in a Deryng apparatus with a closed water circulation. The collected oils were transferred to a closed vials.

Gas chromatographic analyses

Sample (5 μL) was transferred to closed chromatographic vial and evaporated on a heating plate. An Agilent 7890A gas chromatograph (Agilent Technologies, Inc., Santa Clara, Cf. USA) was equipped with a Supelcowax-10 30 cm × 0.32 mm × 0.25 mm column. An injector was maintained at 270°C. Initial temperature of 40°C was

maintained for 1 min, then rose to 220°C with a rate of 4°C/min. Helium (0.5 cm^3/min) was used as the gas. Analysed sample mass ranged from 33 to 333Da. Temperature of the ion generator was maintained at 220°C. SPMR injections were performed in a splitless manner. Chromatographic signals were identified by comparison with mass spectra available in the NIST 11 library [22]. Area under particular chromatographic peaks were calculated involving computer program installed in the chromatograph.

Results and Discussion

Figures 1 and 2 present results of watering rocket with LPGP-treated kinds of water upon leaves and roots of the plants, respectively.

Figure 1. Rocket watered with various kinds of the LPGP-treated water.

Source: own research.

Figure 2. Rooting of rocket watered with various kinds of LPGP-treated water.

Source: own research.

Results of estimations of the yield of crops are presented in Table 1.

Table 1. Quantitative characteristics of the rocket crops watered with LPGP-treated kinds of water[a].

Estimations	Non-treated Water	LPGP treated water		
		LPGPA	LPGPN	LPGPC
Number of plants	4.84 ± 0.15a	5.02 ± 0.16a	5.79 ± 0.33b	5.12 ± 0.33a
Height of plants/1 pot [cm]	38.1 ± 4.0a	42.4 ± 2.1a	51.6 ± 2.4b	46.3 ± 2.4a
Total mass of plant [g]	12.52 ± 0.51a	14.27 ± 0.77b	20.86 ± 0.35c	15.17 ± 0.47b
Total number of leaves	36.2 ± 1.1a	41.2 ± 1.4b	45.3 ± 1.2c	48.4 ± 1.1d
Number of leaves per plant	4.9 ± 1.1a	4.2 ± 1.2b	5.1 ± 1.4a	4.3 ± 1.1b
Mass of stems [g]	2.53 ± 0.13a	3.29 ± 0.19b	4.96 ± 0.31c	3.79 ± 0.21d
Total mass of foliage [g]	7.93 ± 0.39a	9.99 ± 0.64b	12.08 ± 0.32c	10.99 ± 0.14d
Mass of one leaf	2.559± 0.012a	3.137± 0.013b	3.751 ±0.012c	3.514± 0.012d

[a] Average number of plants collected from triplicated experiments involving 3 × 24 trays. Each tray contained 10 seeds. Presented data were recalculated for the number of plants in one tray.

Source: own research.

Effect of watering rocket with LPGP-treated water upon fat, protein and carbohydrate content, and content of chlorophylls, carotenoids, ascorbic acid and sulphur compounds are given in Tables 2 and 3, respectively.

Table 2. Fat, protein and carbohydrate content in rocket watered with non-treated and LPGP--treated kinds of water.

Water	Content [g/100g]		
	Fat	Protein	Carbohydrates
Non-treated	0.7±0.01	2.6±0.02	96.7±0.01
LPGPA	0.6±0.01	2.8±0.02	96.6±0.02
LPGPN	0.6±0.01	3.1±0.01	96.3±0.01
LPGPC	0.6±0.02	2.9±0.01	96.3±0.01

Source: own research.

Table 3. Effect of LPGP treated water on the content of chlorophylls, carotenoids, ascorbic acid and sulphur compounds in watered rocket.

Water	Chlorophyll [mg/g]			Carotenoids [mg/g]	Ascorbic acid [mg/g]	Sulphur compounds [%]
	a	b	Total			
Non-treated	1.332 ± 0.016a	0.378 ± 0.016a	1.882 ± 0.031a	0.339 ± 0.011a	0.332 ± 0.016a	0.44 ± 0.02a
LPGPA	1.713 ± 0.012b	0.359 ± 0.011a	2.151 ± 0.012b	0.461 ± 0.011b	0.419 ± 0.009b	0.59 ± 0.01b
LPGPN	1.762 ± 0.013c	0.452 ± 0.009b	2.365 ± 0.011c	0.418 ± 0.010c	0.443 ± 0.015c	0.93 ± 0.03c
LPGPC	1.663 ± 0.012d	0.349 ± 0.011a	2.108 ± 0.012d	0.477 ± 0.008b	0.411 ± 0.012b	0.83 ± 0.02d

Source: own research.

Estimations of dry mass, ash and total sulfur content in rocket watered with particular kinds of water are reported in Table 4.

Table 4. Estimations of dry mass and ash in rocket watered with particular kinds of water.

Water	Dry mass [g]	Ash [%]
Non-treated	7.9 ± 0.1a	2.13 ± 0.02a
LPGPA	8.3 ± 0.2b	2.32 ± 0.02b
LPGPN	9.6 ± 0.1c	3.23 ± 0.01c
LPGPC	8.9 ± 0.1d	2.63 ± 0.02d

Source: own research.

Tables 5 collects data on bioacummulation of cations and anions in so watered rocket.

Table 5. Bioaccumulation of cations in rocket watered with particular kinds of water.

Water	Content [mg/100 g]					
	Cations					
	Na^+	K^+	Ca^{2+}	Mg^{2+}	Mn^{2+}	Fe^{3+}
Non-treated	28 ± 1a	369 ± 3a	156 ± 2a	47 ± 1a	0.3 ± 0.1a	1.5 ± 0.2a
LPGPA	29 ± 1a	377 ± 2b	161 ± 1b	46 ± 1a	0.4 ± 0.1a	1.6 ± 0.1a
LPGPN	29 ± 1a	376 ± 2b	163 ± 1b	46 ± 1a	0.3 ± 0.1a	1.8 ± 0.1a
LPGPC	36 ± 1b	387 ± 2c	167 ± 1c	53 ± 12b	0.6 ± 0.1ab	2.4 ± 0.1b
Anions						
Water	Cl^-	NO_2^-	NO_3^-	SO_4^{2-}	PO_4^{3-}	
Non-treated	218.13 ± 0.01a	0.00 ± 0.00a	41.23 ± 0.01a	119.23 ± 0.02a	9.16 ± 0.02a	
LPGPA	219.31 ± 0.02b	0.00 ± 0.00a	41.83 ± 0.01b	121.32 ± 0.01b	9.07 ± 0.02b	
LPGPN	221.14 ± 0.02c	0.02 ± 0.01b	46.23 ± 0.01c	126.22 ± 0.01c	8.56 ± 0.02c	
LPGPC	224.11 ± 0.02d	0.00 ± 0.00a	42.53 ± 0.01d	120.29 ± 0.01d	8.96 ± 0.02d	

Source: own research.

Composition of essential oils extracted from so planted rocket is given in Table 6.

Table 6. Composition of essential oil collected from rocket watered with non-treated water and water treated with glow plasma in the air (LPGPA), under nitrogen (LPGPN) and carbon dioxide (LPGPC).

Peak number	Retention time [min]	Compound	Content [%] of component in the oil from the plant watered with watera			
			Non-treated water	LPGPA	LPGPN	LPGPC
1	2	3	4	5	6	7
1.	21.38	Butyl isothiocyanate	0.23	–	–	–
2.	21.90	cis-3-Hexenyl acetate	0.31	0.03	0.16	0.09
3.	22.43	4,4-Dimethyl thiacyclobutane--2-one	0.04	–	0.02	–
4.	22.63	5-Methyl hexanenitrile	0.31	–	–	0.11
5.	23.30	Propanal	1.02	1.13	0.98	0.91
6.	24.38	3-Butenyl isothiocyanate	0.02	–	–	–
7.	24.68	Furfural	0.02	0.11	0.35	0.11
8.	25.55	iso-Hexyl isothiocyanate	0.51	0.42	0.38	0.31
9.	25.78	1-Octanol	0.26	0.28	0.38	0.11
10.	26.37	Hexyl isothiocyanate	0.11	–	0.09	–
11.	30.53	Thiophene	0.71	0.62	0.13	–
12.	30.97	2-Methyl propanoic acid	0.11	0.16	0.21	0.3
13.	31.20	Propanoic acid	0.03	–	–	–
14.	31.38	2-Pentanonitrile	6.25	6.11	8.68	7.56
15.	31.67	Nonadecane	0.03	–	–	–
16.	32.10	5-Methylthiopentanonitrile	13.58	13.78	20.39	17.43
17.	32.83	3-Methythiopropyl isothiocyanate	0.51	1.23	1.6	1.49
18.	33.33	Eicosane	0.08	0.10	0.03	0.12
19.	35.00	Heneicosane	0.06	–	–	–
20.	35.58	4-Methylthiobutyl isothiocyanate	62.38	63.26	53.41	61.38
21.	35.87	Eugenol	0.94	1.32	1.11	1.01

1	2	3	4	5	6	7
22.	37.37	5-Metylthiopentyl isothiocyanate	0.62	0.52	0.73	0.68
23.	38.33	Tricosane	0.87	0.73	0.36	0.38
24.	41.67	Pentacosane	1.32	1.12	1.23	0.78
25.	43.20	Isophytol	2.61	2.36	3.38	1.25
26.	43.33	Hexacosane	0.99	0.84	0.84	0.79
27.	44.13	Myristic acid	0.06	0.03	–	–
28.	45.00	Heptacosane	0.82	0.71	0.12	0.14
29.	45.28	Eicosanol	0.03	–	–	–
30.	46.67	Octacosane	0.18	0.18	0.14	0.13
31.	48.33	Nonacosane	1.92	1.82	1.82	1.98
32.	50.00	Triacontane	0.28	0.21	0.32	0.33
33.	51.03	Squalene	0.09	–	–	–
34.	51.67	Untriacontane	0.23	0.19	0.11	0.12
37.	52.58	Linoleic acid	0.31	0.32	0.22	0.22
38.	53.18	Linolenic acid	0.10	–	–	0.06
39.	54.42	Oleamide	2.06	2.32	2.44	2.04
Total numer of components			39	29	30	29
Total yield of essential oil [mL/100 g dry mass]			0.2	0.2	0.2	0.2

[a] Total yield of essential oil = 100%

Source: own research.

In every case, watering with LPGP-treated water provided higher yield of crops (Table 1). Evidently, watering experimental rocket plantations with LPGP-treated kinds of water was beneficial for the yield of crops. LPGPN offered the highest yield of crops. The data showed that watering rocket with LPGPC provided more leaves per one plant, but they are less handsome than these observed in rocket watered with LPGPN. Plants were lusher when watered with particular kinds of LPGP-treated water and the watering with LPGPN was the most efficient in this respect (Figure 1).

The watering with the LPGP-treated water, regardless its kind, decreased the level of fat in the crops by approximately 14%. It was meaningless for the level of carbohydrates and the level of proteins slightly increased. The latter was the highest in case of watering with LPGPN (Table 2).

Application of the LPGP-treated water had a diverse effect upon the level of chlorophylls, carotenoids and ascorbic acid (Table 3). Such watering always increased the level of total chlorophylls but that effect upon the levels of chlorophylls *a* and *b* was not parallel. All kinds of LPGP-treated water always increased the level of chlorophyll *a* but LPGPA and LPGPC decreased the level of chlorophyll *b*.

The borders given below present effect of particular kinds of water upon the level of carotenoids and ascorbic acid:

- carotenoids: non-treated < LPGPN < LPGPA < LPGPC
- ascorbic acid: non-treated < LPGPC $\leq$ LPGPC < LPGPN

Thus, for achieving the crops the richest in carotenoids and ascorbic, watering with LPGPC and LPGPN, respectively, should be recommended. Watering rocket with LPGP-treated water appeared beneficial for formation of sulphur compounds essential for the taste and scent of that plant. Watering rocket with LPGPN was the most beneficial in this respect. Increased yield of crops resulted in an increase in the dry mass of crops and ash from it (Table 4).

An increased yield of dry mass resulted from a higher content of organic components listed in Tables 2 and 3 and bioaccumulated minerals as suggested by an increase in the level of estimated ash. Such kind watering facilitated bioaccumulation of sulphur compounds from the turf. Only watering rocket with LPGPC considerably increased accumulation of cations in the crops (Table 5). It might suggest trapping the cations by carbonic acid formed from CO_2 assimilated from that water. Also bioaccumulation of anions by rocket watered with LPGP-treated water was affected to a certain extent. One could observe bioaccumulation of the NO_2^- and NO_3^- anions in the plant watered with LPGPN. This fact together with increased level of proteins estimated in so watered rocket provided evidence for assimilation of the nitrogen present in LPGPN and its incorporation in processes catalysed by either enzymes or metal ions (Table 5).

Miyazawa et al. [4] isolated 67 components from the essential oil of rocket watered with non-treated water. Among them, 25 components resided in the concentration below 0.1%. Essential oil isolated from the plant grown in the present studies contained 39 components at the concentration of 0.1% and above (Table 6). The number of those components was reduced to 29, 30 and 29 in the essential oils extracted from the plant watered with LPGPA, LPGPN and LPGPC, respectively. That effect resulted solely from the elimination of some components residing in the essential oil isolated from control sample. The watering with all three LPGP-treated kinds of water did not produce any novel components absent in the control sample. The scent of the plant and its essential oil could be modified by the effect of used water upon the yield of components.

Regardless the kind of applied water sulphur containing compounds constituted the major fraction of extracted oils. That fraction contained chiefly isothiocyanates with dominating 4-methylthiobutylisothiocyanate. There were 62.38w% of that compound in the oil extracted from the plant watered with non-treated water. The latter compound was accompanied by other thiocyanates present in amounts below 1w%. 5-methylthiopentane- nitrile and thiophene (13.58 w% and 0.71w%, respectively) completed the composition of the fraction of the sulphur containing compounds. The yield of 4-methylthiobutylisothiocyanate could be slightly modified by watering rocket with LPGPA. An increase by ~1% was noted. LPGPN and PGPC decreased its content by ~10 and ~1%, respectively. Simultaneously, the yield of 5-methylthiopentanonitrile increased by ~0.2 ~7% and ~4%, respectively, and the yield of thiophene declined in the order: non-treated water (0.71%) > LPGPA (0.62%) > LPGPN (0.13%) > LPGPC (0%).

Apart from 10 sulphur containing components, the control essential oil contained also 29 sulphur-free compounds. Among them propanal, 2-pentanonitrile, pentacosane, isophytol, nonacosane and oleamide resided in amount exceeding 1.0 %.

The yield of pentacosane in the control sample declined to 1.12, 1.23 and 0.78%, respectively. That component is toxic to animals because as cytochrome P450 liberates pentanocyanide from it . The cyanide is detoxified and excreted in urine as thiocyanate. It resides also in *Brassica* species and varieties such as broccoli [23]. Its 6.25% concentration in control sample decreased to 6.11% in the essential oil extracted from the LPGPA watered plant and increased to 8.68 and 7.56 in the oil form the plant watered with LPGPN and LPGPC, respectively. Pentacosane is part of the female sex pheromone of the bee *A. nigroaenea*, and of females of the long-horned beetle *Xylotrechus colonus* [24].

The control sample of essential oil contained 2.61% isophytol, a terpenoid alcohol that is used as a fragrance and as an intermediate in the production of vitamin E and K1 [25, 26]. The watering plant with either LPGPA, LPGPN or LPGPC changed the concentration of that component to 2.36, 3.38 and 1.25, respectively. Thus, the watering rocket with LPGPN seemed to be beneficial for the plant. Nonacosane, a hydrocarbon, occurs naturally as a component of an mosquito pheromone [25]. Its 1.92% concentration in control essential oil was practically independent of the kind of water used for watering. The control essential oil contained also 2.06% oleamide. In nature, that amide accumulates in the cerebrospinal fluid during sleep deprivation and induces sleep in animals [27, 28]. For that sake it is considered as a factor for potential treatment for mood and sleep disorders, as well as cannabinoid-regulated depression [29]. It is one of the most frequent non-cannabinoid ingredients associated with spice products [30]. In essential oils extracted from rocket watered with LPGPA or LPGPN the concentration of oleamide increased to 2.32 and 2.44%,

respectively, whereas watering with LPGPC declined the yield of that compound to 2.04%. Watering with either LPGPA, LPGPN or LPGPC increased the concentration of eugenol from 0.94% in control extract to 1.32, 1.11 and 1.01%, respectively. Eugenol is used as a flavour or aroma ingredient in teas, meats, cakes, perfumes, flavourings, and essential oils [31]. It is also used as a local antiseptic and anaesthetic [32, 33]. For that sake the use of LPGPA, LPGPN and LPGPC seemed to be beneficial as watering with those kinds of water increased the level of eugenol in the essential oils.

Elucidation of the mechanisms of observed effects for particular organisms and kinds of used water requires separate studies. Undoubtedly, several factors are involved. Among them condition of solvation of reagents, including enzymes should be taken into account. Composition of the cells and, hence, conditions of osmosis should also be essential. Since clathrates resulting from the LPGP treatment are unstable in acidic media, the pH inside the cells can also be involved.

Conclusions

Watering rocket with the water treated with plasma under nitrogen provides the most lush plant. The kind of plasma treated water had a minor effect on rooting of the plants. Watering rocket with all kinds of plasm treated water offered higher yield of crops and watering with water treated with plasma under nitrogen was the most beneficial in this respect. The watering with the plasma treated water regardless its kind decreased the level of fat in the crops by approximately 14%. It was meaningless for the level of carbohydrates and slightly increased the level of proteins. All kinds of the plasma-treated water always increased the level of chlorophyll *a* but water treated with plasma in the air and under carbon dioxide decreased the level of chlorophyll *b*. The watering with the plasma treated water provides crops of a higher level of carotenoids, ascorbic acid and sulphur containing compounds. Watering rocket with LPGPN was the most beneficial in this respect. Watering rocket with various kinds of the plasma treated water influences the composition of the essential oils extracted from the leaves. No novel components were found in the extracts but the yield of some components was essentially influenced. Diverse effects of various kinds of the plasma treated water provide tailoring functional properties of the plant and essential oil extracted from it.

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