Journal of Elementology ISSN 1644-2296

Jadczak D., Bojko K., Wysocka G., Szymańska M. 2019.
*Yield and biological properties of leaf parsley (Petroselinum crispum (*Mill.*)* Nym. Ex A.W. Hillc Convar. *Crispum).*
J. Elem., 24(2): 803-815. DOI: 10.5601/jelem.2018.23.4.1697

RECEIVED: 18 June 2018
ACCEPTED: 6 November 2018

ORIGINAL PAPER

YIELD AND BIOLOGICAL PROPERTIES OF LEAF PARSLEY (*PETROSELINUM CRISPUM* (MILL.) NYM. EX A.W. HILLC CONVAR. *CRISPUM*)*

Dorota Jadczak, Kamila Bojko, Gabriela Wysocka, Magdalena Szymańska

Department of Horticulture
West Pomeranian University of Technology, Szczecin, Poland

Abstract

The study evaluated yield, quality parameters and biological value of the yield of selected leaf parsley cultivars. The investigated material included marketable yield (entire leaves), and chemical analyses of fresh leaves included the determination of dry weight, total acidity, the content of L-ascorbic acid, chlorophyll a and b and total chlorophyll, total carotenoids, total polyphenols and antioxidant activity measured as the inhibition of DPPH radicals. The aim was investigate a few cultivars of leaf parsley, including ones with curly and with plain leaves. The variety with plain leaves called Plain Leaf produced significantly higher yield of 166.52 t ha^{-1} in 2015 and 97.31 t ha^{-1} in 2016. The cultivars Gigante d'Italia, Plain Leaf and Lisette achieved the highest percentage share of leaf blades in their yield. The cultivars Lisette and Neapolitan parsley showed the highest content of pigments. A comprehensive analysis identified cv. Neapolitan as the most valuable cultivar – the richest in polyphenols and L-ascorbic acid and with the highest antioxidant activity measured by the inhibition of DPPH radicals. With the mean content of calcium at 40 007.5 mg kg^{-1} DM and magnesium at 3208.25 mg kg^{-1} DM in 2016, the leaves of cv. Titan were the richest in elements building bones, teeth, skin and hair. The leaves of cv. Plan Leaf contained high levels of sodium, magnesium, copper, iron, cadmium and manganese. The growing conditions, including soil type, fertilization, moisture content and insolation, may have had influence on yield and biological value of parsley leaf.

Keywords: biological value, macronutrients, micronutrients, leaf parsley.

Dorota Jadczak, Prof., Department of Horticulture, West Pomeranian University of Technology, 17 Slowackiego Street, 71-434 Szczecin, Poland, e-mail: dorota.Jadczak@zut.edu.pl
* Financial commitments: Activity statute, nr 518-07-014-3171-01/18

INTRODUCTION

Leaf parsley (*Petroselinum crispum* (Mill.)) is a biennial plant belonging to the *Apiaceae* (Lindl.) family. It is native to the Mediterranean region and West Asia (Mahmood et al. 2014). As a seasoning vegetable, it is cultivated in Poland on a small scale and its current economic importance remains low. Many cultivars of leaf parsley have not been investigated yet. In Poland, the most valuable cultivars are Festival 68, Gala, Messis, Natalka, Nutka, and Pesto (COBORU 2018). The edible parts are leaves that may be dried, frozen or consumed raw. This highly aromatic herb with great biological value is commonly used in China, Mexico, South America, India, North-East Asia (Wong, Kitts 2006). The leaf rosette of leaf parsley has an upright or semi-upright habit and contains 40-100 tripinnate leaves. It is a rich source of many biologically active compounds, including vitamin C, B and K and minerals (Kmiecik, Lisiewska 1999, Dyduch, Janowska 2004, Kołota 2011, USDA 2017).

Parsley leaves show diuretic and disinfecting properties as their essential oil contains such compounds as apiol, myristicine and α-pinene (Vokk et al. 2011), and they are valued by the food industry for their high content of phenolic compounds (Gaweł-Bęben et al. 2016). Leaf parsley is a popular herb mostly due to its aromatic flavour (Dyduch, Janowska 2004, El-Zaeddi et al. 2016). The species is grown, similarly to root parsley, by sowing seeds directly in the field. It is tolerant to low temperatures and may overwinter.

The aim of the study was to investigate seven cultivars of leaf parsley, including two with curly leaves (Champion Moss Curled and Lisette) and five with plain leaves (Gigante d'Italia, Italian Giant, Neapolitan, Plain Leaf, and Titan). The work also compared the biological value of the yield of the tested cultivars by specifying their dry weight and total acidity and the content of chlorophyll *a*, *b* and total chlorophylls, total carotenoids, L-ascorbic acid, total polyphenols and antioxidant activity measured as a percentage of DPPH radical inhibition. The results of the research will increase the range of varieties of leaf parsley recommended for cultivation

MATERIAL AND METHODS

The experiments were carried out in the years 2015-2016 at the Vegetable Experimental Station in Dołuje, West Pomerania region (53°26′09.6″N 14°24′35.8″E). The assessment involved seven varieties of leaf parsley: Plain Leaf, Lisette, Italian Giant, Neapolitan, Champion Moss Curled, Titan, and Gigante dItalia. The seeds were purchased from two British seed companies: Thompson & Morgan and Chiltern Seeds.

Univariate field experiments were run in triplicate. The seeds were sown on April 15, 2015 and April 12, 2016, on experimental plots with an area

of 1.44 m^2 (1.2×1.2 m), in rows spaced every 30 cm, at a sowing dose 6 kg of seeds per hectare.

Soil samples were collected prior to sowing for the determination of the content of basic nutrients and necessary fertilization. The analysis was performed at the Chemical and Agricultural Station in Szczecin, and its results are presented in Table 1. Missing nutrients were supplemented up to the

Table 1

The content of minerals in the soil samples from the experimental field

Year	pH H_2O	Content of mineral components (mg dm^{-3})						Salinity (mg NaCl dm^{-3})
		$N\text{-}NO_3$	P	K	Ca	Mg	Cl	
2015	7.4	64	114	163	4775	153	14	0.32
2016	8.0	16	104	149	4260	177	16	0.27

level optimal for root parsley based on the following limits: 120 mg N, 50 mg P and 175 mg K (Janas et al. 2013). Potassium fertilizer in the form of potassium sulfate was used on all plots prior to seed sowing. No phosphate fertilization was applied due to the high content of phosphorus in the soil samples. Nitrogenous fertilizer in the form of calcium nitrate was administered in three even doses – two weeks before seed sowing, together with potassic fertilizers as top dressing after plant emergence, and a month later. The experimental plots were prepared in accordance with agricultural principles for vegetable crops sown directly into the field. Agrotechnical treatments during the plant growing season consisted mainly of weeding and irrigation.

Soil on the experimental plots was of the umbrisol type with a high humus content, high sorption capacity and high groundwater level, ca. 95 cm (Mikiciuk, Tomaszewicz 2016).

The crop was harvested once a year, on 24 August 2015 and on 30 August 2016. Immediately after harvest, the yield per 10 m^2 was evaluated, and the total share of leaf petiole and leaf blades was an element of quality assessment. Chemical analyses (entire leaves) were made on an average pooled yield of each variety. The weight of a single sample submitted to an analysis was around 500 g.

Chemical analyses of fresh leaves included the determination of dry weight, total acidity, the content of vitamin C as L-ascorbic acid, chlorophyll *a* and *b* and total chlorophyll, total carotenoids, total polyphenols and antioxidant activity measured as inhibition of DPPH radicals. Dry matter content was determined by drying the leaves to constant weight at 105°C (Krełowska-Kułas 1993). Total acidity (expressed in g per 100 g of fresh weight converted into citric acid) was measured based on titration of an aqueous extract from parsley tissue with 0.1 M NaOH in the presence of phenolphthalein

(KREŁOWSKA-KUŁAS 1993). The content of vitamin C as L-ascorbic acid was determined by Tillman's method (KREŁOWSKA-KUŁAS 1993). The content of total chlorophyll and chlorophyll *a* and *b* and carotenoids was determined according to LICHTENTHALER and WELLBURN (1983). The total polyphenol content was assessed spectrophotometrically with Follin-Ciocalteu reagent and gallic acid as a standard, according to SINGLETON and ROSSI (1965). Antioxi-

Table 2

Meteorological conditions in the years 2015-2016 recorded at the Meteorological Station in Szczecin Dąbie, monthly deviation from the years 1971-2000

Year of study	Months							Sum average
	April	May	June	July	August	September	October	
The average air temperature (°C)								
2015	8.7	12.5	15.6	18.6	21.1	14.1	8.5	14.2
2016	8.8	15.7	18.5	19.0	17.8	16.8	8.6	15.0
Multi-year average 1971-2000	9.8	12.9	16.2	17.8	17.4	13.6	9.1	13.8
Deviation from the multi-year average compared to 2015	-1.1	-0.4	-0.6	0.8	3.7	0.5	-0.6	0.3
Deviation from the multi-year average compared to 2016	-1.0	2.8	2.3	1.2	0.4	3.2	-0.5	1.2
Total precipitation (mm)								
2015	29.0	48.0	32.8	62.0	14.7	34.4	38.5	361.9
2016	20.2	18.9	69.0	50.0	47.8	18.3	55.3	279.5
Multi-year average 1971-2000	36.0	54.0	59.0	65.	56.0	46.0	53.0	369.0
Deviation from the multi-year average compared to 2015	-7.0	-6.0	-26.2	-3.0	-41.3	-11.6	-14.5	-109.6
Deviation from the multi-year average compared to 2016	-15.8	-35.1	10.0	-15.0	-8.2	-27.7	2.3	-89.5
Sunshine duration (h)								
2015	226.3	209.0	191.3	221.2	312.0	186.0	125.0	1703.7
2016	200.4	287.8	267.7	196.4	217.8	256.0	43.1	1704.9
Multi-year average 1971-2000	150.0	220.0	200.0	200.0	200.0	120.0	80.0	1170.0
Deviation from the multi-year average compared to 2015	76.3	-11.0	-8.7	21.2	112.0	66.0	45.0	533.7
Deviation from the multi-year average compared to 2016	50.4	67.8	67.7	-3.6	17.8	136.0	-36.9	534.9

dant activity was determined based on the reduction of free radicals (DPPH), according to YEN and CHEN (1995) and the DPPH inhibition percentage was calculated according to the formula provided by ROSSI et al. (2003). The dry weight content of minerals (calcium, magnesium, iron, copper, zinc, cobalt, nickel, lead, manganese, cadmium) was assessed using atomic absorption spectrophotometry (ASA), which consists in measuring the absorption of cathode ray radiation by free atoms of the element in a mineralized sample (in a 1:1 mixture of nitric and perchloric acid). Sodium and potassium were determined by flame photometry, which consists in measuring the intensity of radiation emitted by induced atoms of the element in the flame of a burner in the mineralized solution (as above). Plant phosphorus discharged into the solution after mineralization (as above) was colorimetrically examined by the molybdenum method based on colour complexes formed by orthophosphoric ions in the presence of molybdates.

The study results were subjected to statistical evaluation with the Tukey's test, for a random block system, and half-confidence intervals were computed at the significance level $\alpha = 0.05$. Statistical calculations were performed with FR-ANALWAR-4.3 calculation package.

An analysis of hydrothermal conditions for a multi-year period and the years of the study was based on the data published on the OGIMET (2018) website for Szczecin. They were used to prepare a chart presenting the distribution of air temperature, precipitation and sunshine duration. Table 2 shows a comparison of data from April to October 2015 and 2016 with the multi-year period 1971-2000 (Table 2). The average air temperature in 2015 and 2016 was conducive to the cultivation of leaf parsley. The warmest month of 2015 was August with the average air temp. of 21.1°C, and in 2016 it was July with the average temp. of 19.0°C. In 2015, the average monthly air temp. between April and October was by about 0.8°C lower than in 2016. Distribution of precipitation was less favourable. In April (seed sowing) of both years, the precipitation was only 20.2-29.0 mm. Therefore, the seeds required irrigation directly after sowing to facilitate their germination. Sunshine duration in the experimental years in April and between August and September was by 533.7-534.9 h longer than in the multi-year period.

RESULTS AND DISCUSSION

Yields of all leaf parsley cultivars are presented in Table 3. The yields varied significantly between the cultivars in abd between the years. In 2015, the highest yield (166.52 t ha^{-1}) was achieved from cv. Plain Leaf. However, there were no significant differences with the yield of cvs. Gigante d'Italia, Lisette or Neapolitan. The smallest yield (74.29 t ha^{-1}) was harvested from cv. Champion Moss Curled, and it was statistically different only from that of Gigante d'Italia and Plain Leaf parsley. In 2016, the most productive cul-

Table 3

Yield of leaf parsley cultivars

Cultivar	Total yield (t ha^{-1})			Yield of leaf blades (t ha^{-1})			Leaf blade share in total yield (%)		
	2015	2016	mean	2015	2016	mean	2015	2016	mean
Plain Leaf	166.52	97.16	131.84	83.50	61.53	72.53	50.14	63.35	55.01
Lisette	132.43	67.15	99.79	78.90	50.97	64.94	59.58	75.91	65.07
Italian Giant	83.42	80.47	81.95	52.60	42.97	47.79	58.50	53.40	56.09
Neapolitan	128.25	57.40	92.82	73.58	25.32	49.45	57.37	44.12	53.27
Champion Moss Curled	74.29	79.36	76.83	43.25	48.63	45.94	58.21	70.60	64.17
Titan	83.37	62.75	73.06	52.36	50.54	51.45	62.80	85.39	72.18
Gigante d'lItalia	147.27	99.31	123.30	90.36	50.93	70.65	52.45	53.52	52.83
$LSD_{\alpha=0.05}$	60.39	39.40	37.38	20.467	0.067	10.223	-	-	-

tivars were Gigante d'Italia and Plain Leaf, but statistical differences were determined only for the yield of Neapolitan parsley. The highest average yield for both study years (131.84 t ha^{-1}) was determined for cv. Plain Leaf parsley. The yields of cvs. Gigante d'Italia and Lisette were on the same level. Italian Gigant, Champion Moss Curled and Titan were the least productive cultivars and their yield reached 81.95, 76.83 and 73.06 t ha^{-1}, respectively.

Kołota et al. (2012) reported the yield of cv. Titan leaves to be 35.51 t ha^{-1}, while for the other investigated cultivars it ranged from 45.41 to 14.08 t ha^{-1}. In our study, the yield of cv. Titan was between 62.75 and 83.37 t ha^{-1}. Leaf parsley yield reported by Karklelienė et al. (2014) was 30 t ha^{-1} for Champion Moss Curled and 32.0 t ha^{-1} for Gigante d'Italia. They also found cv. Festival to be the most productive one, with yield reaching as much as 36.0 t ha^{-1}. Dyduch and Janowska (2004) reported a yield of 127.55 t ha^{-1} for the leaves of cv. Titan. According to Osińska et al. (2012), the yield of cv. Amphia leaf parsley reached 26.10 t ha^{-1}.

An important aspect of leaf parsley yield is the share of leaf blades. Significant, cultivar-dependent differences in their size were observed in individual years of the study. In the first year of the study (2015), this yield was considerably higher for Gigante d'Italia, Plain Leaf, Lisette and Neapolitan parsley (respectively 90.36, 83.50, 78.90, 73.58 t ha^{-1}). In 2016, the highest yield of leaf blades was obtained for cv. Plain Leaf (61.53 t ha^{-1}), and the lowest for cv. Neapolitan (25.32 t ha^{-1}). The yield of the other cultivars ranged from 42.97 to 50.97 t ha^{-1}. For both study years, the highest average

leaf yield was achieved for cvs. Plain Leaf (72.53 t ha), Gigante dItalia (70.65 t ha) and Lisette (64.94 t ha^{-1}).

Kołota (2011) reported an average yield of leaf blades produced by cv. Titan to reach 55.80%. In our study, this share was cultivar-dependent, and it ranged from 44.12% for cv. Neapolitan to 85.39% for cv. Titan grown in 2016. Kołota et al. (2012) achieved a 64.83% share of leaf blades in the total yield of cv. Titan grown in the years 2004-2005.

Dry weight determined in fresh plant material from the cultivars of leaf parsley differed significantly between the study years (Table 4). In 2015,

Table 4

Dry weight and biochemical composition of leaf parsley cultivars

Cultivar	Dry matter (%)			Total carotenoids (mg kg^{-1} FM)			L-ascorbic acid (mg 100g^{-1} FM)		
	2015	2016	mean	2015	2016	mean	2015	2016	mean
Plain Leaf	23.03	15.26	19.15	217.11	213.51	215.31	169.70	251.34	210.52
Lisette	22.17	15.61	18.89	147.50	258.40	202.95	206.38	201.90	204.14
Italian Giant	24.65	16.49	20.57	275.11	208.32	241.71	106.28	233.94	170.11
Neapolitan	21.82	18.45	20.14	305.46	257.18	281.32	121.30	266.16	193.73
Champion Moss Curled	21.93	15.05	18.49	274.42	256.65	265.54	120.58	156.00	138.29
Titan	21.34	15.80	18.57	278.98	166.09	222.53	105.34	159.48	132.41
Gigante d'Italia	21.68	15.18	18.43	277.33	224.59	250.96	95.76	217.32	156.54
$LSD_{\alpha=0,05}$	0.596	0.252	n.s.	132.952	n.s.	n.s.	69.338	113.668	57.816

n.s. – non-significant differences

it was the highest for cv. Italian Giant (24.65%), and in 2016 – for cv. Neapolitan (18.45%). However, average results for both years showed no significant differences in dry weight of the yield. Dry weight values determined in our study were consistent with those reported by other authors. An experiment conducted by Karklelienė et al. (2014) identified Champion Moss Curled as a cultivar with the greatest dry weight (19.4%), while in our study dry weight of this cultivar was 15.05-21.93%. Similarly, dry weight of cv. Gigante dItalia determined by Karklelienė et al. (2014) was 18.3%, and in our experiment it ranged from 15.18 to 21.68%. Lisiewska and Kmiecik (1997) reported dry weight yield of 17.3% for leaf parsley and 20.0% for root parsley.

Significant differences in total carotenoid content were found only in the first year of the study, when their leaf level in cv. Neapolitan (305.46 mg kg^{-1} FM) was higher than in cv. Lisette (147.50 mg kg^{-1} FM). Karklelienė et al. (2014) confirmed the highest carotenoid content in the leaves of cv. Champion

Moss Curled (5.4 mg%), and the lowest – in cv. Gigante d'Italia (5.1 mg%). According to Lisiewska and Kmiecik (1997), the leaves of leaf parsley contain about 9.4 mg 100 g^{-1} FM of total carotenoids.

Despite statistical differences in the content of L-ascorbic acid, no clear patterns were identified for individual cultivars of leaf parsley. In 2015, this compound was the most abundant in the leaves of cv. Lisette (206.38 mg kg^{-1} FM), and the least – in cv. Gigante d'Italia (95.75 mg kg^{-1} FM). In 2016, the highest content of L-ascorbic acid was determined for cv. Neapolitan (266.16 mg kg^{-1} FM), and its mean content for all the investigated cultivars ranged from 132.19 to 212.31 mg kg^{-1} FM. Based on average results for both study years, the cultivars richest in L-ascorbic acid included Plain Leaf, Lisette, Neapolitan and Italian Giant. Mazurek and Pankiewicz (2012) reported that the leaves of leaf parsley contained 210.12 mg 100 g^{-1} of L-ascorbic acid and 222.48 mg 100 g^{-1} of dehydro-L-ascorbic acid, and their content declined during storage. The authors emphasized a high level of this compound in parsley leaves and compared it with fresh lemon, which contains 71.17 mg 100 g^{-1} of L-ascorbic acid. This confirms that parsley leaves have four times more of vitamin C than lemons, generally considered a rich source of this vitamin. Kołota et al. (2012) determined the highest content of vitamin C (370.9 mg 100 g^{-1} FM) in the yield of Karnaval leaf parsley. They also observed a decreasing content of vitamin C on subsequent harvest dates. Karklelienė et al. (2014) reported the highest levels of L-ascorbic acid (162.8 mg 100 g^{-1}) in leaf parsley cv. Champion Moss Curled, and the lowest (138.5 mg 100 g^{-1}) – in cv. Gigante d'Italia.

A comparison of the chlorophyll content in the investigated cultivars of leaf parsley revealed significant differences only for chlorophyll *b* and total chlorophyll in the first year of the study. In both cases, significantly more chlorophyll *b* (798.96 mg kg^{-1} FM) and total chlorophyll (2386.89 mg kg^{-1} FM) was detected in the leaves of cv. Lisette vs. cv. Neapolitan (Table 5). Karklelienė et al. (2014) claimed that an average chlorophyll content in parsley leaves ranged from 0.6 to 3.9 mg kg^{-1} FM). These authors reported the highest total content of chlorophyll in the leaves of cv. Astra (1440 mg kg^{-1}), while the leaves of cv. Gigante d'Italia contained 1250 mg kg^{-1} of total chlorophylls. In our study, the mean total chlorophyll content in cv. Gigante d'Italia was 1952.38 mg kg^{-1} FM. In cv. Champion Moss Curled, thw chlorophyll content determined by Karklelienė et al. (2014) was 1150 mg kg^{-1}, and in our study the total content of this pigment reached 1660.06 mg kg^{-1} FM in 2015 and 1905.13 mg kg^{-1} FM in 2016. Lisiewska and Kmiecik (1997) concluded that a chlorophyll level in root parsley (2030 mg kg^{-1} FW) was by 10.34% higher than in leaf parsley (1660.38 mg kg^{-1} FM).

No significant differences were found for total acidity measured as the content of citric acid in fresh weight of the investigated leaf parsley cultivars (Table 6). Citric acid was the least abundant in 2016 in cv. Plain Leaf

Table 5

Content of *a*, *b* and total chlorophyll in the investigated cultivars of leaf parsley

Cultivar	Chlorophyll *a* (mg kg^{-1} FM)			Chlorophyll *b* (mg kg^{-1} FM)			Total chlorophyll (mg kg^{-1} FM)		
	2015	2016	mean	2015	2016	mean	2015	2016	mean
Plain Leaf	1080.82	1100.88	1090.85	609.56	648.76	629.16	2076.03	2129.59	2102.81
Lisette	1102.71	1034.13	1068.42	798.96	499.78	649.37	2386.89	1796.97	2091.93
Italian Giant	1041.77	1103.33	1072.55	453.59	655.32	554.46	1757.73	2147.02	1952.38
Neapolitan	847.61	1075.26	961.43	282.27	517.63	399.95	1280.64	1897.50	1589.07
Champion Moss Curled	1003.17	1076.65	1039.91	423.45	526.08	474.76	1660.06	1905.13	1782.59
Titan	1010.68	1101.04	1055.86	417.98	762.89	590.44	1665.66	2305.37	1985.51
Gigante d'Italia	1022.00	1092.08	1057.04	435.76	608.81	522.29	1707.47	2067.68	1887.58
$LSD_{\alpha=0.05}$	n.s.	n.s.	n.s.	433.643	n.s.	n.s.	962.253	n.s.	n.s.

n.s. – non-significant differences

Table 6

Total polyphenols, total acidity and antioxidant activity in the investigated cultivars of leaf parsley

Cultivar	Total acidity (% acid lemon FM)			Total polyphenols (mg 100 g^{-1} FM)			Antioxidant activity (% DPPH inhibition)		
	2015	2016	mean	2015	2016	mean	2015	2016	mean
Plain Leaf	128.64	109.56	119.10	342.68	200.75	271.71	2.16	4.34	3.25
Lisette	130.53	114.03	122.28	330.50	193.75	262.12	4.24	7.84	6.04
Italian Giant	154.37	129.13	141.75	459.62	249.82	354.72	7.82	7.12	7.47
Neapolitan	157.63	160.73	159.18	424.42	289.97	357.20	8.62	14.26	11.44
Champion Moss Curled	153.51	129.31	141.41	373.89	232.38	303.13	9.59	12.72	11.15
Titan	166.38	125.88	146.13	300.80	178.98	239.89	6.61	2.70	4.65
Gigante d'Italia	137.22	110.76	123.99	364.31	221.81	293.06	4.80	8.24	6.52
$LSD_{\alpha=0.05}$	n.s.	n.s.	n.s.	32.077	68.995	39.440	n.s.	1.918	n.s.

n.s. – non-significant differences

(109.56% of citric acid FM), and the most abundant in 2015 in cv. Titan parsley (166.38% of citric acid FM). Parsley leaves are a valuable source of antioxidants, mainly polyphenols, and dried leaves stored at low temperature retain 100% of their antioxidants (Śledź, Witrowa-Rajchert 2012). The antioxidant content ranged from 20.3 to 21.8 mg of gallic acid g^{-1} DM. Contrary to that, our study revealed significant differences in the total polyphenol

Table 7

Content of minerals in the leaves of investigated parsley cultivars (mg kg^{-1} DM)

Dry mass (%)	Year	Cultivars of leaf parsley							$LSD_{\alpha=0.05}$
		Plain Leaf	Lisette	Italian Giant	Neapolitan	Champion Moss Curled	Titan	Gigante d'Italia	
	2015	92.30	92.55	92.55	92.59	92.89	92.85	92.84	0.445
	2016	92.12	92.39	92.23	91.91	91.62	91.95	92.10	0.345
	mean	92.21	92.53	92.39	92.25	92.24	92.40	92.47	n.s.
P	2015	5.66	5.66	5.56	6.04	5.49	6.11	6.28	n.s.
	2016	5.51	5.80	5.85	5.54	5.80	5.97	5.87	n.s.
	mean	5.59	5.73	5.71	5.79	5.65	6.04	6.07	n.s.
K	2015	119225.0	108450.0	107525.0	110525.0	95500.0	69600.0	107800.0	n.s.
	2016	106100.0	66875.0	78300.0	72700.0	104250.0	103350.0	94450.0	n.s.
	mean	112662.5	87662.5	92912.5	91612.5	99875.0	86475.0	101125.0	n.s.
Ca	2015	33640.0	28302.5	34075.0	30492.5	26367.5	33322.5	21550.0	n.s.
	2016	23677.0	19147.5	20895.0	17300.0	35595.0	46692.5	10750.0	4475.913
	mean	28658.75	23725.0	27485.0	23896.25	30981.25	40007.5	16150.0	n.s.
Mg	2015	3242.00	2193.50	3102.50	1678.75	1599.75	2477.50	1909.00	205.984
	2016	2542.25	1873.25	2602.25	2128.00	2518.75	3208.25	2651.25	531.653
	mean	2892.13	2033.38	2852.38	1903.38	2059.25	2842.88	2280.13	n.s.
Na	2015	3438.00	1971.00	1106.50	977.10	1399.00	944.25	1035.20	785.064
	2016	1593.50	988.45	1063.00	1567.00	1120.50	772.00	978.55	519.822
	mean	2516.75	1479.73	1084.75	1272.05	1259.75	858.13	1006.88	n.s.
Fe	2015	300.60	308.45	235.65	279.85	425.9	236.1	226.80	61.656
	2016	375.75	252.20	207.95	173.20	285.7	128.1	202.70	53.293
	mean	338.18	280.33	221.80	226.53	355.8	182.1	214.75	n.s.
Zn	2015	47.84	42.69	43.53	38.83	39.70	41.22	31.90	n.s.
	2016	43.20	35.55	31.85	17.80	27.56	56.62	42.71	16.828
	mean	45.52	39.12	37.69	28.31	33.63	48.92	37.30	n.s.
Mn	2015	33.75	26.31	25.04	26.75	31.38	26.76	21.85	7.843
	2016	22.52	18.00	17.31	28.69	18.68	20.29	18.16	n.s.
	mean	28.14	22.15	21.17	27.72	25.03	23.53	20.00	n.s.
Cu	2015	7.17	6.30	4.87	5.12	5.4	6.20	4.36	1.475
	2016	6.50	4.33	6.30	5.42	4.93	5.86	6.85	n.s.
	mean	6.83	5.32	5.58	5.27	5.17	6.03	5.61	n.s.
Ni	2015	4.68	5.33	3.16	3.53	13.04	4.16	3.61	1.756
	2016	4.29	2.89	2.03	1.36	4.33	2.09	1.79	n.s.
	mean	4.49	4.11	2.60	2.45	8.68	3.13	2.70	n.s.
Co	2015	1.35	4.97	7.25	9.37	1.15	5.67	7.12	0.666
	2016	6.29	1.57	7.63	4.56	2.66	0.26	0.75	0.859
	mean	3.82	3.27	7.44	6.96	1.91	2.97	3.93	n.s.
Pb	2015	3.85	5.66	6.88	8.39	1.47	0.78	2.19	4.108
	2016	0.74	1.31	2.68	0.03	1.47	2.60	1.80	n.s.
	mean	2.30	3.49	4.78	4.21	1.47	1.69	1.99	n.s.
Cd	2015	0.19	0.56	0.62	0.79	0.18	0.59	0.82	0.292
	2016	0.55	0.26	0.69	0.49	0.35	0.15	0.29	0.262
	mean	0.37	0.41	0.65	0.64	0.27	0.37	0.55	n.s.

n.s. – non-significant differences

content both between individual years and over the entire study period (Table 6). In 2015, the highest total content of polyphenols (459.62 mg kg^{-1} FM) was detected in Italian Giant parsley, and in 2016 – in cv. Neapolitan (289.97 mg kg^{-1} FM). In 2016, the cultivar Neapolitan also had the highest antioxidant activity measured as percentage reduction of DPPH radicals (14.26% DPPH). The lowest content of total polyphenols (300.80 mg kg^{-1} FM in 2015 and 178.97 mg kg^{-1} FM in 2016) and lowest antioxidant activity (2.70% DPPH in 2016) was observed in cv. Titan.

The content of selected minerals determined in the plant material from individual cultivars of leaf parsley differed significantly between the study years (Table 7). Bojko et al. (2016) reported that basil herb growing in the substrate for seedling production was the richest in magnesium; if grown in high peat it contained the greatest amounts of zinc and cadmium, and cultivated on the substrate for seedling production enriched with coconut fiber showed the highest content of phosphorus, cobalt, nickel and manganese. Studies carried out by Suliburska and Kaczmarek (2011) revealed the highest content of copper (2.4 and 2.0 mg 100 g^{-1}) in the samples of basil and marjoram. In the same experiment, parsley's content of iron, zinc and copper was 21.1-46.5 mg 100 g^{-1} DM, 2.98-3.33 and 0.94-1.52 mg 100 g^{-1} DM, respectively. Our study showed no significant differences in the content of phosphorus and potassium in leaves of the investigated parsley cultivars. The leaves of cv. Plain Leaf were the richest in sodium (3438.0 mg kg^{-1} DM in 2015 and 1593.0 mg kg^{-1} DM in 2016). The lowest levels of this element were detected in 2015 in the leaves of the cultivars Champion Moss Curled, Italian Gigant, Neapolitan, and Titan parsley. A similar trend was observed in 2016. The highest content of lead was confirmed in the leaves of cvs. Neapolitan, Italian Gigant and Listette (8.39, 6.88 and 5.66 mg kg^{-1} DM, respectively in 2015). In 2015, the leaves of cv. Champion Moss Curled demonstrated the highest content of nickel (13.04 mg kg^{-1} DM) and iron (425.90 mg kg^{-1} DM), and the leaves of cv. Neapolitan were the richest in lead and cobalt.

The results of our study, as well as the conclusions of Suliburska and Kaczmarek 2011 and Bojko et al. 2016 indicate diverse mineral content in the investigated cultivars of leaf parsley. This trait probably depends on the growing conditions, including the soil type, fertilization, moisture content and insolation.

CONCLUSION

1. The highest yield was determined for Gigante d'Italia, Plain Leaf and Lisette cultivars of leaf parsley.

2. The cultivars Gigante d'Italia, Plain Leaf and Lisette achieved the highest percentage share of leaf blades in their yield.

3. The parsley cultivars Lisette and Neapolitan had the highest content of pigments.

4. Cv. Neapolitan was the most valuable in terms of biologically active substances, as it was the richest in polyphenols and L-ascorbic acid, as well as showing the highest antioxidant activity measured by inhibition of DPPH radicals.

5. Finally, cv. Plan Leaf featured the highest content of sodium, magnesium, copper, zinc, iron and manganese.

REFERENCES

Bojko K., Czajka J., Meller E., Szymańska J. 2016. *The influence of a substrate type and the method of cultivation on the yielding of sweet basil (Ocimum basilicum* L.*)*. Ann. UMCS, Sect. EEE, Horticultura, 26(4): 33-41. (in Polish)

COBORU 2018. *Research Centre for Cultivar Testing*. Varieties entered in the national register. Available at: http://www.coboru.pl/polska/rejestr/odm_w_rej.aspx?kodgatunku=PLW. (in Polish)

Dyduch J., Janowska K. 2004. *Yielding of some parsley (Petroselinum sativum* L. ssp. *crispum) cultivars*. Acta Sci. Pol., Hort. Cult., 3(1): 145-151. (in Polish)

El-Zaeddi H., Martinez-Tomé J., Calín-Sánchez Á., Burló F., Ángel A., Carbonell-Barrachinaá A. 2016. *Volatile composition of essential oils from different aromatic herbs grown in Mediterranean Regions of Spain*. Foods, 5(41): 2-13. DOI: 10.3390/foods5020041

Gaweł-Bęben K., Rybczyńska K., Bujak T., Karaś M., Jakubczyk A., Nizioł-Łukaszewska Z. 2016. *Impact of the type of solvent on some selected biological properties of parsley Petroselinum crispum (*Mill*) leaf extracts*. Żywn-Nauk Technol. Ja., 1(104): 142-15. DOI: 10.15193/ /zntj/2016/104/108. (in Polish)

Janas R., Górnik K., Grzesik M. 2013. *Instructions for ecological methods of growing parsley (Petroselinum crispum* Mill.*) for seed*. Edit. Kawa-Miszczak L. InHort Skierniewice, 1-15. (in Polish)

Karklelienė R., Dambrauskienė E., Juškevičienė D., Radzevičius A., Rubinskienė M., Viškielis P. 2014. *Productivity and nutritional value of dill and parsley*. Hort. Sci. (Prague), 41(3): 131-137. DOI: 10.17221/240/2013-HORTSCI

Kmiecik W., Lisiewska Z. 1999. *Comparison of leaf yields and chemical composition of the Hamburg and leafy types of parsley*. I. *Leaf yelds and their structure*. Folia Hort., 11(1): 53-63.

Kołota E. 2011. *Yield and quality of leafy parsley as affected by the nitro gen fertilization*. Acta Sci. Pol., Hort. Cult., 10(3): 145-154.

Kołota E., Winiarska S., Adamczewska-Sowińska K. 2012. *The effects of genetic and agronomic factors on quality of leafy parsley yield*. Pol. J. Environ. Stud., 21(4): 937-942.

Krełowska-Kułas M. 1993. *Test on the quality of food products. Determination of the acidity of the general methods of potentiometric titration*. PWE, Warszawa (wyd. I), 560. (in Polish)

Lichtenthaler H.K., Wellburn A.R. 1983. *Determination of total carotenoids and chlorophylls a and b of leaf extracts in different solvent*. Biochem. Soc. Trans., 603: 591-592.

Lisiewska Z., Kmiecik W. 1997. *Effect of freezing and storage on quality factors in Hamburg and leafy parsle*y. Food Chem., 60(4): 633-637. DOI: 10.1016/S0308-8146(97)00048-4

Mahmood S., Hussain S., Malik F. 2014. *Critique of medicinal conspicuousness of persley (Petroselinum crispum): A culinary herb of Mediterranean region*. Pak. J. Pharm. Sci., 27: 193-202.

Mazurek A., Pankiewicz U. 2012. *Changes of dehydroascorbic acid content in relation to total content of vitamin C in selected fruits and vegetables*. Acta Sci. Pol., Hort. Cult., 11(6): 169-177.

Mikiciuk G., Tomaszewicz T. 2016. *The evaluation of fertility of intensively cultivated soils on the base of forest soil trophism index*. Inż. Rol., 163(43): 29-38. (in Polish)

OGIMET. 2018. *Climate report*. Avaliable on: http://ogimet.com/cgi-bin/gsodres?lang=en&mode=1&state=Pola&ind=&ord=REV&ano=2016&mes=04&day=01&ndays=31

Osińska E., Rosłon W., Drzewiecka M. 2012. *The evaluation of quality of selected cultivars of parsley (Petroselinum sativum* L. *ssp. crispum*). Acta Sci. Pol., Hort. Cult., 11(4): 47-57.

Rossi M., Giussani E., Morelli R., Scalzo R., Nani R.C., Torreggiani D. 2003. *Effect of fruit blanching on phenolics and radical scavenging activity of highbush blueberry juice*. Food Res. Int., 36: 999-1005.

Singleton V.L., Rossi J.A., Jr. 1965. *Colorymetry of total phenolics with phosphomolybdic--phosphotungstic acid reagents*. Am. J. Enol. Vitic., 16: 144-158.

Suliburska J., Kaczmarek K. 2011. *Evaluation of iron, zinc and copper contents in selected spices avaliable on the Polish market*. Rocz. PZH, 62(3): 271-271. (in Polish)

Śledź M., Witrowa-Rajchert D. 2012. *Changes in the content of chlorophyll and phenolics during storage of microwave-convection dried parsley leaves*. Zesz. Probl. Post. Nauk Rol., 570: 97-106. (in Polish)

USDA. 2017. *National nutritional database for standard references.* Available on: https://ndb.nal.usda.gov/ndb/foods/show/3045?fgcd=&manu=&lfacet=&format=&count=&max=50&offset=&sort=default&order=asc&qlookup=parsley&ds=&qt=&qp=&qa=&qn=&q=&ing=

Vokk R., Lõugas T., Mets K., Kravets M. 2011. *Dill (Anethum graveolens* L.*) and parsley (Petroselinum crispum (*Mill.*)* Fuss.*) from Estonia: Seasonal differences in essential oil composition*. Agron. Res., 9: 515-520.

Wong P.Y.Y., Kitts D.D. 2006. *Studies on the dual antioxidant and antibacterial properties of parsley (Petroselinum crispum) and cilantro (Coriandrum sativum) extracts*. Food Chem., 97: 505-515. DOI: 10.1016/j.foodchem.2005.05.031

Yen G.C., Chen H.Y. 1995. *Antioxidant activity of various tea extracts in relation to their antimutagenicity*. J. Agric. Food Chem., 43: 27-32.