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ORIGINAL PAPER

ASSESSMENT OF THE SEA BUCKTHORN GROWING IN URBAN CONDITIONS – THE QUALITY OF BERRIES AND LEAVES

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Abstract

The sea buckthorn is a plant valued for its berries, used by people and eaten by animals. It is grown in urban areas as an ornamental shrub with berries and leaves. The shrubs are characterised by their high resistance to drought, soil salinity or air pollution. The aim of the research carried out at the University of Technology in Szczecin, in Western Pomerania, was to check the influence of the city's conditions on the quality of berries: mineral and chemical composition, as well as the content of L-ascorbic acid, nitrites and nitrates in shrubs growing along roads. The content of micro- and macronutrients as well as the colour and Green index of leaves were determined. Soils were characterised by similar and low salinity (0.31-0.41 g kg^{-1} NaCl). The content of various minerals in leaves varied depending on the test site and it was most often correlated with the soil content of these elements. Leaves collected from shrubs which grew next to a street contained more lead (1.06-1.27) but significantly less cadmium (0.08-0.11 mg kg^{-1}) than berries collected in an orchard (Cd 0.17 and Pb 0.83 mg kg^{-1}). The content of organic constituents in berries varied depending on the site of harvest. At the site beside the road, the study revealed a higher level of soluble solids (11.35%), L-ascorbic acid (2312 mg kg^{-1}), organic acids (10.2 g kg^{-1}) and nitrates (47 mg kg^{-1}). All of the examined berries had a low level of nitrites (0.02-0.07 mg kg^{-1}). It has been demontrated that leaves picked from the Hergo cultivar shrubs were darker (parameter L* - top 47.3), greener – especially at the top (parameter a* -13.1). They also had a higher Green index value than the leaves of shrubs growing beside the road (38.2). There is a high level (-0.81) correlation between the measured a* parameter CIE and Green index (SPAD), The sea buckthorn is perfect for urban areas. It is decorative, resistant to urban conditions and has valuable berries, which do not accumulate harmful constituents (heavy metals, nitrates, nitrites).

Keywords: ascorbic acid, colour, heavy metals, Green index, nitrates, nitrites, reflectance.

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INTRODUCTION

The sea buckthorn (*Hippophaë rhamnoides* L.) has a wide range of occurrence, from Europe to western Asia. Sea buckthron shrubs tolerate drought, salinity of soil and air pollution. They can grow in light, breathable soils and in heavier ones. The modest habitant requirements and resistance to harsh conditions make the plant useful for the restoration of degraded areas (Kawecki et al. 2001, Zieliński, Nowak 2004). The sea buckthorn is recommended for cultivation in urban areas because it can withstand the globally occurring tendency of decreasing rainfalls (Roloff et al. 2009) and, by being a shrub with ornamental leaves and berries, it looks atractive in green areas of cities (Renda, Woźniak 2012). Plants grown by people in green areas of towns belong to specific ecosystems, which not only contribute to the aesthetic value or the microclimate of a city, but also create habitats for urban fauna and avifauna. With the increasing human pressure on bird habitats, changes in the living space of birds are recorded. Birds start to settle in urbanised areas, what limits their access to natural food. This is why park plantations set up in right locations in a city, should they comprise shrubs with berries which are willingly eaten by birds, may be effective in providing them with a natural source of food. The sea buckthorn berries contain valuable nutrients and serve as bird food, mainly for fieldfares. The berries have a high content of vitamins, especially vitamin C, phenolic acids, unsaturated fatty acids, and micronutrients (Jurikova et al. 2012, Rop et al. 2014). They are used in the food, wine, pharmaceutical and cosmetic industries (Li, Schroeder 1996). Such a wide range of advantages offered by the sea buckthorn suggests that it should be used on a larger scale and be planted in green areas in cities. This is true providing that the berries of shrubs which are grown beside roads, in areas overexposed to negative influences, are valuable and unpolluted with undesirable compounds.

The aim of the research was to describe the influence of city conditions on the quality of berries picked from shrubs growing beside roads of the city of Szczecin. The colour of berries and leaves as well as the dependence between the colour and the Green index of leaves were also described.

MATERIAL AND METHODS

Characteristics of the area of research and plant material

The research took place in Szczecin, a coastal city situated in north-western Poland which remains under the influence of the Baltic Sea. In Szczecin, the average annual air temperature (in years 1951-2006) is 8.7°C, the coldest month is January: -0.5°C (Bielec-Bąkowska, Piotrowicz 2013), the average annual precipitation is 538 mm, the highest precipitation occurs in July, approx. 75 mm. Female shrubs (not belonging to a specific cultivar) were selected for the research at Południowa Street in Szczecin, which is an urban section of National Road No. 13 with high traffic intensity KR5 (*State report* 2012). The shrubs grow along a tree-meter-wide median strip of the street. Stand 1 is situated near Hackena Roundabout, stand 2 is situated midway along Południowa Street, and stand 3 is situated near Uniwersyteckie Roundabout. A control stand (no 4) consisted of Hergo cultivar shrubs growing in an ochard owned by the University of Technology in Szczecin, in the province of Western Pomerania. The soil in which the shrubs were grown, regardless of the stand, had high pH value, high amounts of phosphorus, potassium and magnesium, and a low level of soil salinity. The soil under the stands situated in the median strip of the street was classified as sandy loam. This soil had much lower levels of cadmium and lead than the soil collected from the orchard, which was described as medium soil - silt loam (Table 1).

Table 1

The characteristics of soils in which the sea buckthorn shrubs grew

Growing site*	pH (KCl)	Chloride salinity (g kg^{-1}NaCl)	Field water capacity (% ww-^{1})
1	7.5*b***	0.38*a*	22.4*a*
2	7.5*b*	0.31*a*	19.7*a*
3	7.6*b*	0.41*a*	21.8*a*
4	6.2*a*	0.34*a*	46.2*b*

* 1-3 sites beside a road – non-varietal shrubs, 4 orchard – Hergo cultivar shrubs
** means followed by the same letter do not differ significantly at $P = 0.05$ according to the Tukey's multiple range test.

Methods

The soil in which the shrubs grew was collected for analyses along a straight line perpendicular to the street at a distance of 0.5 m from the edge of the carriageway, and from rows in the orchard where the control shrubs grew. Composite soil samples were prepared, collected with an Egner sampling stick from the humus level (0-30 cm). The experiment was carried a randomised sub-block design, and samples of soil and leaves were collected in mid-July in triplicate. The estimation of the content of minerals in dry weight was carried out in accordance with the Polish Standard (PN) using certified reagents. The following were determined in the soil samples: the total content of nitrogen, assimilable phosphorous and potassium, and replaceable calcium and magnesium. The leaves underwent determinations of the general content of the analyzed elements. After mineralisation in H_2SO_4 (96%) and H_2O_2 (70%), N was determined in soil and P, K, Ca, Mg were analysed in leaves. K and P were determined in the soil by extraction in $C_6H_{10}CaO_6$, while Ca, Mg were assayed by extraction in $C_2H_3O_2NH_4$. The content of micronutrients (Cu, Zn, Mn, Fe) and heavy metals (Pb, Cd) was determined after mineralisation in HNO_3 (65%) and $HClO_4$ (70%) in the ratios 1:1 for soil and 3:1 for leaves. The total nitrogen concentration was determined by the Kiejdahl destillation method using a Gerhardt 30. The content of potassium and calcium was measured with atomic emission spectrometry, whereas the magnesium content was tested with flame atomic absorption spectroscopy using an iCE 3000 Series. The phosphorus content was determined with the Egner-Riehm method at 660 nm wavelength, on a spectrophotometer Marcel s 330 PRO. The content of microelements was determined on a iCE 3000 Series (IUNG 1972).

Berries chosen for the analyses were picked at the end of September, when they were fully ripe. For a better efficiency of juice extraction, berries were homogenised in a blender and heated up to 50°C with pectinase (Rapidaza Super). After1 hour, the pulp was pressed in a laboratory hydraulic press for 10 min at the final pressure of 300 kPa. Further, the acidity was determined by titration of a berry homogenate water extract with 0.1 N NaOH to the end point of pH 8.1 (measured with an Elmetron pH meter). Titratable acidity was determined by the potentiometric method and expressed as equivalents of citric acid 100 g^{-1}. The content of soluble solids was determined with a digital refractometer PAL-1 (Atago, Japan). L-ascorbic acid, nitrates and nitrites were measured with a RQflex 10 requantometer (Merck) and expressed in mg – 100 g^{-1} of berry juice. The Green index was measured with a Chlorophyll Meter SPAD-502 (Minolta). The measurements were made on the same 50 leaves from 3 specimens. The colour of leaves and fresh-cut berries was measured directly on a spectrophotocolorimeter Minolta CM-700 (Konica Minolta Sensing, Inc., Osaka, Japan). The CIE L^* (lightness), CIE a^* (green-red) and CIE b^* (yellow-blue) were read using a D_{75} light source at the observer angle of 10° and consisting of a head with an 3 mm diameter measuring area (*Hunterlab*… 2012).

The soil from sites located in the strip separating the street had high pH value and bulk density. The soils at all the sites were characterised by similar low salinity (Table 1). Regardless of the stand, the soils were characterised by a high content of K, P and Mg. in comparison to the optimal mineral content of soil by SADOWSKI et al. (1990). The street soil was characterised by lower levels of Cd, Pb and Mn than the soil from the orchard (Table 2).

The results were subject to statistical analysis using Statistica 10.1 (Statsoft, Poland). Correlations between variables were analysed using the Spearman's correlation significant at $p < 0.01$ and $p < 0.05$. The values were evaluated by the Tukey's test and the differences at $p < 0.05$ were considered significant.

Table 2

Mineral composition of soils in which the sea buckthorn shrubs grew

Growing site*	N	P	K	Mg	Ca	Fe	Mn	Zn	Cu	Cd	Pb
	(g kg-1)	(mg kg-1)									
1	5.73*a***	98.1*b*	162.7*b*	49.2*b*	682*b*	112.4*b*	23.5*a*	22.4*a*	8.41*b*	0.083*a*	23.0*a*
2	8.41*b*	74.8*a*	99.6*a*	38.4*a*	788*b*	108.0*b*	19.9*a*	42.5*b*	4.39*a*	0.093*a*	20.6*a*
3	6.78*a*	75.2*a*	151.9*b*	55.1*b*	736*b*	135.2*c*	31.3*b*	26.9*a*	5.88*a*	0.130*b*	17.2*a*
4	17.33*c*	123.3*c*	284.7*c*	72.7*c*	452*a*	83.4*a*	57.3*c*	37.0*b*	7.52*b*	0.296*c*	31.3*b*
Correlation coefficients soil-green index	0.77***	0.36	0.22	-0.57	0.56***	0.16	0.44	0.61	0.49***	0.55***	0.64***

*, ** for explanation, see Table 1,
*** Correlation significant at the level of $P < 0.05$.

RESULTS AND DISCUSSION

The content of most macro- and micronutrients in the sea buckthorn leaves was higher in plants growing in the orchard, which may result from the cultivation process (Table 3), i.e. fertilisation and watering. Excess of nutrients can be also disadvantageous. Excess nitrogen is toxic to crops and can extend the duration of their growth (Hachiya et al. 2012). The levels of most of the tested ingredients fell within the lower range of the optimal con-

Table 3

Mineral composition of sea buckthorn leaves

Growing site*	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	Cd	Pb
	(g kg-1)					(mg kg-1)					
1	9.82*a***	1.37*a*	7.01*a*	4.17*a*	1.76*a*	135*a*	33.6*a*	9.7*a*	11.4*a*	0.09*a*	1.15*bc*
2	11.74*b*	1.62*b*	8.24*a*	6.55*b*	1.90*ab*	197*b*	54.7*c*	12.8*a*	10.1*a*	0.11*a*	1.06*b*
3	9.35*a*	1.53*ab*	9.56*b*	6.11*b*	2.53*c*	156*a*	48.9*bc*	11.2*a*	12.5*a*	0.08*a*	1.27*c*
4	12.30*b*	1.95*c*	11.37*c*	5.69*b*	2.11*b*	278*c*	42.1*ab*	17.4*b*	16.7*b*	0.17*b*	0.83*a*
Correlation coefficients soil-leaf	0.59***	0.65***	-0.17	0.94***	0.73***	0.35	0.07	0.85***	0.47	0.24	0.61

*, ** for explanation, see Table 1, *** for explanation, see Table 2

tent for berry shrubs. The Zn and Cu content in leaves of plants from the street stands was lower than in the orchard, and for Mn, it was lower than the one specified in standards. Leaves, just like fruits, were also characterised by a low content of cadmium and a high content of lead. EGOROVA and NEVEROWA (2013) provided lower values of metals in leaves than it was found in the present research. The accumulation of heavy metals in plants depends on a plant's species and organ, including the type of fruit, for example the lowest quantities of harmful heavy metals are accumulated in nuts, while the highest quantities are gathered by berries. T*he highest level of* heavy metals was found in fruits of *Rubus fruticosus*, where it was much higher than in the sea buckthorn berries (HOFFEN, SÄUMEL 2014). The atmospheric deposition of trace metals on the fruit surface apparently has a stronger effect than their uptake from soil (MADEJÓN et al. 2006).

In order to characterise the studied shrubs, the colour of their leaves was measured along with their Green index values (Table 4). This study

Table 4

Colour of leaves of sea buckthorn shrubs

Growing site	Leave colour - CIE L* (100 white, 0 black) a* (-100 green, +100 red) b* (-100 blue , +100 yellow)						Green index (SPAD)		Correlation coefficients between CIE *a and green index	
	top			bottom			top	bottom	top	bottom
	L*	a*	b*	L*	a*	b*				
1	61.2	-11.3	17.4	69.1	-5.0	15.7	29.5	14.8	-0.81(**)	-0.67(*)
2	52.8	-9.5	22.1	67.4	-4.7	17.3	34.8	16.5		
3	56.0	-6.8	18.3	64.7	-3.6	16.8	37.1	17.7		
4	47.3	-13.1	20.8	66.9	-5.3	18.4	38.2	16.4		

Growing site – see Table 1

showed that the upper side of a leaf was darker than its bottom side. The upper side also had higher indicators of a* and b* parameters. Of the studied plants, the brightest leaves (L* parameters - bottomside 69.1; top side 61.2) were grown by the shrubs at stand 1. Those plants also had the lowest Green index of leaves. The Green index is highly correlated with the amount of chlorophyll responsible for the green colour (PACEWICZ, GREGORCZYK 2009). The amount of chlorophyll in leaves is correlated with the richness of soil. higher Green index of leaves is connected with more nutrients in the soil. The content of mineral ingredients in leaves indicates the plant's nutritional condition (PELTONEN et al.1995, MACIOROWSKI et al. 2007, NOWAK, ZIELIŃSKI 2009). This has been verified by the results of the present study. The shrubs growing in the orchard with the soil richer in nutrients had a higher Green index of their leaves. A correlation was found between the content of minerals in the soil and the value of the Green index of nitrogen, magnesium and heavy metals (Tables 2, 4). Moreover, leaves with a high Green index had the highest rate of green colour (parameter a*). The correlation of both parameters was highly significant. Similar dependences were ascertained in another study on several varieties of sea buckthorn shrubs (OCHMIAN et al. 2014).

The sea buckthorn berries have a distinctive yellow to orange colour, a* and b* parameters (Table 5). The colour of the berries in our study, described

Table 5

Colour of sea buckthorn berries

Growing site	Berry colour CIE L* (100 white, 0 black) a* (-100 green, +100 red) b* (-100 blue , +100 yellow)					
	surface			flesh		
	L*	a*	b*	L*	a*	b*
1	58.3	26.4	36.1	37.0	7.5	20.7
2	53.5	33.2	40.7	44.1	15.2	28.8
3	39.7	37.8	59.0	56.1	26.3	48.4
4	45.6	34.4	54.3	43.4	12.6	33.0

Growing site – see Table 1

by L*a*b* parameters, was close to the colour of berries of *Diospyros kaki* (VEBERIC et al. 2010, CHEŁPIŃSKI et al. 2013, OCHMIAN et al. 2016). Although all of the berries were picked at the same time, significant differences in their colour were noticed. Evidently, the highest chromatic values of the parameters identifying the colour of parenchyma (a* and b*) as well as the brightest parenchyma (L* 56.14) were determined for the berries picked from shrubs at stand 3. Those berries had the darkest epidermis and the lowest rate of L* parameter: 39.7. This shows that they had reached the highest maturity, which also had an impact on their chemical composition. Berries with the darker epidermis and brighter parenchyma had less chemicals (Table 6).

The above berries also had the highest reflectance index, at the level of 60%, starting from 620 nm (Figure 1). The berries picked at this stand were

Table 6

Chosen physical and chemical parameters of sea buckhorn berries

Growing site*	Soluble solids (%)	Dry matter (%)	Juice pH	Titratable acidity (g kg^{-1})	L-ascorbic acid (mg kg^{-1})	Nitrates - NO_3 (mg kg^{-1})	Nitrites - NO_2 (mg kg^{-1})
1	9.32*a***	12.3*b*	3.48*a*	10.20*c*	2312*b*	47*b*	0.03*ab*
2	9.71*ab*	11.7*a*	4.34*c*	8.53*a*	1854*a*	59*c*	0.07*c*
3	11.35*c*	13.9*c*	4.03*b*	9.17*ab*	1927*a*	33*a*	0.04*b*
4	10.35*b*	12.5*b*	4.47*c*	9.34*b*	2184*b*	41*ab*	0.02*a*

*, ** for explanation, see Table 1 and 2

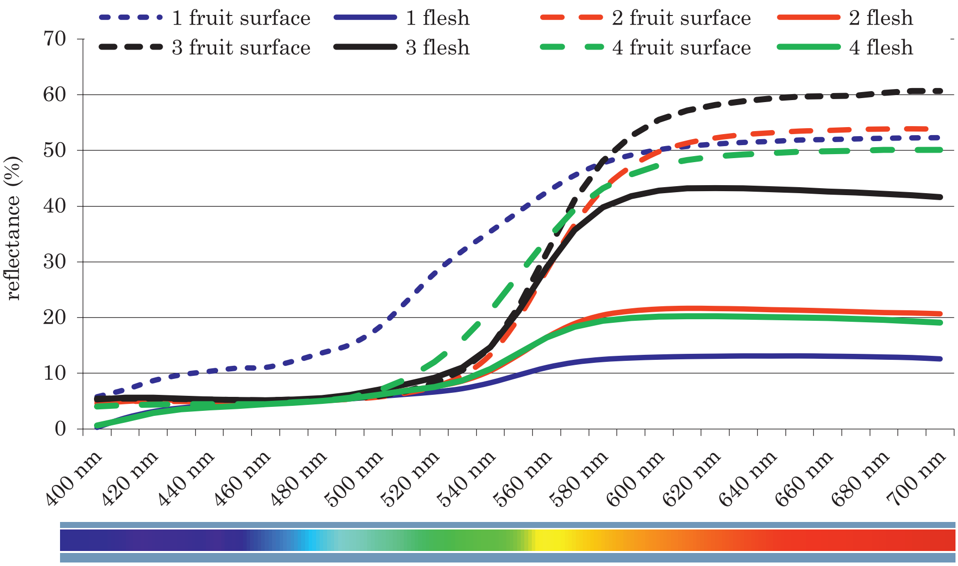

Fig. 1. Reflectance of the berries

also distinguished by the brightest colour of parenchyma (L* 56.14), and had the highest a* and b* parameters. This indicates that their parenchyma exhibited the highest saturation of pigments, which is also verified by the high reflectance index of above 40%. The reflectance index of the parenchyma of other berries was 20% and the a* and b* parameters were much lower, especially for berries at stand 1. A similar reflectance index value was obtained for berries of grapevines, but at different wavelengths: 400-500 nm (Ochmian et al. 2013).

The berries picked at stand 3 had the largest amount of extract and dry matter, but the smallest amount of organic acids, L-ascorbic acid and nitrates (Table 6). The least mature berries, characterised by high firmness and colour parameters, were picked at stand 1. The amount of dry matter in sea buckthorn berries of may range from 12.4 to 16.0%, whereas the amount of extract may vary between 6.2 and 11.5% (Zadernowski et al. 2005). The present results are close to the data reported from other studies. The amount of organic acids was varied, i.e. from 8.53 to 10.20 g kg^{-1} at the roadside stands and 9.34 g kg^{-1} in the orchard. These values are 1.3 to 3.0% lower than the ones demonstrated by Zadernowski et al. (2005). Similar dependences were ascertained in respect of the pH of juice from sea buckthorn berries. These berries have a large permanent amount of vitamin C, because they do not have enzymes to dissolve it. In addition, polyphenolic antioxidants and flavonoid compounds in berries make that vitamin stable. The amount of ascorbic acid in sea buckthorn berries varieds highly in the range of 28 - 201 mg 100 g^{-1} (Yao et al. 1992) in populations grown in Finland, 120 to 315 in berries of plants grown in Europe on coastal sand dunes, and from 405 up to 1100 mg

100 g^{-1} in the Alps (Zadernowski et al. 2005). According to Rop et al. (2014), the berries of cv. Hergo had 418 mg 100 g^{-1} of vitamin C. The amount of L-ascorbic acid in the berries analysed in our experiment was within the lower range of values reported by the quoted authors (Table 6). It depended on a stand in which the shrubs were grown and ranged from 1854 (stand 2) to 2312 mg kg^{-1} (stand 1). Regardless of the growing site, the berries had low amounts of nitrites (0.02-0.07 mg kg^{-1}) and nitrates (33-59 mg kg^{-1}). Those amounts are lower than allowed in products of special use. The permissible nitrate content in vegetables used for nutrition of babies and young children should not exceed 200 mg $NaNO_3$ kg^{-1} (*Commission Regulation EC* ... 2006).

CONCLUSION

A significant correlation was found between the P, Ca and Mg content in soil and leaves. Leaves collected from shrubs which grew in the median strip contained significantly less cadmium than the limits set by applicable standards. The berries at the stands located beside the road and in the orchard were of similar quality. The amount of nitrites or nitrates did not reach the detrimental level. The assessment of the colour component parameters of the berries helps to estimate the maturity of berries, which is connected with their quality, but further research has to be conducted in this regard. The colour of leaves, which is highly correlated with the amount of chlorophyll, is connected with the richness of soil. Darker leaves indicate better nutrition of leaves.

The ornamental appeal, resistance to urban conditions and nutrient-rich berries suggest that the sea buckthorn deserves to be planted in cities.

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