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THE INFLUENCE OF SHURBS CUTTING METHOD ON YIELDING AND QUALITY OF THE GOJI BERRIES (*LYCIUM BARBARUM* L.)

WPŁYW CIĘCIA KRZEWÓW NA PLONOWANIE I JAKOŚĆ OWOCÓW GOJI (*LYCIUM BARBARUM* L.)

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Streszczenie. W doświadczeniu porównywano: wzrost krzewów, plonowanie, parametry fizyczne owoców oraz ich skład chemiczny w zależności od metody cięcia krzewów – liczby pędów głównych. Materiał stanowiły jagody goji rosnące w Sadowniczej Stacji Badawczej Katedry Ogrodnictwa Zachodniopomorskiego Uniwersytetu Technologicznego w Szczecinie. Jagody goji (*Lycium barbarum* L.) charakteryzują się właściwościami prozdrowotnymi i odżywczymi. Od wieków stanowią niezwykle ważny element tradycyjnej medycyny chińskiej. Są tam stosowane, jako bardzo istotny składnik zdrowej diety, m.in. ze względu na występowanie cennego kompleksu polisacharydowego LBP (Lycium Barbarum Polysaccharides). Cięcie pędów pobudziło wzrost krzewów. Na krzewach ciętych na 3 pędy wyrosło więcej krótszych pędów odziomkowych, natomiast pędy jednoroczne były najdłuższe. Liście z krzewów ciętych były ciemniejsze (L* = 41.2 i 39.8) oraz miały wyższy indeks zazielenienia (42,1 i 44,8), w porównaniu z krzewami, z których nie usuwano pędów (L* = 37,3; SPAD = 43,5). Stwierdzono również istotną zależność pomiędzy indeksem zazielenienia a wartością parametru a* (r = 0,92*). Cięcie krzewów, a zwłaszcza mocne – na 3 pędy, ograniczyło plonowanie, wpłynęło jednak na zwiększenie wielkości owoców.

Key words: chemical composition of fruits, goji, green index, fruit size, yielding.
Słowa kluczowe: goji, indeks zazielenienia, plonowanie, skład chemiczny owoców, wielkość owoców.

INTRODUCTION

Goji berry (*Lycium barbarum* L.), also known as common wolfberry, belongs to the *Solanaceae* family (Jin et al. 2013). Commercial volumes of wolfberries grow in Japan, Korea, and Taiwan, but mostly in China where cultivation area exceeds 82 000 ha (China Daily Staff reporter 2004). Traditional food and medicine in East Asia have become increasingly popular in Europe and North America (Potterat 2010).

Goji berry bushes reaching a height of 3 meters, have arched overhanging twigs covered with spines. Fruits are bright red berries, characterized by an elongated shape and sensitivity (Bogacz 2009; Llorent-Martinez et al. 2013). To protect the fruits against any damage during harvest they should be shaked on soft mats, or plucked with the stulk. Two years old plants can be harvested with approximately 2 kg of fruit each. Goji berries are of high health and

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nutrition properties (Bogacz 2009; Amagase and Farnsworth 2011). The most valuable and most arousing the interest component of the goji berry is a polysaccharide complex LBP (Lycium Barbarum Polysaccharides), which is soluble in water (Luo et al. 2004). The presence of this component influences the bioactive therapeutic effectiveness of fruit goji. It either positively affects the function of the immune system (Gan et al. 2004; Amagase et al. 2009). Many studies indicate that the complex polysaccharide common Wolfberry can inhibit the growth of the tumor cells (He et al. 2012).

In fruits may be present an alkaloid with strong biological effect – atropine. A large amount have been detected in fruits originating in India (Harsh 1989). However, the amount of atropine which is supplied from the consumed amount of berries has no adverse impact on human health. The content is far below toxic levels (Adams et al. 2006). The lethal dose is 60–100 mg (Marquart and Schaefer 1997). Atropine is recommended in traditional Chinese medicine to treat arthritis (Lin and Chen 2002).

Lycium barbarum prefers well-drained slightly alkaline soils, however shrubs will grow in almost any type of soil (Peaceful Valley Farm Supply 2013) especially in sunny locations. Under such conditions, fruits will have the highest quality. Goji Berry plants will handle winter temperatures to –9°C and summer temperatures up to 38°C. Goji Berry plants have an extensive root system and are very drought tolerant once established. However first fruition is typically observed in 2–3 year-old plants. Shrubs cut are one of the basic agricultural treatments. It gives a significant impact on plant yielding and crop quality. It is a laborious procedure and out of a collection of fruits requires much labor effort. Uncut shrubs are easily thicken, which leads to uneven ripening of fruits and deterioration of their quality (Rusnak 2012). Fruits are formed on current year's wood. Pruning encourages new growth, increasing yields. Pruning is important to allow good light penetration and air circulation. Typically, pruning is not required during the first year. However, in the following years the cut is recommended to stimulate the shrubs to vigorous growth. After about 3 years usually start to grow up additional new shoots from the root system. Therefore it is important to reduce the number of these shoots. You can prune at the end of the growing season or in very early spring (Maughan and Black 2015, Planting instructions, http://isons.com/pdfs/Isons_Goji_Berry_planting_Instructions.pdf).

The aim of the study was to compare and determine the effect of cutting on the growth of shrubs of goji berries cultivar No. 1. It was also examined the quality of the fruit – their physical parameters and chemical composition.

MATERIAL AND METHODS

The studies were carried out in the Laboratory of Orcharding at the Department of Horticulture, West Pomeranian University of Technology in Szczecin during years 2013–2015. The soil in the orchard was an agricultural soil with a natural profile, developed from silt-loam with a considerably lower density of 1.21 mg · m^{-3}, a pH 6.9 and a higher water capacity, it also contains much more organic matter − 33.1 g in kg of soil. Regardless of the site, the soils were characterized by similar low salinity EC 0.35−0.43 mS · cm^{-1}. The soil, in which the shrubs grew, regardless of the stand, in comparison to optimal mineral content of the soil by

Sadowski et al. (1990), was characterized by a high content of P (78 mg · kg^{-1}), K (164 mg · kg^{-1}) and Mg (52 mg · kg^{-1}). Every year in the spring nitrogen fertilization was used at a dose of 90 kg N and shrubs were watered in order to maintain optimum soil moisture.

The research station is located in the north-western part of Poland in the Szczecin Lowland. The majority of the West Pomeranian Province belongs to the zone 7A on the Heinz and Schreiber's "Map of zones of plant resistance to frost". However, in the area of Szczecin and in the nearby northern region, minimal temperatures range from –12°C to –15°C, which corresponds to values typical of zone 7B.

The *Lycium barbarum* L. shrubs, cultivar 'No 1' were planted at a spacing of 3.5 x 1.1 m in 2008 year. The experiment was carried a randomized sub–block design (3 replicates of 3 plants). In the year 2010 shoots were cut out from the shrubs according to the scheme.

Scheme of the experiment. Starting this year the control shrubs had been applied with sanitary cuttings only, while in other objects there had been removed all new basal shoots. Since 2013, year-by-year one old shoot was replaced with new one-year old shoots growing on roots: control – uncut bushes, bushes cut into 3 main shoots, bushes cut into 6 main shoots.

The following parameters were measured after the growing season: the height of the bushes, the length of one-year growths (without shoots growing on roots), the number of basal shoots.

During the first harvest of fruits, the index of leaf greenness (Chlorophyll Meter SPAD-502, Minolta, Japan) and color of leaves were measured. The color of leaves and fresh-cut berries (25 fruit from each shrub) was measured with 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 D75 light source and the observer angle at 10° and consisting of a head with 3 mm diameter measuring area. There were measured leaves collected from the central part of the one year shoots –10 leaves from 3 shoots from each shrub.

Fruits were harvested manually with gently shaken, from all the shrubs covered by the experiment. They were used to prepare the aggregate sample on which were made measurements. Physical features of fruits (fruit size, firmness) were measured on fresh berries immediately after the harvest. The fruit weight was measured with RADWAG WPX 4500 electronic scales (0.01 g accuracy). Fruit diameter, firmness was measured with a FirmTech2 apparatus (BioWorks, USA) of 100 randomly selected berries from three replicate was expressed as a gram-force causing fruit surface to bend 1 mm.

Dry matter content was measured after drying at 105°C – 3 repetitions of 100 grams from each combination.

For juice extraction efficiency berry were homogenized with a blender and heated up to 50°C. with pectinase (Rapidaza Super) – 3 repetitions of 100 grams from each combination. Afterward (1 hour), the pulp was pressed a laboratory hydraulic press. Further, the acidity was determined by titration of a water extract of berry homogenate with 0.1 N NaOH to an end point of pH 8.1 (measured with an Elmetron pH meter). Titratable acidity was determined by potentiometric method and expressed as equivalents of citric acid 100 g^{-1}. Soluble solids content was determined with a digital refractometer PAL-1 (Atago, Japan). L-ascorbic acid, nitrates and nitrites content was measured with a RQflex 10 requantometer (Merck) and expressed as mg per 100 g berry juice.

The content of the pro-vitamin A was examined by HPLC with UV detection. Identification of phenolic compounds was checked by the UPLC-PDA/MS method. The fresh fruits were extracted with methanol acidified with 2.0% formic acid. The extraction was performed twice by incubation for 20 min each under sonication (Sonic 6D, Polsonic, Warsaw, Poland) and with occasional shaking. Next, the slurry was centrifuged at 19.000 × g for 10 min, and the supernatant was filtered through a Hydrophilic PTFE 0.20 µm membrane (Millex Samplicity Filter, Merck) and used for analysis. The content of polyphenols in individual extracts was determined by means of the ultra-performance liquid chromatographyphoto-diode array detector--mass spectrometry (LC-PDA-MS) method. All extractions were carried out in triplicate.

In order to determine the significance of differences, a one-factor analysis of variance was carried out, followed by the assessment of the significance of differences using the Tukey's test. The statistical analyses were performed using the Statistica 12.5 (StatSoft Polska).

RESULTS AND DISCUSSION

Wolfberry is a shrub with thick, heavily ramose shoots. It can grow up to 2–3 meters high (Bogacz 2009). Based on our experiment, it was found that the heavy cutting of basal shoots foster the growth of shrubs. The plants carried out on 3 main shoots were lower than the bushes not cutted. They produced instead a large number of short basal shoots and long one-year shoots (Table 1). It also increased cross sectional area of left shoots.

Table 1. Characteristics of goji shrub *Lycium barbarum* L. depending on the method of cutting. The average of the years 2013–2015
Tabela 1. Charakterystyka krzewów goji *Lycium barbarum* L. w zależności od sposobu cięcia. Średnia z lat 2013–2015

Measured feature – Badana cecha		The number of shoots – Liczba pędów		
		control kontrola	6 shoots 6 pędów	3 shoots 3 pędy
Height shrubs – Wysokość roślin [cm]		246b	238b	217a
Shoot main cross-sectional area Powierzchnia przekroju poprzecznego pędu szkieletowego [cm^2]		4.52a	7.05b	12.37c
Total number of basal shoots Liczba pędów odziomkowych		2.7a	6.5b	9.2c
Average length of basal shoots Średnia długość pędów odziomkowych [cm]		36b	117ab	82a
Average length one-year shoots Średnia długość pędów jednorocznych [cm]		54a	66ab	79b
Green index − Indeks zazielenienia (SPAD)		37.3a	42.1b	44.8b
Leaves color − Barwa liści	L*	43.5a	41.2ab	39.8b
	a*	–43.2a	–44.6a	–48.5b
	b*	21.4b	18.8ab	14.6a
Correlation coefficient − Współczynnik korelacji SPAD/a* r = 0,92				

Mean values denoted by the same letter do not differ statistically significantly at 0.05 according to t-Tukey test. Wartości średnie oznaczone tą samą literą nie różnią się statystycznie istotnie według testu Tukeya na poziomie istotności 0,05.
r – a significant correlation coefficient – współczynnik korelacji istotny na poziomie 0,05.

The leaves green index is highly correlated with the content of chlorophyll in leaves (Pacewicz and Gregorczyk 2009). On this basis we can conclude, among other things about condition of the plants. Leaves from the cut bushes had similar value of green index (44.8 SPAD – 3 shoots, 42.1 SPAD – 6 shoots), significantly higher than the leaves of not cut shrubs (37.3 SPAD). There was observed a significant correlation (r = 0.92*) between the green index, and the value of the parameter a*. The most green leaves were collected from shrubs cutted to 3 shoots. They were characterized by the highest value of green index (Table 1). A similar value of green index were characterized leaves of highbush blueberry (Ochmian 2012). Leaves measured on the cutted shrubs, especially cutted into 3 shoots were also darker, what is shown by the lower value of the parameter L*.

Cutting of shrubs resulted in a significant decrease of yield, while improved quality of the fruit (Table 2). The biggest fruits yield (3.12 kg from shrubs) characterized shrubs which have not undergone a cut. With shrubs carried out in 3 main shoots collected 1.94 kg of fruit. These fruits results in comparison to the collected from the remaining plants were highest - weight of 100 fruit was 67.0 g, the length of 14.8 mm and the diameter 9.9 mm. They were similar to the fruits of cultivar 'No. 1', but much smaller than the fruit of 'New Big' – 94.3 g (Poterańska and Ochmian 2015). Fruit size is a factor that mainly determines the attractiveness of the fruit. Consumers are looking for large fruit, nicely dyed, characterized by a pro-health properties.

Table 2. Yielding and quality of goji berries depending on methods of cutting. The average of the years 2013–2015
Tabela. 2. Plonowanie oraz jakość owoców goji w zależności od sposobów cięcia. Średnia z lat 2013–2015

Measured feature – Badana cecha		The number of shoots – Liczba pędów		
		control kontrola	6 shoots 6 pędów	3 shoots 3 pędy
Yield − Plon [kg/shrubs]		3.12c	2.65b	1.94a
Weight of 100 fruits − Masa 100 owoców [g]		52.2a	59.1b	67.0c
Fruits diameter − Średnica owoców [mm]		9.0a	9.5ab	9.9b
Fruits lenght − Długość owoców [mm]		13.3a	14.4b	14.8b
Fruits firmness − Jędrność [G · mm^{-1}]		186a	166ab	142b
Fruits color − Barwa owoców (CIE)	L*	35.3a	33.4ab	29.7b
	a*	27.9a	31.0ab	33.7b
	b*	41.3c	36.2b	27.9a
Dry matter − Sucha masa [%]		15.5b	15.2b	14.3a
Soluble solids − Ekstrakt [%]		12.9ab	12.3a	13.6b
Titratable acidity − Kwasowość [g · 100 g^{-1}]		1.11b	1.23b	0.91a
Nitrites − Azotyny NO_2 [mg · 1000 g^{-1}]		0.71a	0.84a	0.97a
Nitrates − Azotany NO_3 [mg · 1000 g^{-1}]		47b	40b	28a
Provitamin A − Prowitamina A [mg · 100 g^{-1}]		14.3ab	11.6a	16.9b
L-ascorbic acid − Kwas L-askorbinowy [mg · 100 g^{-1}]		24.5a	29.6a	40.1b
Total polyphenol − Suma polifenoli [mg · 100 g^{-1}]		43.7c	34.9b	29.4a

Explanations see Table 1 – Objaśnienia jak w tab. 1.

Goji berries are very fragile fruits, with a low firmness, close to the delicate fruit of blue honeysuckle berries (Ochmian and Grajkowski 2007). To reduce the risk of damage the fruit should be harvested with the stalk (Cieślik and Gębusia 2012). Fruits harvested from the

bushes not cut (control) were firmer (186 G^{-1} mm) from the fruit obtained out of the bushes carried out in 3 shoots (142 G mm^{-1}). Firmness is a characteristic dependent on the method of cultivation of the species, in particular the size of the fruit. Larger fruits are usually characterized by lower firmness (Ochmian and Kozos 2014; Ochmian et al. 2014).

Coloration of fruit peel of cultivars *Lycium barbarum* L.: is variable, from the taint bright yellow-orange to dark orange-red (Poterańska and Ochmian 2015). Goji berries from our studies were dark orange-red, especially those collected from the the bushes cut into 3 main shoots. Strong cuttings resulted in better access of light and fruits ripen faster. It was a similar color to the fruit of other of cultivars goji berries (Poterańska and Ochmian 2015) and sea-buckthorn berries (L* 45.5, a* 20.2, b* 36.7), however, they were darker than them (George and Cenkowski 2007).

Goji berries in its composition contain many valuable nutrients, which are characterized by a very high biological activity. They are classified to the super-fruit (Kulczyński et al. 2014). They are the source of vitamin A, L-ascorbic acid, also contain polyphenols (Paszkiewicz et al. 2012). The richest in vitamin A (16.9 mg · 100 g^{-1}) and L-ascorbic acid (40.1 mg · 100 g^{-1}) have proved to be fruits obtained from the goji bushes cut into 3 shoots. However, this cutting method caused a decrease of polyphenol content in fruits to the level of 29.4 mg · 100 g^{-1}. The highest content of polyphenols was found in fruits harvested from control bushes 43.7 mg. In addition to fruit for medicinal purposes you can also use the leaves. They are characterized by similar polyphenol content as fruit. Larger quantities of polyphenols were found in the leaves of *Lycium chinensis* – 80.64 mg (Mocan et al. 2014). Compared to other berry plants, for example blackcurrant (614.0 mg) (Witkowska and Zujko 2009) goji contained a small amount of polyphenol compounds. The content of L-ascorbic acid is similar to blue honeysuckle berries (Szot et al. 2014). Goji berries do not have the ability to excessive accumulation of detrimental to health nitrates. Regardless of the number of main shoots of shrubs, nitrate levels in the fruit of Chinese wolfberry meets the most stringent requirements for the groups of plant foods intended for the infants and young children. According to the permissible nitrate content in vegetables meant for feeding babies and young children should not exceed 200 mg $NaNO_3$ kg^{-1} (WE 1881). Berries harvested from bushes of 3 shoots contained the most nitrite (0.97 mg · 1000 g^{-1}). While the fruits from the control bushes have accumulated the smallest nitrite, but contained the greatest amount of nitrates. In the studies of Poterańska and Ochmian (2015), nitrates and nitrites in goji berries have occurred in similar quantities. The fruit flavor is determined mainly by the relationship between acids to extract. The highest acidity characterized fruits harvested from plants shoots cut into 6 (1.23 g · 100 g^{-1}) while they had the lowest overall content of the extract (12.3%). Fruit of the shrubs cut into 3 main shoots had the highest extract content (13.6%) and the lowest acidity (0.91 g · 100 g^{-1}). The fruit from the plant carried out in 3 main shoots were also specified by the smallest dry weight (14.3%).

CONCLUSIONS

1. The cut shrubs, especially into 3 shoots, produced a higher number of shorter basal shoots, while the longer one-year shoots.
2. The leaves from the bushes cut into 3 and 6 main shoots were characterized by a higher value of the green index. They were also darker and characterized by higher value of a* color parameter.

3. There was found a significant correlation between green index, and the value of the parameter a*.
4. Cutting of bushes reduced yielding, and also had influence for the quality of the fruit. Fruits were bigger and darker but they had less content of polifenols. The bigest influence for the quality of the fruits had cutting of shrubs for three shoots.

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Abstract. In the experiment were compared: the growth of shrubs, yielding, the physical parameters of fruits and their chemical composition depending on the method of cutting bushes – the amount of main shoots. Research material consisted of goji berries grown in Department of Horticulture Research Station of the West Pomeranian University of Technology in Szczecin. Goji berries (*Lycium barbarum* L.) are characterized by high potential of health promoting properties and nutritious. They have been extremely important part of traditional Chinese medicine for ages. They are used there as a very important part of a healthy diet, due to the appearance of the complex polysaccharide valuable LBP (Lycium Barbarum Polysaccharides). Cutting of shoots stimulated growth of shrubs. Bushes cut into 3 shoots grew with larger number of shorter basal shoots, while the one-year shoots were the longest. The leaves of the cut bush were darker (L* = 39.8 and 41.2) and had a higher green index (42.1 and 44.8), in comparison to uncut bushes (L* = 37.3, SPAD = 43.5). It was also found that there is a significant correlation between the green index and the value of the parameter a* (r* = 0.92). Cutting of shrubs, especially into 3 shoots, reduced yielding however influenced increasing the size of the fruit.